MSC

MODERN STEEL CONSTRUCTION

January 2008

Designing for Serviceability

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Steel Availability

Design Software Trends

United Steel Deck

Designer's Checklist for DECK

DECK DESIGN DATA SHEET 3*

COMPOSITE FLOOR DECK

- ☐ Check fire rating requirements ... Designs Dxxx in U.L. (pp. 47-49 of our manual). Note on project drawings when the fire rating requires spray fireproofing.
- ☐ Check relative costs of lightweight and normal weight concrete. Note: Lightweight concrete can usually fulfill fire rating needs with thinner slabs.
- ☐ Check pour stop requirements. (p. 45 of our manual)
- ☐ Check hanger requirements - for ceilings, ducts, pipes, etc.
- ☐ Check maximum unshored spans to select deck gage and pattern. Note: It usually costs less to have unshored construction. (pp. 21-41 of our manual)
- ☐ Check the SDI Construction Loading (p. 17 of our manual)

ROOF DECK

- ☐ Check fire rating requirements... Designs Pxxx in U.L. (p. 14 of our manual) Note on project drawings when the fire rating requires spray fireproofing (typically P7xx and P8xx series)
- ☐ Check loads for: 1. snow drifting 2. additional dead load from ballasted roof systems 3. maintenance loads...use SDI criteria. (pp. 4-9 of our manual)
- ☐ Check any other insurance requirements such as Factory Mutual. Specify the critical perimeter zones.
- ☐ Check diaphragm shear and stiffness requirements and select the fastener type and pattern.

FORM DECK (CENTERING)

- ☐ Check fire rating requirements... Designs Gxxx in U.L. (p. 61 of our manual)
- ☐ Check requirements for finish. If deck is galvanized it will last the life of the structure and will always carry the slab weight; if the deck is uncoated or if the deck is shored, the slab should be reinforced to carry the slab weight as well as live loads.
- ☐ Check venting requirements if the deck is supporting an insulating fill... always use galvanized deck for this purpose.
- ☐ Check our new Bridge Form brochure for economical bridge construction.

ALL DECK

- ☐ Check material specifications. The proper specification for galvanized steel is ASTM A653; <u>the ASTM specification is A1008 for steel that is to be left uncoated or painted (but not galvanized)</u>; minimum acceptable yield point of steel is 33 ksi. The proper specification that covers the galvanized coating is ASTM A924.
- ☐ Check CMC Joist & Deck for any deck information - prices, delivery, design data. Use our website to download our manual in either standard or metric units and to find our office nearest to you.

* REVISED 2007

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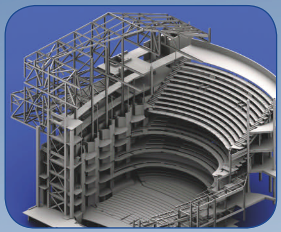
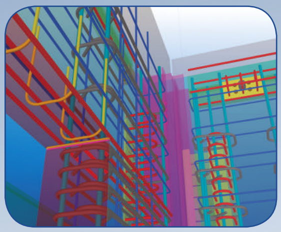
“At the end of the day, your 3D model will most probably end up in Tekla Structures, so why not start with it!”
– Ray Young, Arup

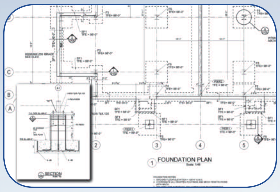
Structures That Do The Job

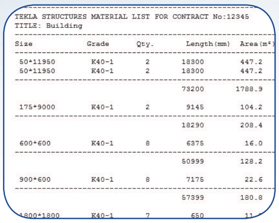


COLLABORATE – *Exchange model data with architects and other designers*



DESIGN – *Use the best structural modeling tool to bring your ideas into practice*

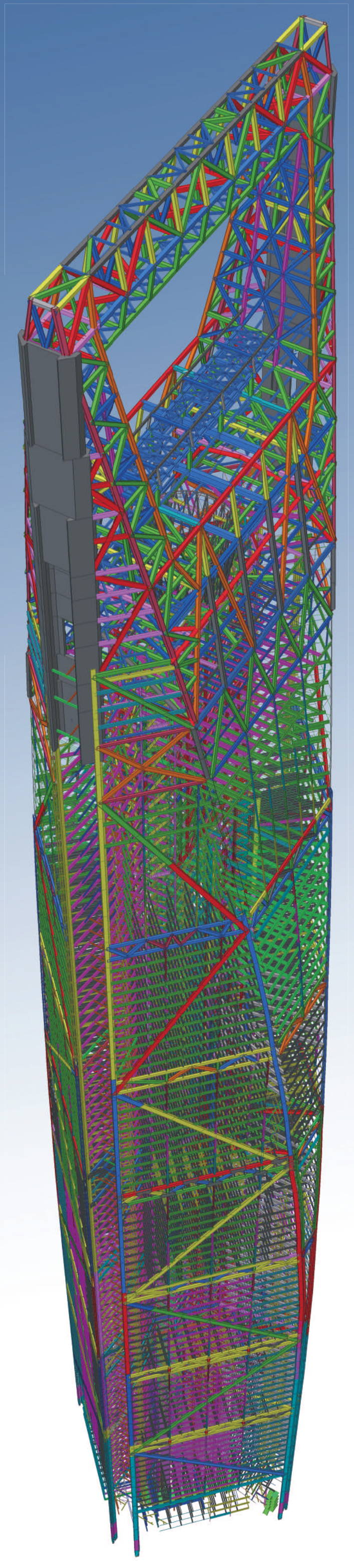




TEKLA STRUCTURES MATERIAL LIST FOR CONTRACT No:12345
TITLE: Building

Size	Grade	Qty.	Length(mm)	Area(m^2)
50*11950	K40-1	2	18300	447.2
50*11950	K40-1	2	18300	447.2
			73200	1788.9
175*9000	K40-1	2	9145	104.2
			18290	208.4
600*600	K40-1	8	6375	16.0
			50999	128.2
900*600	K40-1	8	7175	22.6
			57399	180.8
1800*1800	K40-1	7	650	11

DELIVER – *Produce quality plans, elevations and details directly from the model*



Model: Financial Center, Shanghai, China

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ON THE COVER: Lamar Construction Company corporate headquarters, Hudsonville, Mich.

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editor's note

A LITTLE MORE THAN TWO DECADES AGO, I CAN REMEMBER SITTING WIDE-EYED THROUGH A LECTURE BY ZAHA HADID AT THE DAWN OF THE DECONSTRUCTIONISM MOVEMENT. The models and drawings (while her fame was growing, she hadn't yet built many significant structures) were amazingly beautiful and complex. And all I could think was, sure, they might work when someone with a degree in mathematics does the design, but what happens when others emulate her work?

While Hadid, the first woman to win the Pritzker Prize for Architecture, is well-known to the public in Europe, in the U.S. the leading practitioner of this complex and trendy architecture is the inimitable Frank Gehry. And as with Frank Lloyd Wright before him, questions remain about the constructability—as well as the long-term durability—of his projects.

Now those questions have blossomed into public view through a lawsuit filed by MIT over the award-winning Stata Center. While architectural critics adore the project, it hasn't been such a hit with students and faculty, who complain the building is too loud, complicated, and distracting, and doesn't provide occupants with enough privacy. The lawsuit claims that Gehry and the general contractor on the project (Skanska USA) "committed design and construction failures on the project, which caused, among other things, masonry cracking, efflorescence, and poor drainage at the outdoor amphitheater; efflorescence and mold growth at various locations on the brick exterior vertical elevations; persistent leaks at various locations throughout the building; and sliding ice and snow from the building." Further, the suit contends the designer "failed to provide design services and drawings in accordance with the applicable standard of care."

So what does this mean for the rest of us? First, I think it points to a need to fully embrace building information modeling. While Gehry is recognized for his use of sophisticated modeling tools, he has long insisted on using an incredibly complex program that does not readily integrate with standard structural engineering packages. How many of these issues could be avoided if there were greater cooperation and teamwork between the full design and construction team?

Second, it demonstrates the need for greater practical experience in the design office. The nature of the "starchitect" is that young graduates flock to work under the master while the more experienced flee to shops where they can gain greater recognition and autonomy. The story of Stata Center is in reality a cautionary tale about the danger of hubris. The result? Those who should naturally question and improve the details of the project are too inexperienced to do so. And this lesson can easily be extrapolated to the detailing and fabrication community. In the short term, you might save a buck or two by off-shoring a lot of your work. But in the long term, you lose the value provided by an experienced and knowledgeable detailer and the innate value-added advice that an experienced fabricator can't help but provide.

Finally, it points to the need for architects, engineers, and contractors to work more closely together, a lesson that Gehry never seems to embrace. In 1998, I had the opportunity to tour the Guggenheim Museum in Bilbao with its designer. His insights were fascinating. Afterwards, I asked Gehry if he was interested in keynoting the 1999 North American Steel Construction Conference (for more information on the 2008 Steel Conference, please visit **www.aisc.org/nascc**), and he responded that at his age he wasn't really interested in traveling to talk to a bunch of engineers. How many problems could be avoided if he had a different opinion of his design colleagues?

(Do you have an opinion on Frank Gehry's work? Visit **www.modernsteel.com** and post your reader feedback!)

Scott Melnick

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HELLO
WORLD

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

Connection Strengths in the 13th Edition Manual

I have questions about the evolution of the connection strengths shown in the 9th edition manual compared to the values in the 13th edition. Why are they different?

There has been substantial research and testing on connections since the introduction of the 1989 ASD specification. The tables included in the 13th edition *Steel Construction Manual* are based on the 2005 AISC specification and reflect the culmination of that research. Yes, connection capacities per the 2005 AISC *Specification for Structural Steel Buildings* and the 13th edition *Steel Construction Manual* are higher in many cases than for the 1989 ASD specification and 9th edition manual. It depends, though, on which limit state controls, as some went up and others went down. Also, it depends upon what changes were made in design procedures given in the *Manual*.

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

PJP Weld Throat

How is the throat calculated for a partial-joint-penetration groove weld with fillet weld reinforcement? Is it the addition of the two weld throats?

You have to find the shortest distance from the PJP root to the outer edge of the weld assembly and use that as the throat thickness. This may not be the vectorial sum of the respective throats. This obviously depends on whether the fillet weld is larger or smaller than the PJP weld, and which PJP weld profile is used. Please refer to AWS D1.1 section 2.3.2.7.

Amanuel Gebremeskel, P.E.

Washers for Anchor Rod Installations

I have a project where base plate anchors were set too short to install both a washer and nut. The holes in the base plate are only 1⁄16 in. oversized for 1-in.-diameter anchors, so the contractor is requesting to eliminate the washers. How can I assess the uplift capacity of such an installation?

AISC specification requirements for steel-to-steel bolted joints are not applicable to anchor rods or the nuts on anchor rods. In the assessment of "short" anchor rods, consider what the purpose of the anchor is in the structure. In many cases, a column is always in compression in the final structure; the rods simply hold the column in place and accommodate temporary erection forces.

The hole sizes recommended for base plates in Table 14-2 of the 13th edition AISC manual are intended to facilitate the setting tolerances of other trades. The washer sizes given are such to cover the hole should the anchor be positioned to one side of the hole, and to provide a stiff surface upon which to tighten the nut and to keep the washer from dishing in the hole. When the hole diameter in the base plate is 1⁄16 in. more than the rod diameter, it is unlikely that a washer would be necessary for either of these purposes.

The other alternative is to consider the strength of the connection with the partially engaged nut. If the tensile load on the anchor rod is not required to develop the full strength of the rod, a partial nut engagement may be acceptable. The authors of an article titled "An Ounce of Prevention," which appeared in the May 2004 issue of *Modern Steel Construction*, provide suggestions on how to approach such an evaluation. Back issues of MSC can be accessed at **www.modernsteel.com**.

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

KL/r Modified for Single-Angle

For a single-angle compression member, I followed AISC specification section E5 to calculate the modified *KL/r*. I also calculated KL/r_z, and it turns out to be greater than *KL/r* modified. Should I use the larger of the two (*KL/r* modified, or KL/r_z) in section E3?

If you are in compliance with E5 (including attaching the angle using the longer leg, then you can use the limits on L/r_z that are provided at the ends of the both sections (a) and (b). In the first case the limit is $0.95L/r_z$ and in the second case it is $0.82L/r_z$. In essence, with your condition, you are still designing for KL/r_z but with a K value of less than 1.0 because of the higher end restraints.

Amanuel Gebremeskel, P.E.

Shoring Removal

In composite beam design and construction, if the design basis is shored construction, how long do the shores need to remain in place?

We cannot give you a definitive timeframe; however, the Commentary to Section I3.1c of the AISC specification provides guidance for assumed strength during construction. Therein it is stated that "It is usually assumed for design purposes that concrete has hardened when it attains 75% of its design strength."

It is probably worth adding that shored construction is not commonly used in steel structures.

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

Double Angle Connection - Table 10-1

The beam web strength portion of Table 10-1 in the 13th edition manual checks block shear rupture, shear yielding and shear rupture depending on the coping condition of the beam in question. When determining the connection capacity for a bolted-welded beam-to-girder connection, both Table 10-2 and the bolt and angle portion of Table 10-1 must be checked to find the limiting value. If the beam is coped at one or both flanges, there are no additional checks against block shear rupture, shear yielding, and shear rupture. Does AISC recommend checking these limit-states, or is it unnecessary for a connection with a welded beam web? If they must be checked, is there another table to expedite this check?

Table 10-1 also includes a check of bolt bearing on the beam web in the beam web strength portion.

Page 10-11 of the 13th edition AISC manual includes a discussion of why those checks are not carried out in the table.

Essentially, the thinnest web thickness is being used for the given weld size. If you do end up using web thicknesses that are less than those derived from the equations on page 10-11, then you do have to reduce the available strength given in the table by the ratio of the actual thickness to tmin.

Please note that in both tables 10-1 and 10-2 with coped beams you still have to check for flexural yielding and local buckling of the beam web as per Part 9.

Amanuel Gebremeskel, P.E.

Recycled Content

We are working on a project that is pursuing LEED certification. We are pursuing material resource credits 4.1 and 4.2 and are using structural steel as a major part of achieving this credit. We would like to bump them up as much as possible without creating a non-competitive bid environment. Where can I find information to determine the appropriate credits?

The website at **www.aisc.org/sustainability** provides documentation that the United States Green Building Council has agreed to accept in documenting the recycled content of various types of structural steel. This is contained in the article titled Steel Takes LEED with Recycled Content (LEED-NC v2.2), which can be found on the aforementioned website.

John Cross, P.E.

Butt Splicing W-shape Beams

I have a contractor who would like to butt splice two W14x22 beams together. He is proposing to use a complete joint penetration groove weld that will be done in the shop. The splice will occur 4 ft from the end on a 20-ft span. Will this weld develop the full strength of the section?

It is very difficult to provide a butt welded splice between two W-shapes that will develop the full cross section. This is because weld access holes need to be made in the web to facilitate the welding operation for the flanges. Often, only the flange area of the beam will be assumed to provide the flexural resistance in such a case. Thus if a splice is needed, it would be wise to locate it away from the point that the full section is required. If you have a simply supported, uniformly loaded beam, the described splice location at 0.2L would seem to accomplish this.

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

Fully Restrained or Partially Restrained

What is the ratio of end moment to beam rotation that must be achieved to consider a connection fully restrained rather than partially restrained (slope of FR line in Figure 12-1 of the 13th edition *Steel Construction Manual*)?

As per Fig. C-B3.3 (page 220) in the commentary to section B3.6 of the 2005 AISC specification, the FR slope is above 20EI/L at service loads. For simple connections this stiffness is below 2EI/L. A good discussion of what load amount to use to come up with stiffness values is included on page 219. Analyzed at service levels all stiffness values between 2EI/L and 20EI/L are considered PR connections and their stiffness, strength and ductility must be considered in design.

Amanuel Gebremeskel, P.E.

Suspended Sprinkler Loads

The fire marshall is objecting to hanging fire sprinkler pipe from the bottom chords of steel bar joists. I can find no reference to disallow this in our building code. Numerous contractors are contacting our building department, wanting to know the basis of this objection. I would assume that the design professional of record has reviewed what is being hung from the joists and has performed a structural calculation of the imposed loads.

Open web joists and joist-girders are not covered by the AISC specification; rather they and covered by publications of the Steel Joist Institute (**www.steeljoist.org**). Steel joists are a manufacturer-designed component, based on load criteria supplied by the engineer of record (EOR). You may want to check with the EOR for the project to see what loads had been specified and to see what was included for sprinklers. The SJI specifications contain restrictions relative to hanger locations being at panel points unless otherwise defined, and the magnitude of hanging loads must be considered in the design. You may want to contact SJI for further information on the subject.

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

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

Kurt Gustafson is the director of technical assistance and Amanuel Gebremeskel is a senior engineer in AISC's Steel Solutions Center. 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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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 Does the 13th edition AISC manual provide information on the dimensional tolerances for rolled structural steel shapes?

2 What is the reason for differentiating between K_{des} and K_{det} in Table 1-1 of the 13th Edition AISC manual?

3 What is the warping constant C_w, and how can one evaluate it?

4 Does the AISC manual provide recommended minimum inside radius values for cold bending of plates?

5 Are washers required for snug-tight joints?

6 When evaluating the risk of corrosion, how is galvanized steel base metal affected when connected using stainless steel fasteners?

- **a.** It is not affected at all.
- **b.** The corrosion of the base metal may be markedly increased by the fastener
- **c.** The base metal causes corrosion within the fastener to be markedly increased

7 How can a single-plate shear connection be considered pinned? Does it not introduce minimal moment into the supported beam?

8 How much (or little) rotational stiffness is required to consider connections as pinned, partially restrained (PR), and fully restrained (FR)?

9 What is the recommended maximum hole size in a base plate for a 1¼-in.-diameter anchor rod?

- **a.** 1⅜ in.
- **b.** 1¾ in.
- **c.** 2¹⁄₁₆ in.

10 How much of the nut must be engaged by ASTM A325 bolt threads, in order to be considered as properly installed?

TURN PAGE FOR ANSWERS

steel quiz

ANSWERS

1 **Yes.** Tables 1-22 to 1-26 of the 13th edition AISC manual include ASTM A6 tolerances for structural shapes. Table 1-27 includes tolerances for rectangular and square HSS, Table 1-28 has tolerances for round HSS and pipe, and Table 1-29 has permissible variations from flatness for rectangular sheared plates.

2 The two distinct values for *K* are used depending on whether one is designing or detailing. A survey of steel producers has shown that there is variation in the radii used in production. To avoid fit-up problems during detailing, or overstating the section property for design, two different values are given.

3 The warping constant is a section property that indicates how much warping contributes to torsional stiffness in open sections. It is listed for wide flanges, channels, and WT sections in Table 1 of the AISC manual. AISC *Design Guide 9* also includes equations for the evaluation of C_w for various common sections and provides a general equation in Appendix C.

4 **Yes.** Table 10-12 of the AISC manual includes minimum inside radius for cold-bending of plates.

5 As per Section 6.1 of the RCSC specification, washers are not required in snug-tight joints unless sloping surfaces or slotted holes are included.

6 **b.** Table 2-6 in the AISC manual presents a summary of information that can be used for corrosion related preliminary material selection purposes.

7 Within Part 10 of the AISC manual there are various simple shear connections presented that have sufficient rotational ductility to be considered pinned. How such ductility is achieved is described on page 9-13 in Part 9 of the manual (a combination of plate deformation, rotation at the bolt line, and bolt hole deformation).

8 As discussed in the commentary to section B3.6 of the 2005 AISC specification, a minimum stiffness of $20EI/L$ is required to consider a moment connection fully restrained (FR). At $2EI/L$ the connection is considered pinned while the intermediate values are classified as PR moment connections.

9 **c.** Table 14-2 in the AISC manual recommends that the hole size not exceed $2\frac{1}{16}$ in.

10 **a.** As per section 2.3.2 of the RCSC specification (included in Part 16 of the AISC manual), "the bolt length 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."

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

Steel SolutionsCenter

STANDARDS

AISC/SSPC Draft Now Available for Review

In April 2006, AISC and the Society for Protective Coatings (SSPC) announced the formation of a joint committee with the goal of creating a single standard for shop-painting structural steel. This joint committee invites public review and comment on a draft, *Certification Standard for Shop Application of Complex Protective Coating Systems (Enclosed, Covered, or Open Shop)*.

The draft certification standard will be available for a 45-day period of public review and comment beginning January 14, 2008 and concluding February 29, 2008. This review period provides individuals and organizations that may be affected by implementation of this standard with a valuable window of opportunity to share concerns and offer value-enhancing suggestions and recommendations. A copy of the draft standard will be available in the News section of the AISC web site (**www.aisc.org**) with instructions for submitting comments.

When complete, the standard will support a certification program jointly sponsored by both AISC and SSPC and that will supersede the current SPE and QP 3 programs. The standard describes requirements for certification of firms that shop-apply complex painting systems. The jointly sponsored certification will confirm to owners, the design community, and the construction industry that a firm has knowledgeable personnel and the organization, experience, procedures, and equipment to provide surface preparation and application of complex painting systems in a shop facility according to contract specifications. Availability of this program is targeted for the second half of 2008. Until then, AISC will continue to offer its Sophisticated Paint Endorsement (SPE), and SSPC will continue to offer its QP 3 program.

Comments submitted by the public during the review period will be given full consideration by the joint committee developing this standard and used to prepare the final drafts of these documents for review and approval by the governing boards of AISC and SSPC.

For additional information about the AISC/SSPC joint program, contact:

AISC Certification
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Chicago, IL 60601
312.670.7520
certinfo@aisc.org

SSPC Shop Certification Program
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Pittsburgh, PA 15222
412.281.2331
damiano@sspc.org

PROJECTS

Construction of Art Institute of Chicago Pedestrian Bridge Now Under Way

Courtesy of the Art Institute of Chicago

Another architectural icon in Chicago is currently under construction. The Nichols Bridgeway, designed by architect Renzo Piano, will connect the Art Institute of Chicago's upcoming Modern Wing (also designed by Piano) to Millennium Park, adjacent to the city's Loop area. Unlike the curving bridge designed by Frank Gehry in the northeast section of the park, Piano's pedestrian bridge will be a straight, slim, sword-like structure. It will rise gently from grade level near the southwest corner of the Great Lawn of Gehry's Pritzker Pavilion to cross 23 ft above Monroe Street and land at restaurants and a sculpture garden 60 ft above on the third floor of the Modern Wing.

AISC member Chicago Metal Rolled Products was consulted by the program manager, the Rise Group, in late 2005 concerning this bridge, whose cross section will look something like the hull of a ship, with curved steel plate on the bottom, a flat surface on top, and stiffeners in between. Specializing in curving structural steel, sheet, and plate, Chicago Metal's reputation for precision forming was strengthened by having curved 570 tons of 12- to 20-in. diameter pipe for the trellis over the Great Lawn at Millennium Park.

The 600-ft-long footbridge will have five supporting locations in the park and two off of cantilevers at the Modern Wing. The design includes ⅜-in., ½-in., and ⅝-in. plate that's 12 ft wide and 20 ft long and curved to a 10-ft radius. The top of the bridge will have a walkway that's heated in winter to melt ice and snow.

In something of a role reversal, both the program manager and the general contractor, Turner Construction, asked Chicago Metal for referrals on structural steel fabricators whose expertise matched this challenge, and eventually chose AISC/NSBA member Industrial Steel Construction of Gary, Ind., a company known for its extensive national bridge work.

The design went through several iterations before it was decided that the bridge would incorporate a box girder with a curved bottom covered by a curved soffit plate. A mock-up of a 10-ft-long section of the bridge was constructed with both a welded and a bolted joint. Piano viewed the structure as it was hoisted to the height where it would connect to the Art Institute. After an afternoon and evening viewing (with uplighting), he approved the prototype with further refinement of the weld preparation, and construction of the bridge began. The bridge will be factory-built in 70- to 90-ft-long sections in Gary, shipped to the jobsite, and supported by falsework while the sections are bolted and welded together. The completed structure will incorporate a 2,000-ft-radius camber and a 200-ft span over Monroe Street.

The Modern Wing is scheduled for completion in 2009.

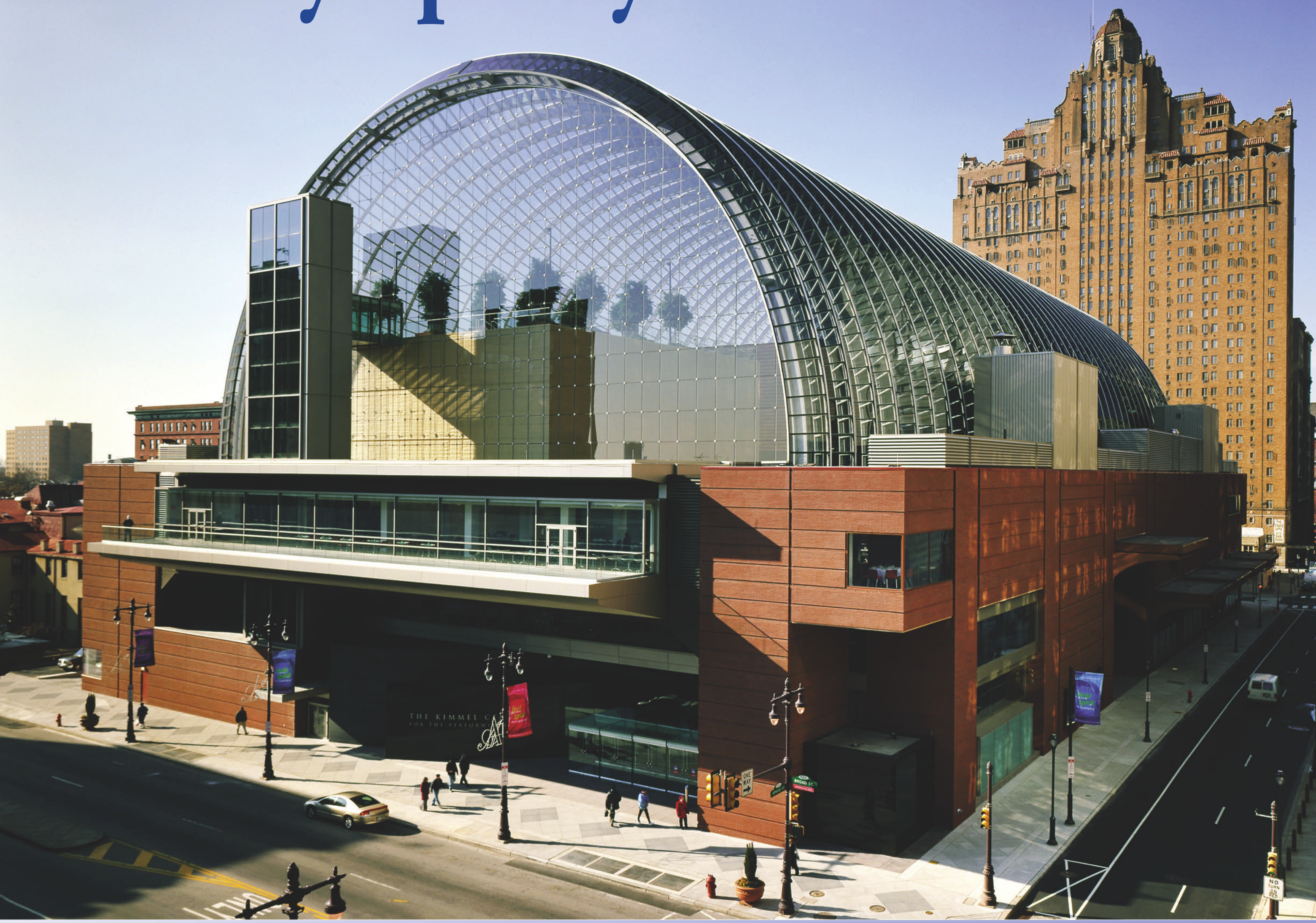

Photo by Jeff Goldberg

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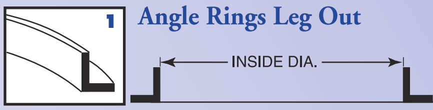
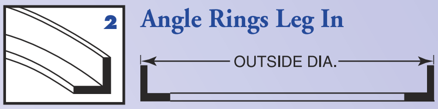
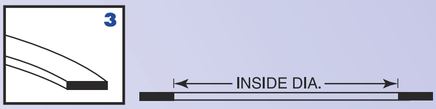


10"x10"x1" Angle

Angle Rings Leg In


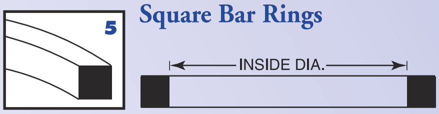
10"x10"x1" Angle

Flat Bar Rings The Hard Way


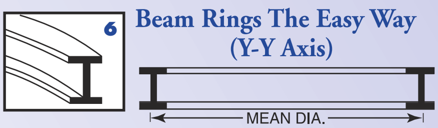
24"x10" Flat

Flat Bar Rings The Easy Way

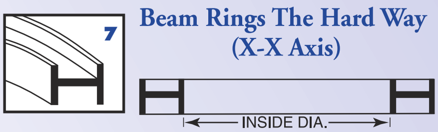

36"x12" Flat

Square Bar Rings


18" Square

Beam Rings The Easy Way (Y-Y Axis)


44"x 285#, 36"x 848#

Beam Rings The Hard Way (X-X Axis)


44"x 285#

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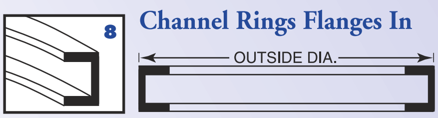
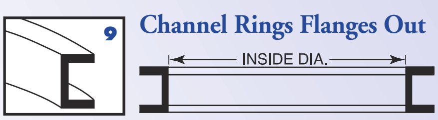


Any Size

Channel Rings Flanges Out


Any Size

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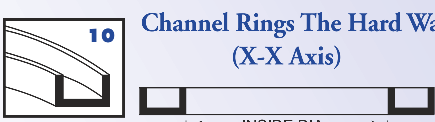

Any Size

Tee Rings Stem In


22"x142 1/2# Tee

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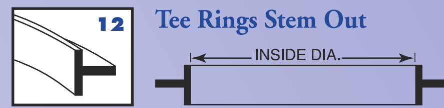
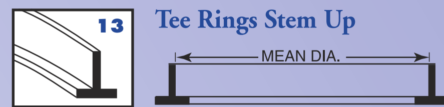
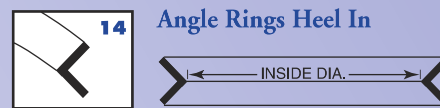
Tee Rings Stem Out


22"x142 1/2# Tee

Tee Rings Stem Up


22"x142 1/2# Tee

Angle Rings Heel In


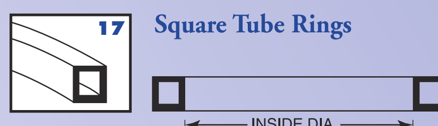
8"x8"x1" Angle

Angle Rings Heel Out

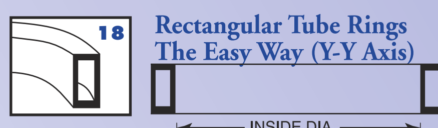

8"x8"x1" Angle

Angle Rings Heel Up

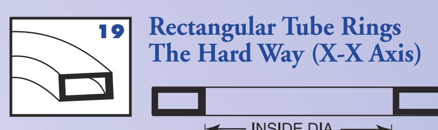

8"x8"x1" Angle

Square Tube Rings


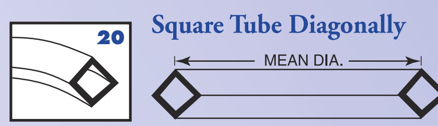
16" Square Tube
20"x12"x1/2" Tube

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


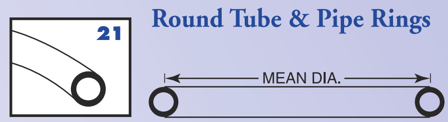
20"x12"x1/2" Tube

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


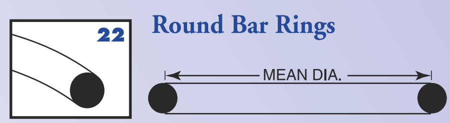
20"x12"x1/2" Tube

Square Tube Diagonally


12"x5/8" Square Tube

Round Tube & Pipe Rings


20" Sched. 80 Pipe

Round Bar Rings


Any Size

We also curve stair stringers, helical hand rails, off-axis bends, formed shapes and extrusions.

EVENTS

Blast-Resistant Course Hits Texas

Blast-Resistant and Anti-Terrorism Design, a short course for engineers and architects, sponsored by Protection Engineering Consultants, will take place February 4–8, 2008 in San Antonio. This intensive course will cover significant topics in blast-resistant and anti-terrorism design, including:

- ✓ Physics of blast and structural response
- ✓ Blast test methods and data
- ✓ Analytical and computational methods for blast loads predictions and structural response
- ✓ Analysis and blast-resistant design of building, cladding, and framing components
- ✓ Design and analysis for steel, reinforced concrete, reinforced masonry, and timber
- ✓ Anti-terrorism design
- ✓ Progressive collapse design
- ✓ Design/analysis of windows, frames, and mullions

Presenters will provide software and design aides as well as multiple opportunities to use these tools in practical, problem-solving applications, enabling participants to gain experience and confidence. Bound course notes and software will be provided.

A special feature of the course is a shock tube testing demonstration. On Thursday, February 7, course participants will attend a shock tube test at a facility in the northern San Antonio area. Shock tubes are commonly used to simulate explosions for evaluating structural components. Using the software and knowledge acquired in class, participants will predict the response of a structural element, such as a wall panel, door, or window, then will discuss the data and results in class the following day.

Dates

Monday, Feb. 4 – Friday, Feb. 8, 2008

Times

Monday – Thursday: 8 a.m. – 5 p.m.
Friday: 8 a.m. – 2:30 p.m.

Location

Best Western Hill Country Suites
18555 Highway 281 North
San Antonio, Texas 78258
210.490.9191 or 866.784.8346

Accommodations

The Best Western Hill Country Suites is offering short course participants a special rate of $94.99. If you choose to stay at the Best Western, mention "PEC Short Course" when you call. The cut-off date for reservations at this rate is Jan. 11, 2008.

Participants may, of course, make their own arrangements for accommodations, and there are numerous exceptional locations in the San Antonio area.

PROJECTS

Staggered Truss Webcam

Chicago's first staggered truss project is now underway and a live webcam is capturing the construction. The Staybridge Suites Hotel, which was designed by structural engineer Structural Affiliates International in Nashville and architect Valerio Dewalt Trane in Chicago, is scheduled to open in mid-2008. The fabricator and erector is AISC Member K & K Iron Works. For more information on the project, and to view the webcam, please visit **www.aisc.org/staybridge**.

AISC and the Associated Steel Erectors will host a breakfast presentation on the project and conduct a hard hat tour on Friday, Feb. 8, 2008. The program is free. For more information, contact Tabitha S. Stine, P.E., LEED AP, AISC's Great Plains Regional Engineer, at stine@aisc.org or by telephone at 708.647.9395.

ENGINEERING JOURNAL

Call for EJ Papers

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

Please send your paper in duplicate to Cynthia Duncan, Editor, c/o AISC, 1 E. Wacker Drive, Suite 700, Chicago, IL, 60601, or e-mail your submittal to duncan@aisc.org.

Detailed information on our review process and requirements for submittals can be found in each *Engineering Journal* issue or at **www.aisc.org/ej**.

In addition, all published papers are eligible for the Best EJ Paper of the Year award. Cast your vote for the best *Engineering Journal* paper of 2007 at **www.aisc.org/ejsurvey** and become eligible for a free trip to the 2008 North American Steel Construction Conference, held April 2–5 in Nashville. A drawing will be held in early March 2008.

All articles published in *Engineering Journal* in 2007 are included in the survey (excluding Discussions). The winning author will also receive free registration to the 2008 NASCC, as well as round-trip airfare and a one-night stay at the conference hotel.

Cast your vote today! Votes will not be accepted after February 28, 2008.

letters

A New Way to Read MSC

Thank you for the "as-printed" link to the magazine. I wish more publications and newspapers would include the same format. It's great for when you remember reading an article but the magazine is long gone in the recycle bin. Thanks again for a great publication!

Glenn Ernst
OMNI Technical Services, Inc.
St. Johns, Mich.

To view previous issues of MSC, as well as the current issue of MSC, which appears exactly as the printed version—including all advertisements—visit www.modernsteel.com. —Editor

Vertical Integration

BY PAUL DANNELS, AIA, AND MEHDI SETAREH, P.E., PH.D.

A Michigan construction firm creates a unique spatial relationship between its corporate offices and the rest of its facility.

HERE'S A THOUGHT: WHEN A CONSTRUCTION COMPANY LOOKS INTO BUILDING ITS OWN FACILITY, does it keep things simple, given its in-depth knowledge of the building process—or does it challenge itself even more than when it's building for a client?

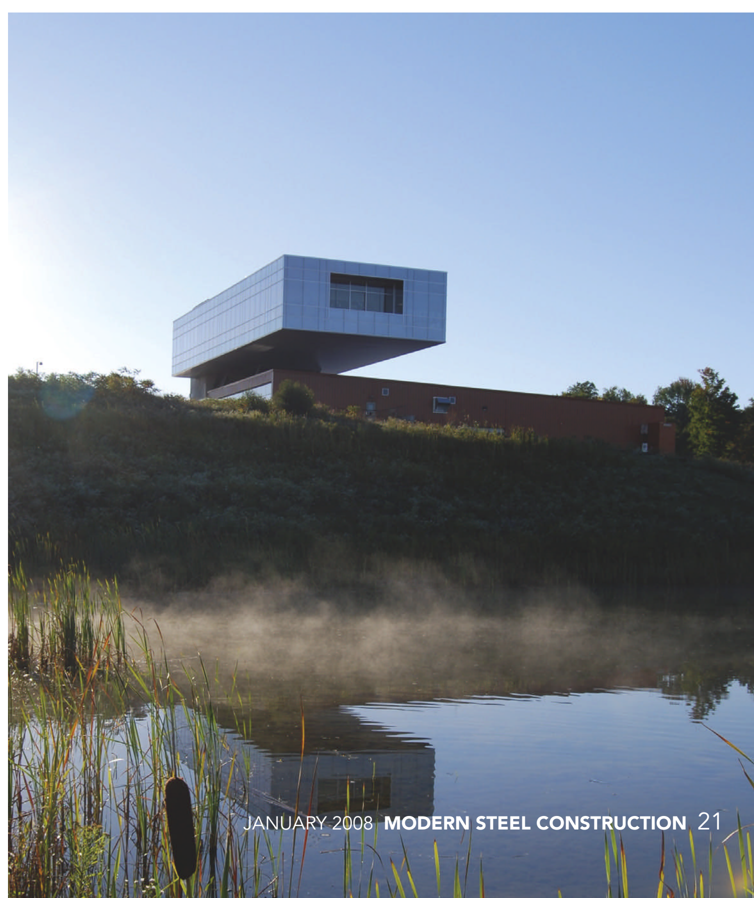
In the case of Michigan firm Lamar Construction Company, the answer is the latter. When building its new headquarters, which opened in 2007, the company chose to place its corporate offices not in front of its shop, garage, and warehouse facilities, but cantilevered above them, thus tasking the building team (of which it was a member) with creating a satisfying work environment in a challenging structural context.

As the architect sought to realize Lamar's unconventional vision, early discussion with the structural engineer established some guidelines that would impact all aspects of the office design. Two 16-ft-deep, 112-ft-long cantilevered trusses were envisioned that would support the office from a vertical circulation shaft. These trusses would architecturally define perimeter office units as well as primary traffic aisles.

Designing for Constructability

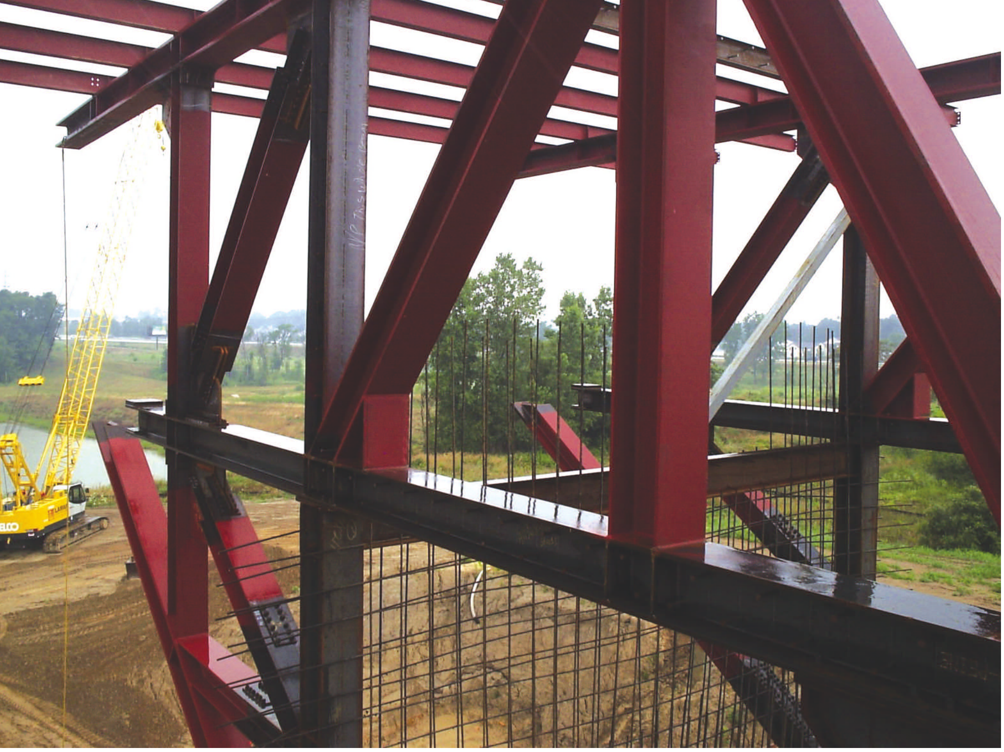
From the start, the design team planned for lateral drift of the office space to be controlled through the torsional resistance of a concrete support shaft. However, two constructability consider-

“When a construction company looks into building its own facility, does it keep things simple...or does it challenge itself even more than when it’s building for a client?”



ations shifted the design in the direction of using of a full-height steel frame embedded within the concrete shaft walls.

The primary benefit of the steel frame was to help distribute truss reaction forces into the shaft. With some connection forces being well over 1,000 kips in magnitude, the steel frame (covered with shear studs for composite behavior) could develop reaction forces far greater than a traditional anchor bolt design in a thin concrete wall. During construction, the steel frame acted as an armature, supporting the formwork for the concrete shaft. It also provided a means to maintain both position and alignment of connection members throughout the casting of the walls. This alignment was critical because it allowed for precise launching of



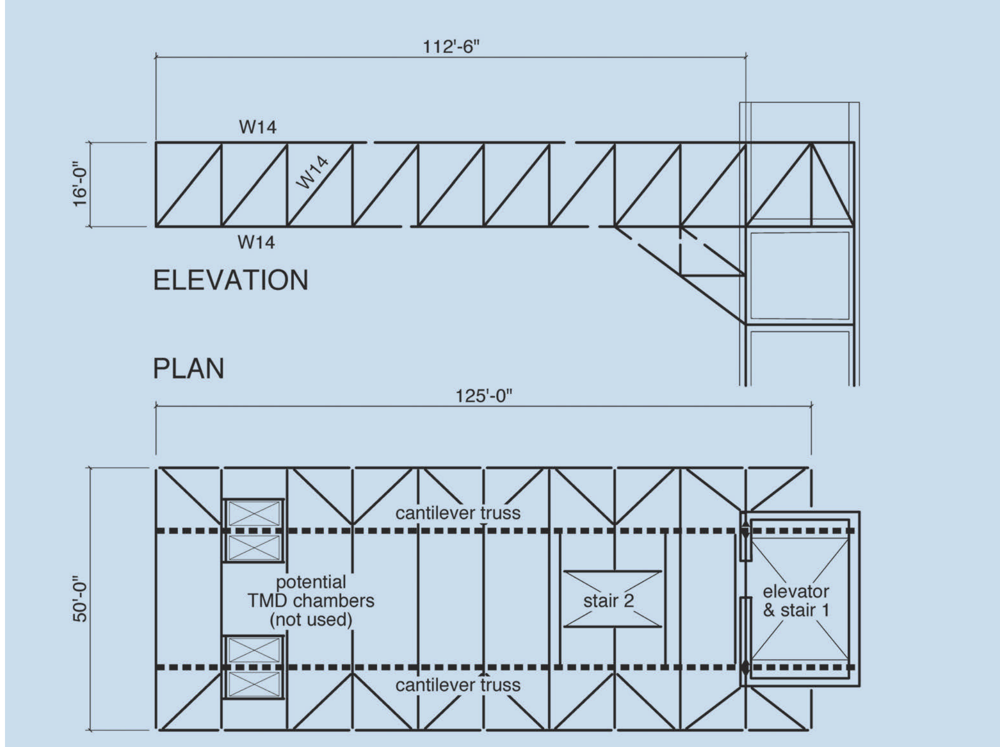
A steel frame sheathed in concrete provides the structural support for the massive cantilevers.

the truss, which was designed and fabricated with approximately 3 in. of pre-dead load upward camber at the cantilever end.

An additional construction challenge was presented by shipping and lifting considerations that dictated the use of field welds to complete the connection of a W14×370 brace member. The field welds required qualification in conformance with the American Welding Society (AWS) D1.1 *Structural Welding Code* and around-the-clock field welding. In advance of the work, procedures were prepared and a mock-up of the joint was welded in the field to identify conditions that could delay field welding and to verify that the procedures prevented lamellar tearing due to the jumbo sections and high restraint. After welding of the mock-up, the erector delivered the welded joint to the laboratory for qualification testing. The final preparation involved constructing suspended blinds at the connection locations in order to protect welders from the harsh Michigan winter conditions while they performed their work.

Designing for Comfort

Understanding the building's pedestrian traffic flow was the main consideration in designing the truss. Early dynamic analyses suggested that all of the possible engineering solutions would likely provide satisfactory vibration characteristics for both lateral and torsional motions. Vertical vibration, however, presented some concern. Although anticipated accelerations were low, it was determined that



The offices are supported by a truss 16 ft deep that cantilevers 112 ft from a supporting tower.

even the most reasonable truss designs would yield vertical vibration frequencies akin to those produced by fast foot traffic.

In order to increase the building's natural frequency such that it would not be excited by these normal walking rates, the structural stiffness had to be substantially increased. Adding stiffness meant adding bulk to the members and their connections, which would in turn add both cost and visual obstructions to the project. The building had been initially conceived as a relatively light structure, so there was little opportunity to improve its vibration characteristics from that perspective.

The team's solution, outlined in the following section of this article, was to design for vibration levels above that of normal walking frequencies and to make provisions for tuned mass dampers (TMDs) to be installed only if deemed necessary. No one on the team wanted to use TMDs as an initial design solution, but they recognized their benefits as a back-up system. This would save the owner the initial economic and aesthetic ramifications of unexpectedly massive trusses, while still ensuring a vibration-free workspace.

With this approach in mind, a preliminary TMD design was provided that promised to control uncomfortable vibration under worst-case projections. The office floor system was then designed to be framed with a pair of concealed chambers that would accommodate the mounting of TMDs (if they proved to be necessary) to the bottom chords of the cantilever trusses.

Dynamic Analysis and Testing

Based on the preliminary design drawings, a three-dimensional finite element model of the building structure was created using the SAP2000 software. The initial estimates of the structure's fundamental frequency showed that the building was not susceptible to wind excitations. However, the structure's first two modes of vibration were 1.5 Hz and 2.1 Hz, which made it susceptible to annoying vibrations from foot traffic.

The floor performance was subjected to three components of walking force, which resulted in a maximum vertical acceleration well above the acceptable limit. A number of modifications were made with the goal of increasing the natural frequencies to a range well beyond the normal walking range of 1.6 Hz to 2.3 Hz (representing slow to brisk walks), to prevent resonance or increase the structural mass to reduce the acceleration level.

The final design of the structure, after several modifications, resulted in natural frequencies of 2.6 Hz, 3.4 Hz, and 5.4 Hz for the vertical, lateral/torsional, and torsional modes, respectively. Even though the natural frequencies were outside the range that could be excited by the first two harmonics of normal walking excitation due to construction variations, assumptions made on modeling of the non-structural elements (in particular, the outside glazing), and the fact that finite element models generally tend to overestimate the natural frequencies, there was a high probability that the completed structure would have somewhat lower natural frequencies. The team recognized that such lower natural frequencies could result in vibrations above acceptable limits, thus the provision was made for TMDs as a fall-back option. It was determined that eight 2,000-lb TMDs would be able to reduce the vibration of the vertical and torsional modes to levels well below the perceptible range in the case that occupants experienced uncomfortable vibration.

To check the floor's structural performance and make preparations in case the TMDs were necessary, a series of dynamic modal tests using an electrodynamic shaker were conducted as soon as the concrete floor was poured and the outside glazing installed—but before the raised floor, partitions, and any interior finishes were installed. As expected, the natural frequencies were less than the analytical estimates. The main contributor to this discrepancy was found to be the consideration of the stiffness of the outside glazing. The measured natural frequencies were 2.7 Hz, 3.0 Hz, and 3.3 Hz for the vertical, lateral/torsional, and torsional modes, respectively. These values were outside the range of the first harmonic of walking excitation. A number of walking tests were conducted with the walker's pace synchronized with the vertical mode natural frequency. This resulted in acceleration levels as high as three times the acceptable limit. However, since the natural frequency was high (2.6 Hz), the person had to jog to keep up with the rhythm. As the floor was expected to be acceptable under normal walking scenarios, a series of random walks were also conducted with all resulting in acceptable levels of vibration.

A second round of dynamic testing was conducted after building completion, with a similar set-up to the first tests. The as-built natural frequencies were 2.3 Hz, 2.5 Hz, and 3.0 Hz for the vertical, lateral/torsional, and torsional modes, respectively. These values were well within the range of predicted natural frequencies by the analytical model after modifications based on the first round of tests.

Controlled walks at the speed of the measured natural frequencies were conducted, which only resulted in accelerations slightly above the acceptable limit (0.7% g) for the vertical mode excitation. However, since this constituted a brisk walk (135 steps per minute), the probability of such vigorous strolls is very low in an office space. More normal walks at an average speed of 120 steps per minute (2 Hz) resulted in vibration levels well below the perceptible limit. One important aspect of the building that contributes to the low level of vibrations is the limited width of the hallways, which typically allow only one person to walk through at a time, thus restricting traffic flow.

No TMDs

With a quantitative understanding of the building's performance and positive occupant feedback since the opening of the building in July 2007, the TMDs were determined to be unnecessary, and the floor chambers built to house them remain unused. But those chambers ultimately served the project well: They allowed the design team to confidently work beyond their range of experience to create a workspace of unprecedented character. MSC

Paul Dannels is a principal at Structural Design Incorporated (sdi), Ann Arbor, Mich., and an instructor at Lawrence Technological University. Mehdi Setareh is a professor of engineering at the School of Architecture and Design of Virginia Tech and president of Setareh Structural Engineering, LLC, Blacksburg, Va.

Owner/General Contractor
Lamar Construction Company, Hudsonville, Mich.

Architect
Integrated Architecture, Grand Rapids, Mich.

Structural Engineer
Structural Design Incorporated, Ann Arbor, Mich.

Fabricator
Van Dellen Steel, Dutton, Mich. (AISC Member)

Vibration Consultant
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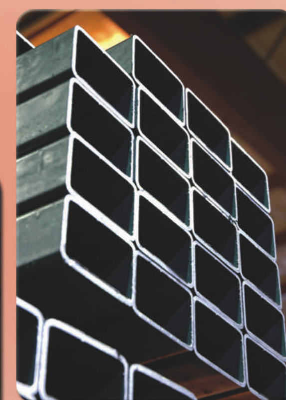

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The Cost Equation
when designing for floor vibrations

BY LINDA M. HANAGAN, PH.D., P.E., AND MELISSA C. CHATTORAJ

When it comes to selecting floor framing systems for vibration serviceability, consider more than than just structural costs.

CHOOSING FLOOR FRAMING FOR A STEEL OFFICE BUILDING IS OFTEN BASED ON STRUCTURAL COST, with some consideration for floor vibration serviceability. In essence, a lowest structural cost vs. vibration performance decision is made. When lowest structural cost wins, the result can be a floor system that is susceptible to walking-induced vibration that occupants find disturbing. By looking beyond structural cost and examining the other construction costs that are impacted by floor system selection, the perceived cost savings of choosing a lightweight system might not be as favorable as one might think. In this paper, we'll examine three steel-framed floor systems for other associated costs to show that if a seemingly inexpensive floor system is, in fact, susceptible to vibration problems, it may not be so inexpensive after all. We'll evaluate these three prototype designs, representing typical structural framing, for vibration performance, structural cost, fire protection cost, and façade cost.

Floor System Designs Evaluated

A typical bay layout was developed and used for the three floor system designs, and is shown in Fig. 1. The three floor systems designed were as follows:

1. Open-web steel joists supported by rolled steel girders with a 1-in.-deep steel form deck supporting a 2½-in. lightweight concrete topping slab (total slab depth is 3½ in.).
2. Composite steel beams and girders with a 2-in.-deep composite steel deck supporting 3¼-in. lightweight concrete topping slab (total slab depth is 5¼ in.).
3. Non-composite steel beams and girders with a 3-in.-deep composite steel deck supporting a 4½-in. normal weight concrete topping slab (total slab depth is 7½ in.).

Details of the designs and governing assumptions can be found in Chattoraj (2005), and a summary of the design results is presented in Table 1. In all of the designs, the girders run along the lettered column lines, and the beams or joists run along the numbered column lines. Other system characteristics presented in this table are described in subsequent sections.

Evaluation for Vibration Serviceability

The three floor system designs described were evaluated for floor vibration serviceability using the walking vibration criterion in the AISC *Design Guide 11* (Murray, et al. 1997). The criterion for offices requires that the following inequality be met:

$$\frac{a_o}{g} \geq \frac{a_p}{g} = \frac{P_o \exp(-0.35 f_n)}{\beta W}$$

where a_o/g = 0.5% for offices; P_o = 65 lb for offices; β = 0.03 for regular offices with hung ceilings below; f_n is the fundamental natural frequency of bay, Hz; and W is the effective panel (bay) weight.

The details of this analysis can be found in Chattoraj (2005), and the results of this evaluation are presented in Table 2. The composite and non-composite systems are found acceptable for both bay sizes with the non-composite system having the best vibration performance. The joist system was found unacceptable for vibration performance with the 30-ft by 30-ft bay being most susceptible to objectionable vibration levels due to people walking in the space. This system was redesigned two different ways to result in an acceptable design. The first redesign changed only the joist size to yield acceptable performance; the second redesign changed the slab, deck, concrete, joists, and girders to offer a less expensive redesign. Summaries of the redesign results and vibration evaluation are also included in Tables 1 and 2, respectively.

Design for Fire Protection

Floor system configuration has an impact on the fire protection design to meet the required two-hour fire ratings in the code. Several configurations meeting fire protection requirements were studied for each floor system. The least expensive option was selected for use in the cost

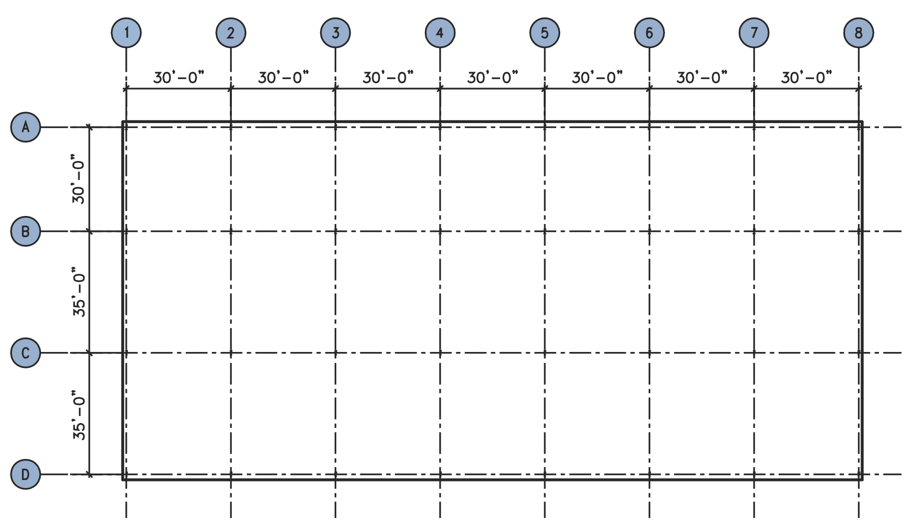

Figure 1. Prototype building floor plan.

Table 1. Summary of Floor System Characteristics

	Joist System	Non-Composite System	Composite Beam System	Redesign No. 1	Redesign No. 2
Topping Slab (in.)	2.5	4.5	3.25	2.5	4
Deck Depth (in.)	1	2	2	1	1.5
Concrete Type	Lightweight	Normal-Weight	Lightweight	Lightweight	Normal-Weight
Beam (30 ft span)	20LH6	W18x35	W16x26	28LH11	24LH9
Beam (35 ft span)	24LH6	W18x40	W18x35	28LH13	28LH9
Beam Spacing	4′-3⅜″	7′-6″	10′-0″	4′-3⅜″	5′-0″
Composite/Non-Composite	Non-Composite	Non-Composite	Composite	Non-Composite	Non-Composite
Girder	W24x76	W27x84	W24x55	W24x76	W27x84
Column Type	Wide-Flange	Wide-Flange	Wide-Flange	Wide-Flange	Wide-Flange
Vibration Susceptibility	Susceptible	Not Susceptible	Not Susceptible	Not Susceptible	Not Susceptible
Story Height	13′-2″	13′-0″	12′-10″	13′-6″	13′-8″
Structure weight (tons)	453	967	600	480	805
Fire Protection Type	Rated Ceiling	Unprotected Deck	Unprotected Deck	Rated Ceiling	Rated Ceiling
Column Protection	Spray	Spray	Spray	Spray	Spray
Sprinklers / No Sprinklers	No Sprinklers	No Sprinklers	No Sprinklers	No Sprinklers	No Sprinklers
Façade Type	Curtain wall	Curtain wall	Curtain wall	Curtain wall	Curtain wall

comparison presented in the next section. Other options and more details on the selected options are presented in Chattoraj (2005). For the joist system, a rated ceiling is required to achieve adequate fire protection without using sprinklers (a more expensive option). This is primarily because the slab has insufficient thickness to act as a fire barrier. The steel framing members in the composite and non-composite systems require spray-on fireproofing to achieve the two-hour fire rating. In the composite system a 3¼-in. lightweight topping slab on composite deck was selected because this is the minimum thickness that can be used without adding spray fireproofing to the deck. Similarly, the non-composite system was configured with a 4½-in. normal-weight topping slab to avoid the need for spray fireproofing on the deck to achieve a two-hour fire rating.

Cost Comparison

The cost per square foot of floor area was calculated using RS Means (2004) for the structural system, the curtain wall system, and the fire protection system. These are the primary costs affected by the selection of the floor system. The percentages noted in Fig. 2 are the cost differences for the various systems with the joist floor system as the basis. Assuming a constant finished ceiling height, the curtain wall cost is a function of the depth of the floor construction. The composite system produced a shallower depth and, therefore, reduced cost for the curtain wall. This differential will vary with individual designs. Since the non-composite and composite systems were designed with adequate slab thickness to achieve a two-hour fire rating without spraying the deck, the cost of protecting these floor system structures is less than protecting a joist system. Rated ceilings are more expensive and only the increased cost of the ceiling system was included as a cost in fire protection.

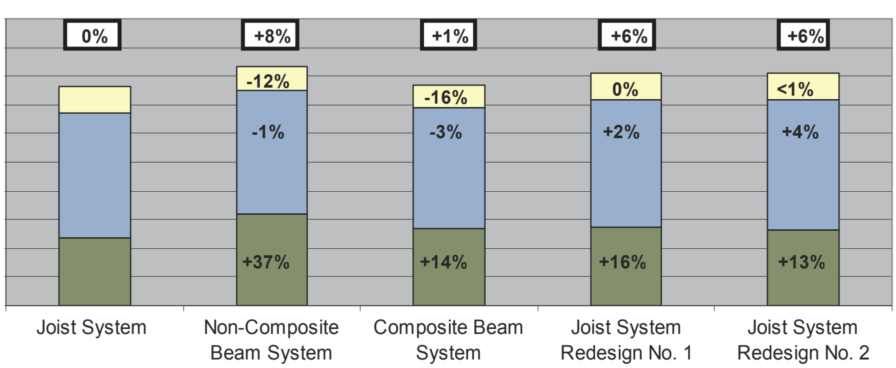

Figure 2. Relative cost differences using the joist system as a basis.

Conclusion

All of the floor system structural members in this case study are designed for the same purpose and loads, and the costs vary by as much as 37%. Each lighter-weight system in this paper is less costly than the heaviest system, the non-composite beam system. Therefore, lighter-weight systems can be economical from a strength, deflection, and vibration serviceability standpoint. However, the lowest cost option here is not the best option overall because it is susceptible to excessive vibration. As a result, the building must be examined as a whole to find the best option.

To obtain the lowest-cost building for the given bays and loads, the least-weight wide-flange beams with a large spacing

Table 2. Summary of Vibration Evaluation

	Joist System	Non-Composite Beam System	Composite Beam System	Joist Redesign No. 1	Joist Redesign No. 2
30-ft by 35-ft Bay					
f_n (Hz)	4.4	6.0	5.1	4.7	4.3
W (kips)	63.1	179.0	123.4	83.0	109.2
a_p/g (%)	0.73	0.15	0.29	0.50	0.40
Limit, a_o/g (%)	0.50	0.50	0.50	0.50	0.50
Susceptible to Excessive Vibration?	Yes	No	No	No	No
30-ft by 30-ft Bay					
f_n (Hz)	3.7	4.8	4.2	5.2	3.5
W (kips)	72.9	204.8	123.1	70.9	130.8
a_p/g (%)	0.81	0.20	0.40	0.50	0.49
Limit, a_o/g (%)	0.50	0.50	0.50	0.50	0.50
Susceptible to Excessive Vibration?	Yes	No	No	No	No

and a 3¼-in. lightweight topping slab or a 4½-in. normal-weight topping slab should be used. With these slab configurations, the fire protection costs will be kept to a minimum. In addition, the strength design should meet the vibration susceptibility criteria from the beginning. If the strength design leads to a vibration-susceptible floor system in lieu of changing one component of the system, the entire system should be redesigned. Furthermore, the depth of the floor system should be as shallow as possible to allow for reduced exterior skin costs.

Several general conclusions can be drawn that are applicable to buildings outside of this case study. One conclusion is that the strength design of a floor can meet the vibration susceptibility criteria without greatly increasing the overall building cost. Another is that the floor system has an effect on the remainder of the building and cannot be viewed successfully as an independent feature. The most important conclusion, however, is that the building must be evaluated as a whole to determine the cost-effectiveness of the floor system. MSC

Linda Hanagan is an associate professor in the Department of Architectural Engineering at the Pennsylvania State University. Melissa Chattoraj is a project engineer for THP Limited, Inc., Cincinnati.

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Acknowledgments

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Small Footprint, Big Results

BY ANJANA KADAKIA, P.E.

Philadelphia's Comcast Tower maximizes its small footprint with a narrow core that gets a little help from a tuned liquid column damper.

NOT LONG AGO, THE BLOCK BETWEEN 17TH AND 18TH STREETS ON JFK BLVD. IN DOWNTOWN PHILADELPHIA WAS A PARKING LOT. But thanks to positive market conditions and an increased demand for top-tier commercial development in this vibrant office district, the site was ripe for a world-class office building.

The site's new resident, Comcast Tower, will be the tallest building in Philadelphia at 975 ft and the tallest between New York and Chicago. Set for occupancy in 2008, the building features 58 stories of steel floor framing and a concrete core. Design elements include an 80-foot glass cube tower top, which accommodates high winds and wind-related sway, and a nine-story winter garden at the base. The building also contains three levels of below-grade parking, and a plaza and food court supported on the below-grade public transportation system.

Challenging, Yet Exciting

Comcast Tower was an exhilarating project from the start, but the tower's design features, such as the glass cube, column-free lobby area, and slim shape—not to mention the inherent challenges posed by building on a small footprint—presented some challenges.

How would we create an attractive, column-free lobby, encompassing three stories, and a nine-story winter garden if the main tower columns penetrate the base? How would we address the proximity of the existing subway line beneath the plaza when constructing the tower and a deep basement? How could we economically provide the luxury features, such as 15- and 17-ft ceiling heights, that the upscale project required? How would we address the wind pressures that skyscrapers experience, especially given the tower's height to width ratio?

Anjana Kadakia is a principal with Thornton Tomasetti's Newark, N.J. office and was the chief engineer for Comcast Tower.

At 975 feet, Philadelphia's Comcast Tower is the tallest building between New York and Chicago.

And perhaps most challenging: How would we build Philadelphia's tallest tower on a relatively small and irregularly shaped footprint?

To address the footprint issue, the design employed 18- to 54-in.-thick, 6- to 10-ksi concrete core walls as the lateral load resisting system, and composite concrete-on-metal-deck floor construction supported on composite steel beams spanning from core to steel columns at the perimeter. A ten-ft-thick concrete mat forms the foundation for the concrete core while 6- to 10-ft-deep caissons support the perimeter columns to keep the structure within the property lines.

Comcast Tower's lateral system is quite slender: While the building's height-to-width ratio is 8, the height-to-concrete-core-width ratio is 21. The narrow core was necessary to provide the owner with a 45-ft column-free rentable space between the core and façade. At the same time, the tower height was set to provide the required square footage of office space.

With a slender core, wind-related sway issues were expected, so the structural engineers designed a TLCD (tuned liquid column damper) at the 950-ft level within the concrete core. The TLCD enables the building to meet acceptable acceleration limits for human comfort. The water column reduces sway by applying inertial and damping forces opposing building motion. The U-shaped column is proportioned to cause the liquid to oscillate freely at a frequency that matches one or more of the structure's natural frequencies. Damping is created by generating turbulence in the water as it moves through vanes or grates, transforming motion into heat.

With a building core of 10 to 20 ft wider, the tower wouldn't have required this damper. But again, the project's design was driven by its relatively small footprint. Even with its slender proportions, Comcast Center will be the largest building in the world with a TLCD.

One of the most interesting challenges as structural engineers was the three-story open lobby entrance. Creating it required interrupting two major building columns above. To transfer these columns, we created a 90-fot span Vierendeel truss between the 6th and 17th floors. It features 48-in. by 30-in.by 8-in.-thick built-up columns and 40-in.-deep wide-flange beams. In addition, to create a three-story, 30-ft-wide column-free atrium, perimeter columns at the top of the Vierendeel truss were sloped 15 ft inward towards the core. Redirecting the gravity load this way required large tension and compression struts at the 19th and 17th floors. A trellised plaza leads into the 120-ft-high, 110-ft-wide, 40-ft-deep glass-enclosed winter garden and the tower's lobby.

The height requirement also posed challenges, especially on the upper floors. Comcast Tower's floor heights are 15 ft up to the 43rd floor, then increases to 17 ft from that point upward. This required specialized support framing to keep clear spans of the curtain wall system and elevator guide rails within practical limits. In addition, cantilevered framing at the signature sloping corners of the tower was designed to meet a tight ½-in. deflection limit. The highest occupied floor is 100 ft below the tip of tower.

Not Just the Tallest

In an effort to create not only Philadelphia's tallest, but also its safest, office tower, the team incorporated new building hardening criteria, including reinforced concrete walls enclosing the egress stairs; a stair pressurization system to keep smoke out of the stairwells; and the most advanced elevator, sprinkler, and communication systems technologies.

As Philadelphia's real estate market boomed, Comcast Tower's design followed suit, expanding from the initial design of 760 ft in 2001 to the current height of 975 ft. Such design changes, along with the overlapping design and construction schedules associated with all fast-track projects, made the timely completion of Comcast Tower a major challenge. As the project nears completion, we are thrilled with the result. It makes the extraordinary effort worthwhile. MSC

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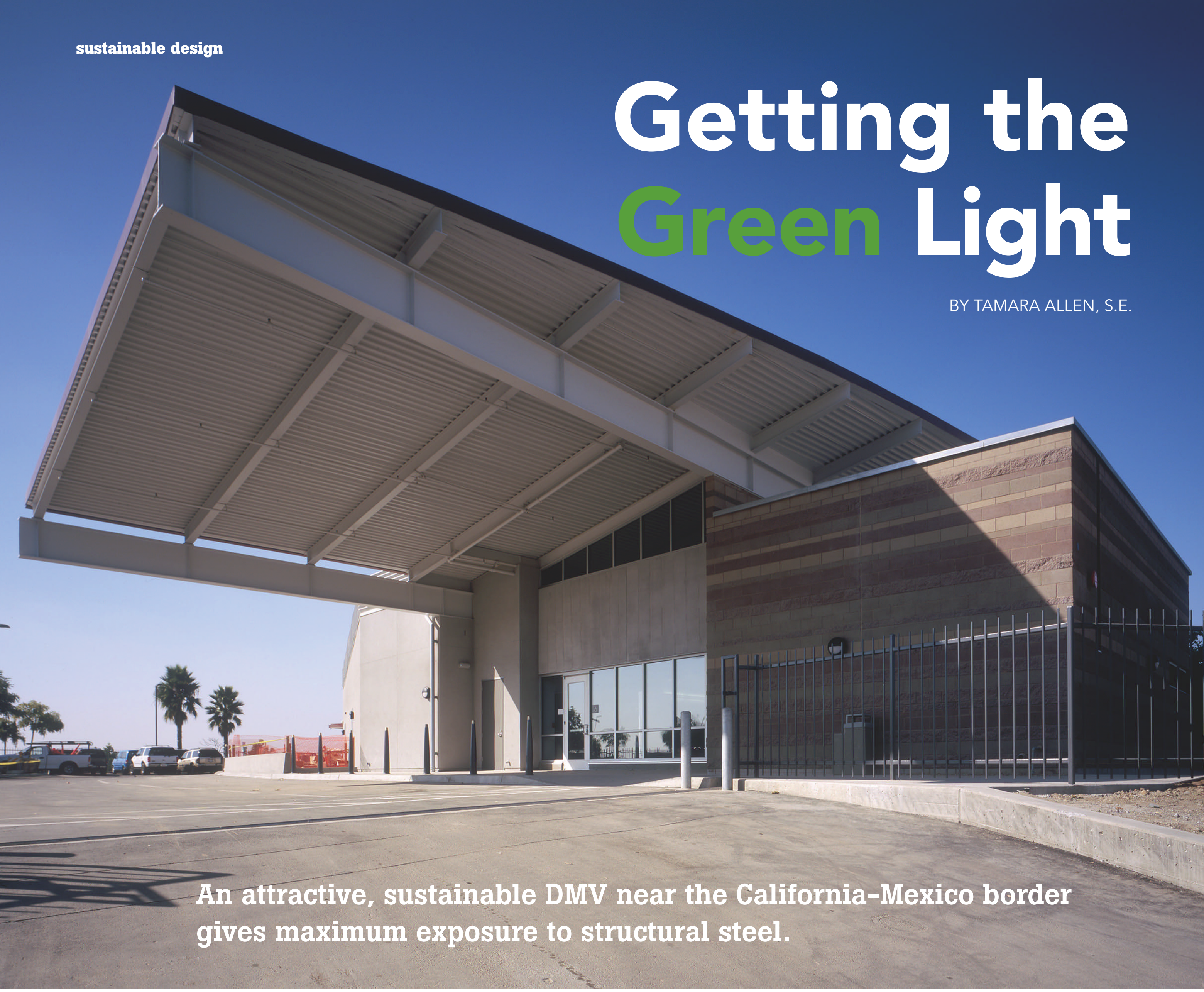
Getting the Green Light

BY TAMARA ALLEN, S.E.



An attractive, sustainable DMV near the California-Mexico border gives maximum exposure to structural steel.

Satoshi Asakawa-Zoom Inc.

WHEN YOU THINK OF VISITING THE DEPARTMENT OF MOTOR VEHICLES, it's difficult not to conjure up images of a dark, gloomy, uninspiring, oppressive waiting environment tempered with bureaucratic waste buried in inefficiency. So when the growing community of San Ysidro, Calif. was slated for an improved DMV Field Office, every attempt was made to break this stereotype.

This new DMV office is designed to alleviate overcrowding from the functionally deficient existing leased facility. Built on a 3.39-acre site, the new 14,656-sq.-foot facility provides a healthier, more enjoyable environment for both employees and customers. The state-of-the-art structure is one of the few buildings owned by the State of California that has been successful in obtaining the United States Green Building Council's (USGBC) LEED Gold Certification. The design incorporates sustainable features geared toward enhancing the user's experience while reducing the building's impact on the environment.

Good-looking and Energy-efficient

Visually, the building is striking. This unique single-story structure is predominately framed with structural steel members placed in synergy with localized areas of masonry walls. Upon first arriving at the building, visitors are treated to dramatic sweeping steel roofs that seemingly float, with grand cantilevers providing shade and shelter for not only the entry to the structure, but also for the vehicle driving exam lanes.

A pair of 30-in.-deep structural steel girders extend from the building, creating an overhang of nearly 45 ft at the western entry. This impressive overhang endows the structure with an expansive shaded area, encouraging users to enjoy the outdoors while waiting. The 30-in. girders continue to the east to form a powerful cantilever of more than 32 ft, providing shelter at the drive aisle for motorists waiting to take their driving exam. A repetitive series of smaller secondary roof beams frame over the top of these massive girders, tailing out with varying lengths to form a gently curved roof edge, thereby softening the appearance of the building at this primary face. Having such a large roof area in Southern California created an ideal location for placement of rooftop photovoltaic solar panels, which serve to compensate for the building's energy load and help the building exceed California Title 24 minimum energy requirements by 34%.

The exposed steel roof beams give character to the roofline. According to the architect, the intent of the long overhang at the drive aisle is to mimic the feel of a Pueblo cave, as the steel projects from the textured masonry block walls, which are designed to invoke the feel of the earth's strata. These masonry walls serve as visual, structural, and environmental anchors. Structurally, they are designed to provide gravity support as well as to serve as shear walls to resist the earthquake forces that play such an important part in building design in this seismically active region. Functionally, the masonry wall placement was chosen to minimize heat gain, as the walls will behave as a thermal mass, absorbing heat and naturally insulating the structure.

Bringing it to Life

Structural steel was the ideal material choice for the primary framing. The structural engineer recognized that steel would be the best means to bring the architect's vision of an open, light-filled space to life, while still accommodating varied roof slopes and flexibility in the placement of braced frames for earthquake resistance throughout the structure. Steel's reputation for being a recycled material also helped in keeping with the design team's aspiration to minimize the environmental footprint of the building.

Architecturally, the choice to expose the structural steel roof framing at the exterior of the building continues to the interior as well, creating an open, airy feel to the public areas. Exposed steel is used as finish material as well, contributing to the building's aesthetics and also minimizing the waste and cost associated with added finishes. Clerestory windows inset between the high and low roofs over the lobby area allow natural light to filter into the room. To support the roofs at the clerestory windows, while also maximizing the window spacing, a large engineered structural steel truss was provided at this juncture. Extensive northern windows, including clerestory and skylight, maximize natural daylight.

These measures, along with efficient lighting and heating and cooling systems provide a comfortable environment. An impressive 98% of the regularly occupied spaces have outdoor views. Additionally, natural daylight is provided for 89% of the regularly occupied spaces.

Steel erection underway at the high roof. The roof framing was left exposed to the interior of the building.

Anney Rosenthal, RNT Architects

Sustainable in San Ysidro

The new California Department of Motor Vehicles facility in San Ysidro received USGBC Gold LEED Certification through the following measures:

- **Recycled materials:** At least 5% of the building's materials are recycled. The contractor recycled 60% of the construction waste (not to mention that structural steel is 95% recycled).
- **Non-heat island roof:** The roofing material is Energy Star rated and is highly reflective.
- **Solar panels:** Rooftop photovoltaic panels compensate for 9% of the building's energy load, helping to exceed the California Title 24 minimum requirements by 34% (40% by LEED standard).
- **Energy efficiency:** A raised floor allows the building's displacement ventilation system to efficiently serve the open office work area through under-floor air distribution. Overhead and under-floor ducts act to distribute air to the public service area's diffuser units.
- **Daylight and views:** Natural daylight is provided for 89% of the regularly occupied space. Skylights, clerestory, and northern windows maximize natural light. Outdoor views are achieved for 98% of the regularly occupied spaces.
- **Thermal energy management:** To minimize heat gain, west- and south-facing windows are tinted and concrete masonry acts as a thermal mass.
- **Air quality:** All paints, sealants, adhesive, and carpeting contain minimally volatile, organic compounds. Floor grates are installed at major entrances to trap outside dirt. These measures help to maintain a high quality of indoor air.
- **Storm water drainage filters:** All catch basins contain filters to trap harmful particles, keeping them from entering the public waterways.
- **Highly efficient irrigation and landscaping:** Water use is reduced by 68% through an efficient irrigation system and drought-resistant planting with low water-use plants.
- **Crash buffers:** Landscaped traffic barrier walls surround the building and define the edge of the facility, protecting the building and its occupants from inexperienced drivers.
- **Reduced water use:** Efficient plumbing fixtures reduce typical water use by 41%.

Daniel Korntved, SDSE Structural Engineers

Interior of the San Ysidro DMV.

Different Dimensions

While not immediately evident from the exterior of the building, the building's footprint is such that the layout is dimensionally quite complex, with very few 90° corners and angles at walls. These plan irregularities, combined with the complex sloping curved roof system, drove the need to preserve dimensional stability as the project transitioned from the schematic model stage through design and into construction. To address this need, three-dimensional modeling was used during design by the structural engineering team, as well as during fabrication by the structural steel fabricator and erector.

Bentley Ram software was used during the design phase, allowing for simplification of the framing layout and design, as well as helping with the economy of the design for both lateral and gravity analysis. To create the structural steel shop drawings, the steel detailer used SDS2. Employing 3D modeling for design and detailing was critical to fabricating and erecting this dimensionally intricate building with little error.

San Ysidro's new DMV facility is a leading example of a "healthy building." The energy-efficient structure combines the beauty of exposed building materials with the comfort of a clean environment. MSC

Tamara Allen is a principal with Stedman and Dyson Structural Engineers (SDSE) in San Diego.

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Justin Maconochie Photography

Innovative Connections, Simple Solutions

Three unique glass-and-steel projects achieve success through highly engineered bolt systems—as well as through the universal principles of simplicity and constructability.

BY TERRY C. PETERSON

THE BENEFITS OF OPTIMIZING STEEL CONNECTIVITY WITHIN A PROJECT ARE ENDLESS. When innovative methods are introduced for joining steel framing members, the results can be phenomenal.

Increasingly, standard weld symbols on structural drawings are being replaced by creative details involving mechanical fasteners. Though bolted connections have been around for several years, exciting new ways of using them has led to a rapidly growing world of mechanical connectivity. As bolting technologies have advanced, they are becoming increasingly popular in solving the quality, aesthetic, time-line, and strength goals of the architect and engineer.

Following are a handful of projects illustrating the successful use of innovative bolting technologies and practices.

Careful Design for Steel Connections

As the last piece of prefinished steel was mechanically bolted into place atop the 208-ft-diameter, 50-ft-tall glazed dome at the Atlantic City Harrah's Resort and Casino's pool complex, Brad Swegles couldn't help but smile at its successful completion. Swegles is a project manager with Novum Structures, LLC, which designed and built the structure. The "hyper-track" time line allocated to design, engineer, fabricate, paint, and erect this 42,000-sq.-ft single-layer dome had seemed improbable when the contract was signed 10 months earlier.

"The great thing about these prefinished, bolted together systems is when the last piece goes in, you're done," says Swegles. "No nasty field painting."

The architectural firm of Friedmutter Group in Las Vegas set forth to accomplish the nearly mutually exclusive design objectives of high transparency combined with long-span. To make for an even more challenging project, environmental loading for Atlantic City's climate unites two of a structural engineer's worse enemies: hurricanes and snow. Had a conventional engineering approach been used in designing the dome, the combination of long-span and loading would have resulted in large, heavy mem-

Justin Maconochie Photography

Atlantic City Harrah's Resort and Casino's pool complex (left) features a 208-ft-diameter, 50-ft-tall glazed dome framed with structural steel.

The 12-ft-wide, 200-ft-diameter glass walkway bridge at the General Motors Corporate Headquarters in Detroit, Mich. (right) is the largest glass walkway structure ever built in the United States, covering 17,580 sq. ft.

bers, thus compromising transparency. To solve the challenge, Novum engineering understood the need to think outside of the box.

In developing a structural grid geometry for the outer surface of any architectural form, Novum begins every project with an analysis of the cladding capabilities and related economics.

"While a geodesic grid surface is much more structurally efficient, it creates a need for triangular shaped glass panels, which cost about twice as much as rectangular glazing," explains Novum preconstruction engineer, Brian Vande Zande.

As a result, Scott Knoblock, project engineer at Novum, created a rectangular grid for the dome's outer surface while selecting a Novum system consisting of forged steel block nodes (joints) and rectangular strut elements. In order to generate a moment-resistant connection in a single layer, two concealed bolts are used to connect each strut end at the node. To generate enough stiffness to resist the loading and span challenges, eight lightweight triangular trusses framed out of the steel block node system were added down the slope of the dome, as well as three concentric circular rings. As it turns out, the triangular trusses provided a very logical raceway for the HVAC pipes in the humidity-challenged space.

"We really tried to minimize the visual impact of the stiffening trusses," adds Knoblock, "but it turned out to be a perfect conduit for the mechanical engineer in executing his work."

Yet another Novum system employing mechanical connections was used to affix the glazing directly to the rectangular-shaped top chord members of the steel block node system. Each glass panel was held by eight edge clamps (two per side) using Novum's edge clamp glazing system, which attached directly to the steel top chord and eliminated the need for costly aluminum framing mullions.

"Eliminating those aluminum framing mullions made the design a lot more transparent, which really pleased the architect," says Swegles.

Maintaining the high-speed time line of the project started with the engineering process. The behavior of pre-tested systems is modeled in Novum's proprietary software, allowing for rapid structural analysis in a highly automated format. In addition, some modular components can be machined rather quickly using instructions generated by the software's output. Accuracy of the fabrication is greatly enhanced by the controlled environment that exists within the plant. Since field attachment doesn't employ any welding, all parts can be prefinished, and on the Harrah's dome project, that consisted of a hot-dip galvanized undercoating followed by an electrostatically applied powder in accomplishing the colored top coat. The parts can be shipped in logically assembled, protected bundles sequenced for installation, in order to minimize shake out time.

"While the challenges of construction always create a few hiccups along the way, the speed and relative accuracy of these prefinished bolted systems not only allowed us to keep our time line, but also provided the architect with the beautiful, lightweight, transparent dome that he had envisioned," reflects Swegles.

General Motors Houses Construction Breakthrough

The use of prestressed bolts to develop a high-strength connection was a key

Cris Burkhalter Photography

component of the successful execution of a 12-ft-wide, 200-ft-diameter glass walkway bridge at the General Motors Corporate Headquarters in Detroit, Mich. The bridge represents the largest glass walkway structure ever built in the United States and covers 17,580 sq. ft. Complicating the construction challenge, the mammoth glass bridge, referred to as the "Circulation Ring," was installed at the third floor of the preexisting Renaissance Center. At the building's ground floor was a very high-traffic retail center with many popular shops and eateries. As a result, access was very limited through a small entrance at the third level of the parking garage, and there needed to be high sensitivity to retail customers below. The combination of these elements resulted in a logistical nightmare.

"A challenge we faced with the General Motors project was incorporating a new structure and building systems within an existing building while providing minimal disruption during an occupied renovation," says Anwar Hakim, associate director at Skidmore, Owings & Merrill LLP, the project's structural engineer. "We worked around this by breaking the overall large project into smaller projects so that these components could be phased and sequential according to the construction schedule."

Surfaces of the Circulation Ring consisted of all glass with curved guardrails on each side and an acid-etched, triple-laminated floor below to enhance privacy. Initially, the structure was envisioned to use field-welded truss elements that would attach to existing concrete columns on one side of the bridge and suspend off cables on the opposite side of the walkway surface. Unfortunately, the logistical challenge of bringing in curved trusses through a small opening, welding them up above occupied space, and field painting pushed the pricing received from local bidders about 50% above budget. With time running out and a serious budget problem on their hands, the project's general contractor, Turner Construction, turned to Novum.

After reviewing the site, the Novum preconstruction team quickly understood the logistical peril that troubled the previous bidders. Converse to the original design of bringing in long members and welding them, Novum chose a completely different tactic in using its factory-finished beam-to-beam system, which consists of tubular steel profiles that are bolted together axially. The engineer of record was initially resistant to this approach because of the huge static and dynamic forces that exist on bridges when loaded with pedestrians, but Novum explained their research and testing that showed that mechanical fasteners could do the job. The elimination of field welding, field painting, and the use of easier-to-handle steel tubes allowed Novum to assemble a design-build proposal that was not only within budget, but also provided an even more aesthetically pleasing look.

The Future of Steel Support Systems

Looking through structures, not at them, has become an ever-increasing architectural trend in the U.S.. Transparency is king, and anything that can be done to reduce the size of structural sections while minimizing the integration required with cladding systems has come to the forefront of engineering and construction challenges. In reducing the size of a structure, tension-only elements, such as rods and cables, can be introduced. They have a much smaller diameter and are correspondingly less visible. Applications of tension-only (e.g., cable nets) and tension-assisted (e.g., grid shells) systems are being commonly used across the country. However, reducing the complexity of integrating glazing systems with a steel supporting structure has been a bit slower moving, even though the corresponding pay-off in improved transparency is similar.

The conventional methodology of "integrating" glass to steel is to utilize two completely independent systems. Typically, a large aluminum mullion (e.g., 5 in. to 8 in. deep) is set on top of the steel. In turn, the mullion receives the glass panels. As a separate system, the glazing mullion can be "shimmed off" the steel in transforming the AISC tolerances of the erected iron to the finer accuracy required for a well-functioning glazing system. Improving the integration of the two systems requires improved erected tolerances to be provided by the supporting steel.

Unfortunately, one of the contributors to reduced tolerances of erected steel is field welding. Heat applied from welding, as well as the installation methodology, can limit how accurate the supporting members can be. One method to tighten tolerances has been the mechanical attachments used in the Novum systems. Tolerances can be significantly improved by machining parts in the factory and welding, when required, under plant-controlled conditions. Parts with higher accuracy are then shipped to the site and connected mechanically without inducing any heat that can warp members during the installation.

Installing a much more accurate steel supporting structure allows for true glazing integration and a greatly downsized and simplified transition from top of steel through top of glass. When executed appropriately, you can begin to view the top chord of the steel system as replacing the standard aluminum glazing mullion referenced above. In doing this, transparency is greatly enhanced, as you have reduced the thickness of the envelope by 5 in. to 8 in., or the thickness of the removed aluminum mullion. To substitute for that bulky mullion, there are a number of highly transparent ways to affix or "glaze in" the glass panels. Some systems included point-supported, edge-clamped, corner-clamped, and line-supported.

Innovative Steel System for Transparency

Line-supported glass is the most challenging system of all, as the top chord of the steel literally functions as the aluminum mullion that it replaces. A thin, EPDM rubber glazing strip is used atop the steel to receive the glass panel. Therefore, the steel has to be virtually perfect. That challenge was placed on Novum by Pelli Clarke Pelli Architects (New Haven, Conn.) when designing the rotunda element at the Overture Performing Arts Center in Madison, Wis., an octagonal structure in plan with a 45.2-ft corner-to-corner dimension and overall height of 25.3 ft.

"We basically had [Novum] sitting with us at the design table," says Robert Mangas of Potter Lawson Architects, Madison, Wis., who served as project architect. "They heard the aesthetic goals that were trying to be achieved and they offered solutions which was very valuable. They really were part of the design team."

Pelli Clark Pelli wanted an incredibly transparent dome to draw in natural light at a very key location of the beautiful facility.

"[The architects] really wanted this to be as slim as possible," says Lou Olson of J.H. Findorff & Sons, Inc, general contractor on the project. "The design team definitely challenged us to minimize the design. "

Initially, the structure was minimized by introducing tension rods along with tubular steel profiles. In regard to the glazing, PCP wanted a completely smooth outside glass surface that eliminated any point support or clamping mechanisms for glass attachment. To accommodate a glazing system that really challenges the supporting steel, Novum turned to its mechanically attached BB-system in order to deliver the appropriate tolerances.

"I think one of the challenges was to keep the profiles as small as possible," says Mangas. "They were looking for as much transparency as could possibly be achieved."

"One of the unique things about it is we had to hide all the fasteners," says Olson of using the BB-System in the design. "I've never before used a system like what was incorporated into this specific structure."

The final "tension-assisted" structure, equipped with a fully integrated glazing system, resulted in substantially smaller steel profiles while eliminating the aluminum mullions. The transparency was breathtaking. And the project was a huge success. MSC

Terry C. Peterson is vice president of sales with Novum Structures.

Why Use Mechanical Connections?

Reduced engineering time. Modeled behavior of pretested systems has resulted in proprietary design tools that reduce structural analysis time, and automates much of the complex shop and fabrication drawing work for both cladding and structure.

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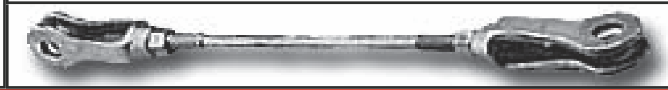

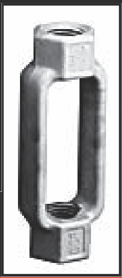

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25 Years is Just the Beginning

BY BRIAN RAFF

AISC's certification program has come a long way in 25 years. Imagine what the next quarter century has in store!

BEGINNING A NEW YEAR ALWAYS PUTS LIFE INTO PERSPECTIVE FOR ME. January is my clean slate, a great time to reflect on where I've been and to daydream about where I'm going. Looking back, I have learned a lot about our current steel industry as well as its history, and it is incredible to see the progression that has taken place over the years. As we take a walk back in time, I would like to acknowledge those individuals and companies who have dedicated their personal and professional lives to shaping and molding this industry into what it is today. Our certified fabricators have helped build this program from the ground up and are the reason for its success.

Growth over Time

Looking at the time line on the following page, it's clear that the AISC Certification program has grown significantly, its participants establishing the program as a credible source of information and quality fabrication based on quality principles. In the late 1960s, the idea of a quality management system within the steel construction industry did not exist as we know it today. Management of quality was implemented by catching defects through product inspection instead of preventing them through standardization of procedures. Although quality management and process control was being refined, it wasn't until 1987 that the International Organization for Standardization (ISO) developed a standard (ISO 9000) that addressed an organization's processes and procedures, and not the product or service itself as product inspection did. The AISC *Standard for Steel Building Structures* is based on the principles of quality management, with features that are tailored specifically for the structural steel industry.

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

The following fabricators have been AISC Certified for 25 years or longer:

AFCO Steel, Little Rock Plant
Augusta Iron & Steel Works, Inc.
Berlin Steel/FEI Ltd.
Bridges & Towers, Inc.
Canron Western Constructors Inc.
Capitol Steel & Iron, LLC
Carolina Steel Corp.
Central Texas Iron Works
Cives Steel Co. Mid-South
Cives Steel Co. New England Div.
Cives Steel Co. Southern Div.
Comm Steel, Inc.
DeLong's, Inc.
Egger Steel Company
Fought & Company
Geiger & Peters, Inc.
Globe Iron Construction Co.
Harris Structural Steel Company
High Steel Structures, Inc.
Hirschfeld Steel Group LP
L.B. Foster Company
L.B. Foster Company, Precise Structural Products
Lehigh Utility Associates
Michelman-Cancelliere Iron Works
Owen Steel Company, Inc.
Paxton & Vierling Steel Company
RP'S Machinery Sales, Inc.
Safety Guard Steel Fabricating
Schlosser Steel, Inc.
Shepard Steel Company
Southwest Steel Fabricators, Inc.
Steel Service Corporation
Stupp Bridge Company
Trinity Industries, Inc.
W & W Steel Company
Zalk Josephs Fabricators, LLC

AISC also recognizes those fabricators that have reached five-year and 10-year milestones. Visit www.aisc.org/certappreciation.

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**.

AISC CERTIFICATION TIMELINE

1950s	Welding was introduced.
1969	The Quality Criteria and Inspection Standards Committee was formed. Members of note include Jack Long, President of American Bridge Co., Div. of U.S. Steel; Jack Coneed, Manager of Bethlehem Construction, Division of Bethlehem Steel; and C. Farnham Jarrard, Jr. of Allied Structural Steel, who became chairman of this new AISC Committee.
1971	AISC published the first edition of *Commentaries on Quality Criteria and Inspection Standard*, a booklet containing recommendations on problem areas of quality control in fabrication and erection.
1976	AISC started the AISC Certification program to establish an industry standard that would enable fabricators to demonstrate that they have a quality system in place.
1976	January 16: Stupp Bros. Bridge and Iron Co. became the first AISC Certified company.
1980	71 plants had been certified by this point.
1984	AISC began to implement awareness marketing for the program to aid interested fabricators who did not know how to begin the certification process.
1995	To improve the quality of the auditing, AISC restructured the program and created the Quality Auditing Company (QAC) to assess fabricators' qualifications. The program's criteria were revised, eliminating redundant issues and adding requirements related to bolting, welding, and quality control procedures. Certification categories, which had once combined bridge and conventional buildings fabricators, were separated in order to make the information on bridge fabricators more pertinent to bridge builders. A Fracture Critical Endorsement and a Sophisticated Paint Endorsement were added to the program this year.
1997	AISC and QAC developed paint seminars in six cities around the country to teach fabricators advances in painting techniques as well as changes in the criteria for sophisticated paint certification.
1998	AISC coordinated its own sophisticated paint endorsement with SSPC: The Society for Protective Coatings' Certification for Independent Painters.
1996	A committee made up of representatives from AISC, the National Erectors Association (NEA), and the Structural Steel Erectors Association of America (SSEA) implemented a program to certify erectors.
2000	The number of Certified fabricators passed 600, and 21 erectors were certified, a number that almost tripled by the end of 2003.
2001	QAC was dissolved and the Quality Management Company (QMC) formed as a limited liability corporation (LLC), retaining its separate company status while moving under the auspices of AISC.
2002	A new AISC *Certification Standard for Steel Building Structures* was created in accordance with modern auditing science methodology, requiring fabricators to describe their business, fabrication, and quality-control procedures in a written company manual that includes all aspects of the fabricator's quality management system.
2003	June: Fabricators in the process of certification could no longer choose to be audited to the checklist, and had to Certify to the *Standard*. By the end of this year, there were more than 700 Certified fabricators in the program.
2005	Release of the SPE Standard.
2006	The *Building Standard* was updated and all certified building fabricators were required to be certified to the new standard.
2007	Active development of three certification standards: erector, component, and shop-applied protective coatings.
2008–	In addition to converting the fabricator certification program to the standard, AISC also plans to implement a new certification category, component certification, in 2008. The conversion of the erector standard is targeted for the second half of 2008 and the bridge program in 2009.

Industry Support is the Key

Today, more than 700 Certified fabricators and 115 Certified erectors support AISC, and should be recognized for building the Certification program from the ground up. At the close of 2007, AISC Certification announced a customer appreciation program to recognize those fabricators that have been Certified for five, 10, and 25 years. All fabricators that have been Certified for more than five years will receive a commemorative flag (shown above) for indoor or outdoor display. The flag represents their long-standing efforts to provide quality fabrication to the steel industry. It signals to their customers, clients, suppliers, and competitors that they have not only the personnel, experience, knowledge, and equipment to deliver a quality project, but also the ability to bid on projects that require Certification. It also shows their employees that they care about them as well as the industry.

The erector Certification program is young, but that does not make our erectors' achievements any less significant. The program has its own distinct characteristics, and as we reach appropriate milestones, erectors will be recognized for their achievements as well.

I would like to personally thank all of our certified fabricators for their unrelenting dedication to our industry and their efforts to improve it through the adoption of quality principles. Your work provides the necessary security and safety to the general public, a value that cannot be measured.

One of the core elements of the *Standard* addresses continual improvement. As you look back at your relationship with AISC, think about all of your achievements, not just for your company, but for the steel construction industry. Have you achieved everything that you set out to do when you began your career in the steel industry? Looking through the history books, it has been an incredible journey. I am happy that you have let me share a few short years with you, and look forward to many more. MSC

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WHAT HAPPENED TO ALL THE SKILLED LABOR?

Providing employees with proper training, technology, and resources will help bring your fabrication shop into the future.

BY LYLE MENKE AND KANDICE GINGRICH

LAST YEAR'S STEEL CONFERENCE in New Orleans revealed a disturbing trend in the structural steel fabrication industry: the continuing lack of qualified, skilled labor in the fabrication shop. This problem continues to erode the effectiveness of structural steel in the price battle with concrete to dominate the construction trade.

Identifying the Problem

During the conference, Peddinghaus Corporation moderated the panel discussion "Will Technology Change Your Fabrication Shop?" to an unprecedented number of attendees. Whether driven by a thirst for knowledge or an understanding of prevalent labor difficulties, this diverse group showed a desire for answers to their problems.

A standing room-only crowd listened intently to the opinions and advice of several industry leaders. One theme remained consistent throughout the discussion: No matter the geographic location, skilled shop labor is rapidly declining, and shop managers need a definite plan to strengthen the future of the structural fabrication industry.

Several attendees spoke up, illustrating just how universal this problem has become:

From the Midwest: "I was walking through my shop one day when it hit me: 60% of my shop workforce was going to retire in less than 10 years!"

From the West Coast: "In assessing the potential employee applicants for shop work, it became pretty evident that I had a huge problem: They were not qualified to work in fast food, let alone in a structural shop."

From the East Coast: "It is evident that the next generation is not prepared or willing to function in a structural shop environment. It's too hot, too cold, too dirty, too noisy, or just 'unfulfilling.'"

Written concerns have also brought attention to this issue. Virtually every publication dealing with metal fabrication has published extensive articles and conducted surveys on the lack of skilled labor plaguing the industry.

Lyle Menke is vice president of marketing and Kandice Gingrich is a technical writer with Peddinghaus Corporation.

What is the Solution?

We can never replace the human factor in business success, but automating the more mundane tasks may provide the solution for many of these labor problems. By using automation to its best advantage, shops will be able to eliminate the simpler tasks, reducing their dependence on newer, untrained employees and allowing more time for training and more specialized tasks. Automation using the technology of today promises a hopeful future for steel fabricators around the world.

Problem-solving through Automation and Labor-saving Technology

Fortunately, many equipment manufacturers and software vendors have already begun to take advantage of technology in order to provide solutions to the structural industry's problems:

Problem: Beam transport using slow-moving overhead bridge cranes has proven to be ineffective and occasionally hazardous.

Solution: Today's systematic beam processing.

- ✓ Progressive fabrication shops employ knowledgeable firms to design shop layouts where materials are handled effectively and efficiently.
- ✓ All stock sections are loaded in the materials yard to save shop space for more sophisticated fabrication (i.e., trusses), which can increase profit over time.
- ✓ Systematic beam processing is designed to maximize tonnage production while minimizing inventory costs for just-in-time fabrication.
- ✓ Cross-transfer systems effectively transport long sections from one bay to another in seconds, nullifying traditional beam-handling methods.

Problem: Manually produced production drawings take time to create and are difficult to apply to physical production.

Solution: Today's building information modeling (BIM) and material requirements planning (MRP) software.

- ✓ Users can create building models that provide data that's immediately useful at any stage of the building process.
- ✓ Data taken from the model can be transferred directly to computer numerical control (CNC) machine tools on the shop floor, minimizing the chance for operator error; thus each fabricated member fits together with unerring precision.
- ✓ MRP software monitors project flow through the shop, from unloading the stock material to loading finished fabricated parts onto trucks for transport.

Problem: Creating detail components using burn tables and other machines requires multiple operators, exposes

Materials handling in fab shops has become more efficient and safer.

Modern machines for producing plate and angle detail connections require minimal staff to monitor all loading, processing, and unloading functions.

workers to unnecessary "table-top" hazards, and takes up too much space.

Solution: Today's machine designs for producing plate and angle detail connections.

- ✓ These machines incorporate multiple technologies such as high-speed drilling, punching, carbide part-making, and high-definition plasma and oxy-fuel cutting.
- ✓ Stock material is handled one piece at a time—faster and much safer than in the past.
- ✓ Modern machines eliminate the need for multiple laborers, requiring only one operator to monitor all loading, processing, and unloading functions.

Accommodating Shop Labor, New and Old

Even with all of these advances, the human element in the fabrication process is no less present or important. Since a successful fab shop will always be dependent on labor, and must evolve along with incoming workers to meet their needs and increase their productivity, innovators have focused on the smaller elements of the job as well. These innovations will eliminate hazards and inconveniences in the workplace, granting new laborers time to learn crucial details of the job from their coworkers:

Problem: Saw flood coolant is hazardous and takes too much time and labor to clean up and contain.

Solution: New band saw coolant technology is now on the market, and new band saws no longer require flood-type lubricant to lubricate the blade and remove chips during the sawing process.

In the past:

- ✓ The coolant had to be mixed with water.
- ✓ Bacteria thrived in the old coolant medium, causing skin problems for workers and creating a foul-smelling workplace.
- ✓ Material was doused with coolant, which left a residue that had to be cleaned before the material could be painted.
- ✓ Old coolant had to be removed by professional clean-up firms, adding one more shop expense.

Today:

- ✓ Technologically advanced machines, using vegetable-based micro-mist coolant, are now available.
- ✓ The coolant can be directly added to the machine—no mixing required.
- ✓ The coolant system's configuration inhibits the introduction and growth of bacteria.
- ✓ The micro-mist is applied in a fine spray directly onto the cutting site, and never in excess.
- ✓ As the mist is applied directly and sparingly to the blade tooth area, disposal is no longer a concern.

Problem: New laborers lack the knowledge and experience to operate and maintain sophisticated machinery.

Solution: New machine controls are outfitted with today's electronic technology.

- ✓ Today's CNC controls with PC front ends provide a back-up system of operation; if one system should fail, the other system keeps the machine functioning.
- ✓ With remote diagnostic programs, machines anywhere on the planet can be accessed by qualified service technicians via the Internet. Corrections can be made quickly and easily.

Problem: A lack of support for machinery and equipment.

Solution: An increase in technical service assistance to meet the needs of growing companies.

- ✓ Using effective communication centers equipped with the latest technology, long-distance technical service is more available than ever, giving fab shops the opportunity to utilize the experience of seasoned service professionals.
- ✓ Skilled technicians can travel more easily than ever before, providing prompt and effective solutions to a variety of issues.

Looking to the Future

The construction world, including the structural steel fabrication industry, has reached a crucial point, one at which technological advancements provide the greatest hope for survival and continued growth. As society becomes more technologically advanced (not to mention dependent), the fabrication shops of the future must adapt to this changing shop environment; if they continue to cling to outdated methods, they run the risk of becoming obsolete.

As evidenced by the NASCC exhibit floor, innovative firms are dedicating substantial engineering research and design investment dollars to provide advanced machine tool solutions that address these labor issues. The "fab shop of the future," using today's advanced technologies, will soon be the standard by which the next generation of structural fabricators will operate. MSC

RECRUITING RESOLUTIONS FOR THE NEW YEAR

Make proactive recruiting part of your company's strategic plan for 2008.

BY TIM R. JOHNSON

WITH THE FIRST OF every year come resolutions. Sadly, most of them are forgotten within a few weeks. We are all guilty of this to some extent. Resolve for healthy eating is cast aside at a fast-food drive-through. Plans to stay organized are lost in a clutter of to-dos. But when you stick to your resolutions, the rewards can be great.

The same holds true at the office. A successful year for your business is often tied to carrying out the resolutions set forth in your strategic plan. But taking a proactive approach to hiring needs is one critical resolution that is often forgotten. Don't let proactive staffing go the way of a new and unused fitness club membership; and don't watch excess turnover and unfilled strategic positions weigh your firm down. Make a resolution to better your business and align recruiting with your strategic plan for the New Year!

Turnover Happens

Turnover is virtually inevitable and is very common at the start of the year. Year-end bonuses have been dispersed. People resolve to evaluate their careers. Competing firms follow up on common year-end recruiting efforts to attract new talent for the New Year.

Estimating an approximate annual employee turnover rate of 20%—standard for the building design and construction industry—means a 20-person firm stands to lose four employees per year, while a 200-person firm stands to lose 40. Without careful attention to staffing and recruiting needs, turnover can leave several empty desks in a company. And these voids can be costly. For example, a mid-level, billable desk costing your firm $75,000 annually, when empty could cause upwards of $225,000 in lost billings for the year—nearly $20,000 per month. But these industry-standard numbers, like the reading on your bathroom scale, can be kept under control. And proper execution of the right employee retention and recruiting strategies can help.

For starters, make a resolution to incorporate employee feedback—collected through year-end or new-year employee surveys, perhaps—into your firm's strategic plan. This provides a process by which to address employee concerns, and it can help control turnover.

When turnover does occur, and it always does, do what you can to benefit from the loss. Conduct exit interviews with those employees who decide to leave. These interviews should be done by someone other than the hiring manager. During any exit interview, go beyond compensation. Ask for thoughts on how to better the firm. Learn what the individual's concerns are. Request opinions on how to enhance career development at the firm. Be sure to keep track of all this data. Use it not only to shape your firm's strategic plan, but also to position yourself to best market your firm to potential employees.

As the New Year is indeed a time when individuals are exploring and seeking out new career opportunities, your firm can absolutely seize the opportunity by seeking *them* out. Keep in mind that top-talent candidates will not be found on job boards. Many of them will be interested in new career options, but they will not be searching the help wanted sections. Find them before they find your competitors—or before your competitors find them first. Open a dialogue with those candidates who can benefit your firm in the New Year, and show them how they would fit into your plans for growth and success. This will preemptively address the weighty costs of empty desks, not to mention ensure quality control and quality assurance through sufficiently staffed talent teams. By incorporating recruiting into your strategic plan, preemptively planning for turnover, and appropriately budgeting in advance for recruiting efforts throughout the year, your firm will be a cut above competitors who rely on a reactive—and more costly—approach.

The Search is On

So how do you bring proactive hiring into your company's strategic plan? First, identify strategic hires your firm plans to make throughout the year. Involve top management when outlining this plan, which should include budgeted hire dates. Assign resources to identify candidates for these strategic hires—networking, internal recruiters, and headhunters, for example.

Next comes budgeting. By incorporating hiring expenditures into your firm's business plan, you avoid being hit with sudden, unexpected costs. You also avoid hitting the panic button when a vacancy opens up at an inopportune time. Consider that one desk empty for three months equates approximately to the cost to identify, recruit, and hire for two positions of the same level—with typical target close dates set at about three months. In addition, make a resolution to create monthly allowances toward recruiting, and stick to it. As a result, your firm will be prepared to deal with the expenses incurred by turnover and will significantly limit costs.

Start Today

With a carefully crafted strategic plan, your firm can ensure success throughout the year. In order to strategize properly and successfully meet goals, a firm must, simply put, have all its bases covered. At the core of a successful team are the right team members. For a firm to ensure sufficient staffing with the best employees, both in terms of new strategic hires and in response to turnover, planning for proactive recruiting is a must-do. Like any resolution, it's a matter of making it—and keeping it. MSC

Tim Johnson is project operations manager of the Engineering Division at SullivanKriess, Inc. He can be reached directly at tjohnson@sullivankriess.com.

59 Tips & More for economical design

COMPILED BY GEOFF WEISENBERGER

MSC surveyed six fabrication engineers to find out what designers can do to make their projects more economical. Our participants were eager to weigh in on just about every topic, from connection details to business practices. But it all boils down to this: Every engineering design has to be fabricated, and paying attention to constructability pays off for everyone involved—in a big way—in the long run.

WELDS

Avoid over-welding:

- A weld never needs to exceed the connected part strength.
- Excessive welding can cause serious problems (distortion, cracking, etc.). This can lead to expensive repairs or even rejections.
- Design welds for connection elements for actual forces.
- The larger a weld, the larger its carbon footprint—and the more emissions it creates.

Avoid all-around welding when not required. Gravity columns to base plates should rarely need welding all around. Normally welding one side of the web, the outside of one flange, and the inside of the other flange is sufficient.

Select fillet welds over partial-penetration groove welds when possible. Select partial-penetration groove welds over full-penetration groove welds when possible. Small and long fillet welds are more economical than large and short welds.

Keep weld sizes at 5⁄16 in. or less for fillet welds (accomodates a single pass); increase length if needed.

For vertical brace connections, match the weld length to the available gusset plate length. Since weld strength is proportional to weld size, but volume of weld metal (the true indicator of weld cost) is proportional to the square of the weld size, use a longer smaller weld if possible. Make as many of the connections the same as possible.

BOLTS

X bolts work in most connections. Where connection material is greater than 3⁄8 in. thick or where the head of the bolt is on the thin side, the thread will not be in the shear plane. So use the strength that is available.

Specify bearing bolted joints, rather than slip critical (SC) joints, whenever possible. It makes the most economical use of bolts, eliminates masking or special paint systems, and reduces installation and inspection requirements. Avoid general statements about using SC bolts; carefully consider their use.

Don't just fill up beam webs with bolt rows. Use the appropriate number of rows for strength requirements.

Provide for tolerances. Use oversized, short-slotted, and long-slotted holes in bolted connections if permitted, and leave extra space for welded connections.

WHO WE SURVEYED

Gary Violette, P.E., President, VSE, Inc., Windsor, Conn.

W. Steven Hofmeister, P.E., S.E., Principal, Thornton Tomasetti, Kansas City

Saul Mednick, Chief Engineer/General Manager, Globe Iron Construction Company, Inc., Norfolk, Va.

Tony C. Hazel, P.E., Senior Structural Engineer, Ferrell Engineering, Birmingham, Ala.

Ron Meng, P.E., Chief Engineer, Lynchburg Steel, Monroe, Va.

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DRAWINGS

Avoid the use of the terms "typical" and "similar" on design drawings. When "typical" is used, note where it applies—which column lines, which levels, etc. If a section is "similar" to another, what is different about it versus what is the same? What the designer intends is not necessarily what we see.

Avoid vague terms that may have many definitions, such as "design for full capacity."

Always show the extent of each section. Where does one section change to another section? Do they turn corners?

Always dimension plans at every level and to the greatest extent possible. Too often we see dimensions on the foundation plan, only to find none at upper floors or elevation and bracing views. We hear the excuse that when the architect changes things, it is too difficult to find and correct all of the dimensions. However, the risk for error is there for someone else who constantly has to transfer this information. It is also very cumbersome to build by.

Provide complete drawings that are coordinated and reviewed by both engineer and architect prior to release. Often, the two sources do not coordinate edge-of-slab dimensions, which are critical to efficient detailing without having to submit RFIs. The later information is received, the more it affects (increases) time and cost.

Complete the structural design to the greatest extent possible, coordinating the structural drawings with the architectural drawings, and show all structural steel on the structural drawings.

Clearly indicate seismic requirements on drawings; for $R > 3$, provide the extent of seismic design or detailing desired in connections to match the response used in the design model. AISC's *Seismic Provisions* provide guidance for information on drawings.

At curved walls, provide arc radius and ordinate location for the center point of each arc; provide an X-Y coordinate for all column locations.

Update drawings after numerous (substantial) "sketch" or "addendum" changes have been made.

Size welds or provide adequate loads for determination of weld schemes required.

Always provide all end reactions, including shear, moment, torsion and axial end reactions. Drawings that don't show actual end reactions can lead to costly and unsafe connections.

Always provide complete load paths (including transfer forces) where there are axial forces. Keep load paths simple.

Specify actual forces for splices when possible; don't specify that braced and moment frame column splices should develop the full tensile or bending strength of the upper shaft. Developing the full tensile or bending strength requires very expensive field splices, often with complete joint penetration welds. Due to typical splice locations and the presence of compressive forces, it is an extremely rare case when full tensile or bending strength needs to be developed.

In the case of tensile forces, don't size the members (braces, truss chords, etc.) based on only the gross section. The effective net section may control and require costly reinforcement. Size tension members based on the gross and the effective net section, staying on the conservative side when the actual connection design is unknown.

Simplify as much as possible. For example, make column-base details symmetrical and use the same spacing for expansion anchors. This expedites the fabrication and erection process and greatly reduces mistakes and repair costs.

Don't over-specify connections. If you don't design the connections on your drawings, you should at least provide actual and complete forces. If the sets of load combinations and connection performance criteria (or architectural constraints) are too complicated to communicate to the steel contractor, then design the connections on your drawings (and enlist the contractor's assistance to verify constructability).

Do not specify moment connections as "full moment capacity." The first RFI you will receive if you do this is, "What is full moment capacity?" (i.e., is it compact or slender?) Real structures normally do not utilize the full moment capacity of very many members, and specifying such will almost certainly require member end supplement plates if you are using bolted construction.

CONNECTIONS

Use single-sided connections, shear tabs, or single angles wherever possible.

Orient columns in moment frames so that moment connections are to the column flanges whenever possible.

Show connection concepts in sufficient realistic detail to accurately depict what the finished connection may look like.

Make embedded plates a minimum 6 in. to 8 in. larger than required for connections as a rule of thumb. Field fixes for embedded plates that are mislocated are time-consuming and expensive.

Avoid cambering moment and braced frame girders. This complicates the connections and adds cost. Keep in mind that these connections provide end restraint and reduce deflection.

Rule of thumb: The more pieces there are in a connection detail, the more expensive it is to fabricate and erect.

Do not over-economize connections. If the overall connection configuration is virtually the same, reducing the amount of weld or bolt count in a single non-repetitive connection, by even a large percentage (e.g., in excess of 25% to 30%), will probably increase the overall time and expense of the project. Repeating connections will reduce connection design, detailing, layout, fabrication, and erection costs due to the reduced learning curve.

BUSINESS

Someone once said that "The most expensive part of the job is cheap detailing." Paying a little more for someone that does quality detailing is almost always worth the extra expense through savings in fabrication and erection problems.

The elephant in the room is that your reputation precedes you. Unreasonable requirements on previous jobs will affect the bid price on the next project.

Develop a relationship with one or two fabricators who you can call to discuss ideas with before you go out to bid.

Understand the fabrication process. Ask the fabricator for a plant tour.

COMMUNICATION

Advise the fabricator when a change is coming and indicated the areas affected by any change. The designer and detailer can "work around" them and not waste valuable time and money when a change will undo all that is being designed/detailed.

Call or visit a local fabricator to determine steel shape availability prior to final member design as well as feasibility for unusual design concepts.

Follow the design sketches provided by the connection engineer. If you have questions or a conflict exists, discuss them with the connection design engineer before making any changes.

Provide "checked" drawings to the maximum extent possible at time of approval. If unchecked at approval, provide checking while the drawings are out for approval and ready for induction into the fabrication shop if nothing is marked during approval.

CODES & SPECS

Choose one specification and one specification only! Do not state that a structure's gravity system connections are to be designed to ASD, then indicate the lateral system as LRFD, or visa versa. Have all systems adhere to either code, but not both.

Understand the seismic codes and indicate your requirements in detail on the structural steel design drawings. Do not simply specify a code then leave it to others to interpret your intent.

Select an *R* of 3 or less whenever possible. When $R > 3$ the AISC *Seismic Provisions* must be applied, which has a significant associated cost implication.

When possible, use standard tolerances established by ASTM A6/A6M, the AISC *Code of Standard Practice for Steel Buildings and Bridges* and AWS. Tighter tolerances will increase costs and construction time substantially.

QUIPS

As a designer, realize that what your professors taught you is only about 1% (maybe .9% for a B.S. and 1.1% for a Ph.D.) of what you really need to know. The good news is that you have about 40 years to learn the rest.

Learn to visualize what you are analyzing and designing (one of the greatest and possibly most underrated benefits of BIM). Find steel fabricators, erectors, and detailers that you can trust and can work with. They will provide tremendous guidance towards acquiring the rest of that 99% that we need to know about the buildings we design.

SAGE ADVICE

A beam, column, or brace connection is not just a dot on a screen with three thin lines approaching it. Moreover, the connection does not care if you used method of sections, method of joints, stiffness method, finite element, Chapter C design, or a simplified rational method. In a large structure, it might be larger than 4 ft by 4 ft, weigh more than a ton, and require 50 shop hours for layout and fabrication and another 25 field man-hours to assemble. It might even be too big to ship!

If you are an East Coast designer that has been taught to delegate connection design to the contractor, do not be afraid to fully design, or even detail, complicated connections. Steel contractors do not make any more money writing RFIs than designers make answering them. Be clear, be complete. However, this does require that, as a designer, you possess an adequate understanding of fabrication and erection. Remember that an ironworker's heavy winter Carhart coat, gloved hands, and TC wrench will require more room than usual to access bolts.

Think about the steel contractor's estimator. You may have had several months to conceive, analyze, and design the structure, and to (hopefully) coordinate it with the architect and other consultants. The estimator may have as little as four to five weeks to receive and print drawings, assess quantities of main and secondary members, and obtain quotes from deck, joist, and paint/galvanizing suppliers. Make your drawings user-friendly. Very few responsible steel contractors will actually "bid what they see and change-order what they don't understand," particularly when they are engaged early in the project (although the designer in me feels compelled to add that a few bad apples can make the whole bunch stink). Do not fill your drawings and specs with boilerplated information.

MODELING

Conduct a physical (model) review of your structure to eliminate interferences and identify multi-connections to columns. The typical "cartoons" don't help when the skews are 20° and not the 45° shown on sections.

PAINTING

Specify paint for only those items that really need it. In a typical building, the steel within the vapor barrier that is not exposed to view should not need paint at all, fireproofed or otherwise. Save the painting for steel that is in a truly agressive or outdoor atmosphere, or that is exposed to view.

Provide clear, thorough paint schemes for locations of application. Paint notes of "everywhere except where fireproofed" don't really help. "If exposed" isn't always clear when studying structural and/or architectural drawings. Don't make the fabricator guess or have to rely on architectural drawings.

MEMBER SELECTION

When showing stiffeners or other plate material, use popular flatbar sizes and UM plate sizes (usually 3/16-in., ¼-in., 5/16-in., ½-in., ⅝-in., ¾-in., and 1-in. thicknesses and widths of 1 in. through 6 in., 8 in., 10 in., and 12 in.). Bars make more sense than handling a 96-in. by 20-ft plate just to cut a few fittings. Also, avoid extremely large and thick angle sizes when dealing with a small amount of fittings.

Use WTs sparingly unless several will be used. Splitting a wide-flange shape is expensive, and it may warp. There is always the issue of kerf (material lost due to the width of the cutting flame if oxyfuel is used in the cutting process). If trusses are being fabricated, WTs may be useful, especially for painting (as opposed to double-angle or similar chords), but keep in mind that web extensions, which are often required, are very expensive.

Least weight is *not* always least cost!

- Select member sizes with sufficient depth to provide reasonable connections. For example, use a W16×26 rather than a W14×22, especially if the member is coped.
- Use heavier columns to eliminate stiffener plates and/or web doubler plates at moment connections.
- Standardize member sizes as much as possible. Steel may often be purchased at lower costs in bulk quantities. If a mill order is required, there may be a minimum order.
- Do not reinforce beam web penetrations if not absolutely necessary.

Avoid expensive through plates at HSS column connections when possible. Favor one-sided shear connections (single-plate and single-angle).

When specifying beam camber, don't specify less than ¾ in. camber.

Review member sizes for connection economy:

- Preferably, a supporting beam should have at least the same depth as the supported beam.
- Favor W12 and W14 sections for typical gravity columns. The distance between flanges makes web connections easier.
- Provide perimeter beams with adequate flange width to support any deck and pour stops, and to allow for welding studs.

YOUR TIPS

Do you have any thoughts on these tips or suggestions of your own that you'd like to add? We'd like to hear from you! Go to **www.modernsteel.com**, click on Reader Feedback, and post your comments in our Reader Forum. MSC

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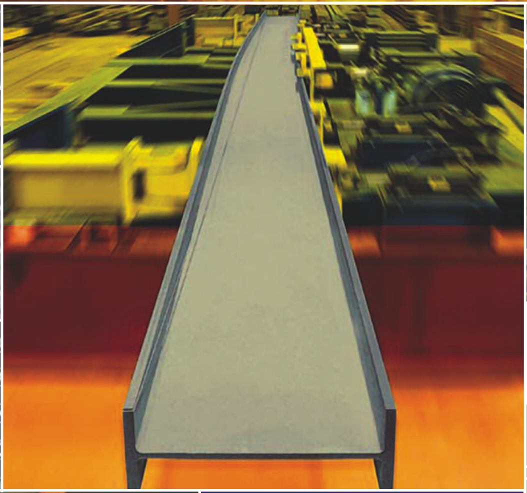

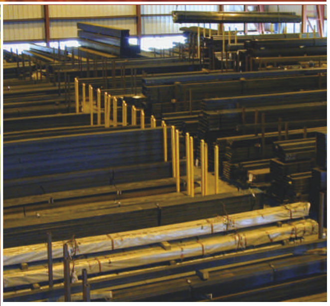

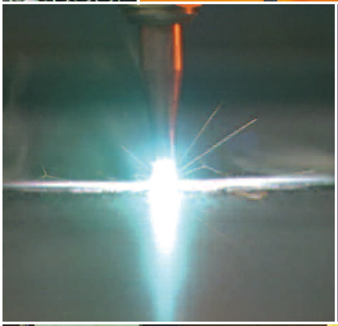

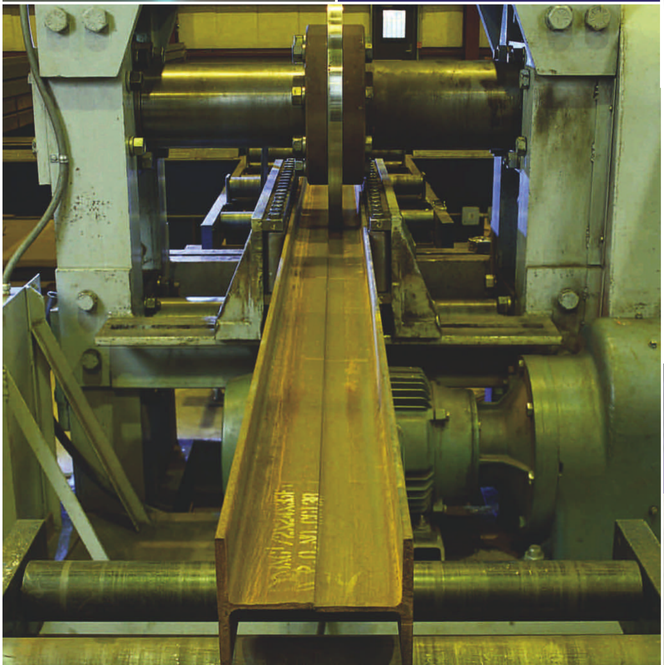

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A Closer Look at Steel Plate Shear Walls

BY JASON ERICKSEN, S.E., AND RAFAEL SABELLI, S.E.

Addressed in AISC's *Seismic Provisions* and covered in AISC's *Design Guide 20,* special plate shear walls are a viable option for many high-seismic designs.

A SHEAR WALL MADE FROM STEEL PLATE MAY SEEM LIKE A NEW IDEA. However, the concept of the steel plate shear wall had been around for decades, and was used in a significant number of buildings, even before the existence of design provisions specifically addressing this structural system. It has been recognized by the National Building Code of Canada and Canadian Steel Design Standard since 1994. Similar provisions were included in FEMA 450 (*NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures*) in 2004. In 2005, the special plate shear wall was added to the AISC *Seismic Provisions for Structural Steel Buildings*, ANSI/AISC 341-05.

The recently published AISC *Design Guide 20*, *Steel Plate Shear Walls* develops the *Seismic Provisions* into a complete design methodology. The design guide discusses the history, research, and design requirements for steel plate shear walls used in both low- and high-seismic applications. This article will discuss the high-seismic applications, focusing on the design requirements and recommendations for the special plate shear wall (SPSW) system as found in the *Seismic Provisions* and the design guide. The term high-seismic, as used in this article, refers to structural systems that are expected to undergo significant inelastic deformations, designed to meet the requirements of the *Seismic Provisions*, and have a redundancy factor R greater than 3.

Terminology

The vertical steel plate connected to the columns and beams is referred to as the web plate. The columns in SPSW are referred to as vertical boundary elements (VBE) and the beams are referred to as horizontal boundary elements (HBE).

Mechanics and Behavior

The web plates in steel plate shear walls are categorized according to their ability to resist buckling. The web plates can be sufficiently stiffened to preclude buckling and allow the full shear strength of the web to be reached. Theses are known as "stiffened" web plates. While stiffening increases the effectiveness of a web plate, it is typically not as economical as the use of the "unstiffened" web plate in which buckling of the web plate is expected.

In typical designs (and as assumed by the *Seismic Provisions*) the webs of steel plate shear walls are unstiffened and slender. The webs are therefore capable of resisting large tension forces, but little or no compression. As lateral loads are imposed on the system, shear stresses develop in the web until the principal compression stresses (oriented at a 45° angle to the shear stress) exceed the compression strength of the plate. At this point, the web plate buckles and forms diagonal fold lines. The lateral loads are transferred through the plate by the principal tension stresses (parallel to the fold lines); the angle of the tension shifts from 45° to an angle α (discussed later).

In high-seismic design of SPSW, it is assumed that lateral loads will be sufficient to cause tension yielding of the web plate along its full height. Thus, the web plate forces are uniform, as shown in Figure 2 (in the elastic range, the web-plate tension stress is far from uniform). Ideally, the web plate at each level will reach its full tension yield simultaneously, or nearly so, and the yield mode of the system will be a multi-story shear mode. The axial yield of VBE (especially at the base), which corresponds to a flexural mode, should be avoided. Flexural yielding of the HBE at the ends (near the rigid connections to the VBE) is also expected as part of the shear mechanism.

Force Distribution

Figure 1 indicates the applied forces and base reactions for a one-story steel plate wall. Figure 2 indicates the internal forces of the elements of the wall system indicated in Figure 1. The forces shown are the result of the applied forces of Figure 1, assuming uniform tension yielding of the web plate. Figure 3 indicates the internal forces for an HBE at an intermediate floor of a multi-story wall system similar to the single-story system indicated in Figure 1. (Note that boundary element end moments are omitted from the illustrations for clarity.) Several interesting points are illustrated in these figures, including:

- The web tension forces on the HBE pull toward the plate. For a HBE at a typical intermediate floor level, the forces from the plate above balance much of the forces from the plate below. However, the HBE at the top level has no such balance of forces, creating significant flexure in this member. For this reason, the HBE at the top level is often much larger than HBE at other levels.
- At the base, the web tension forces (which pull upwards) must be resisted by the foundation. A steel or concrete grade beam with sufficient strength to anchor the tension in the web plate is typically provided.
- The web tension forces on the VBE also pull inward toward the web, creating significant flexure in these members. The VBE must have sufficient flexural strength and stiffness to resist these forces and permit the webs to develop their full tension strength along their entire depth.
- Inward flexure of the VBE is resisted by compression in the HBE at the top and bottom of the VBE segment (typically at each floor). Thus, the HBE are required to resist significant compression.
- Examine the forces at the base of the wall indicated in Figure 1.

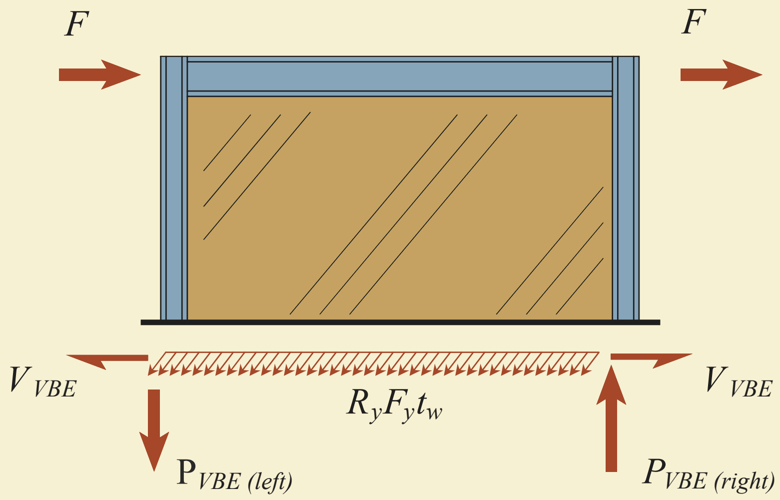


Figure 1. Applied forces and base reactions for a SPSW.

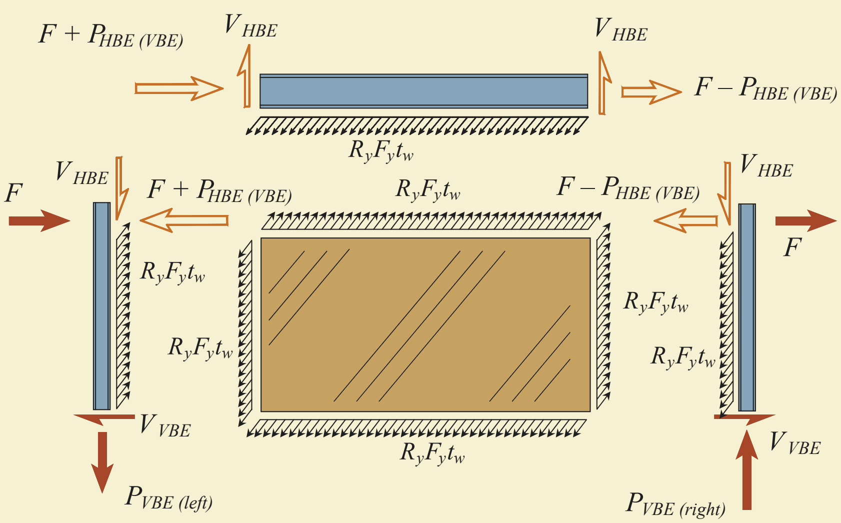


Figure 2. Free-body diagram of the web plate, boundary elements, and SPSW, based on applied forces from Figure 1.

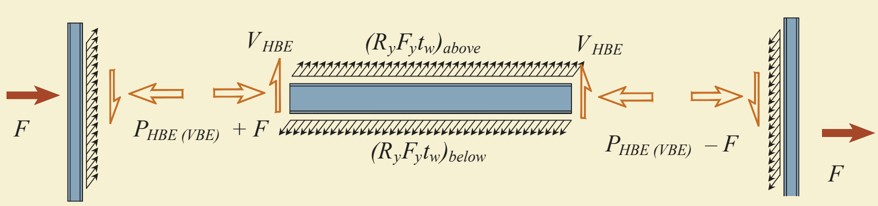


Figure 3. Free-body diagram of the boundary elements for intermediate HBE based on applied forces from Figure 1.

Notes

V_{HBE} = shear force in the vertical boundary element, kips (N)
F = collector force, kips (N)
$P_{HBE\ (VBE)}$ = axial force in the horizontal boundary element due to the vertical boundary element, kips (N)
R_y = ratio of the expected yield stress to the specified minimum yield stress, F_y
F_y = specified minimum yield stress of the type of steel to be used, ksi (MPa)
t_w = thickness of the web plate, in. (mm)
$P_{VBE\ (right\ or\ left)}$ = axial force in the vertical boundary element on the right or left side of the wall, kips (N)
V_{VBE} = shear force in the vertical boundary element, kips (N)

Compression at the base of the right-hand VBE is balanced by both tension at the left-hand VBE and in the web plate. This illustrates that the compression forces due to lateral loads in the VBE are greater than tension forces.

➜ The axial forces in the VBE to HBE connections at either end of the HBE are not symmetric. Examine Figure 2 or 3. At the right-hand connection, the axial force is the difference between two components: the collector force and the inward reaction from the VBE. (This axial force is usually compressive.) At the left-hand connection the axial force is compressive, with the two components adding.

AISC Requirements

Section 17 of the *Seismic Provisions* contains the requirements for the SPSW. Sections 1-8 and 18 contain the requirements for the seismic load resisting system in general. The requirements are summarized in Figure 4. The design guide has guidelines on how to apply the requirements and determine required forces. Generally speaking, the requirements are based on the following principles:

➜ The web plates are assumed to reach full tension yielding at angle α at each level. α is based on the wall geometry and the properties of the boundary elements and determined from equation 17-2.

➜ The webs are designed to meet the demand of the applied load with the shear strength as determined in equation 17-1.

➜ In order to ensure that the webs can reach their full tensile strength, the required strengths of the connections to the boundary elements are based on the fully yielded strength of the web, using the expected tension yield stress, R_yF_y. The web is welded or bolted to the boundary elements in the field by means of a "fish plate," which is welded in the shop to the HBE or VBE.

➜ The boundary elements are designed to remain essentially elastic (with the exception of the anticipated plastic hinging at the ends of the HBE) when the web reaches its expected tensile strength at angle α. Because the webs are assumed to fully yield in tension, the required strengths of the boundary elements and their connections are based on strength of web and the plastic moment strength of HBE, combined with gravity loads.

➜ The VBE-HBE moment ratio must meet the requirements of Section 9.6. Section

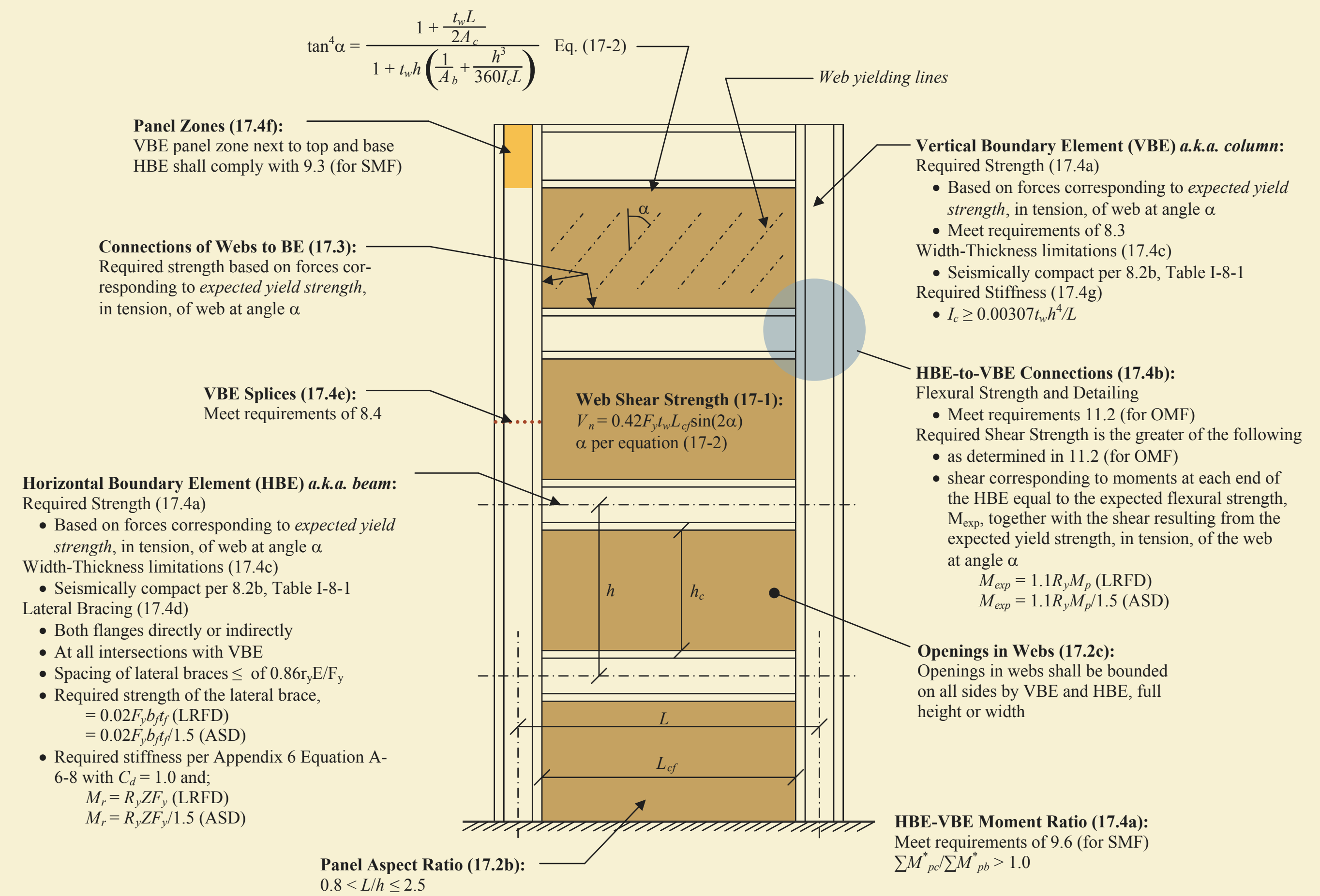
9 presents the requirements for special moment frames (SMF). This requirement is included to provide columns that are generally strong enough to force flexural yielding in beams in multiple levels of the frame, thereby achieving a higher level of energy dissipation.

- The width-thickness ratios of the boundary elements must meet the requirements of Section 8.2b, which is the same requirement as SMF. This requirement recognizes the significant part that frame action plays in the system and ensures that the moment frames elements (i.e., the boundary elements) are compact enough to undergo significant inelastic deformation.
- For the same reason, HBE have lateral bracing requirements consistent with the beams in SMF.
- The connections of the HBE to the VBE are expected to form plastic hinges, but they are not the main source of energy dissipation in this system. The SPSW is not expected to undergo as much drift as an SMF, therefore the requirements of an SMF moment connection are not necessary. Instead, the performance expected from an ordinary moment frame (OMF) connection is required (i.e. beam hinging rather than connection failure). In addition, rigid connections help prevent pinching of hysteretic behavior of the system.
- The stiffness of the VBE is critical to enabling the web to reach uniform tensile yielding in the entire web. Therefore, the VBE is required to have a minimum flexural stiffness in Section 17.4g.
- The panel zone requirements of Section17.4f for the VBE at the top and base HBE of the SPSW are the same as those for SMF (found in Section 9.3). These are generally large HBE and the VBE must be designed to resist the large forces the HBE may impose. Conversely, the intermediate HBE are expected to be small and connecting to sizable VBE. If this is not the case, or if there is an HBE on either side of the VBE, the engineer should use judgment as to whether the panel zone requirements should apply. The authors of the design guide recommend that the requirements of the *Seismic Provisions* Section 17.4f be applied to panel zones at all levels.

Analysis/Modeling

The SPSW system is modeled and analyzed to determine the forces in the elements of the system, determine the distribution of story shear between the web plates and VBE, and to estimate the lateral displacement of the frame (frame stiffness may be the governing criterion in some cases). Two modeling techniques are presented in the design guide as the most suitable for use by practicing structural engineers.

1. **Strip models.** The web plate is replaced by a series of diagonal and parallel tension-only members. This method is outlined in the Commentary to the *Seismic Provisions*. The strips are aligned at the angle α, as determined in equation 17-2, with area and spacing as determined in the Commentary, with a recommended minimum of 10 strips per panel. The authors of the design guide recommend that an average α be used (to simplify the model) wherever the calculated α is within 5° of the average angle. Research and other recommendations for the use of the strip model can be found in the design guide.
2. **Orthotropic membrane model.** The web plate is modeled by orthotropic (properties of the element depend on the axes) membrane elements to model the differing compression and ten-



Notes: All equation and section references (in parentheses) refer to the *AISC Seismic Provisions* unless noted otherwise. All symbols, except *hc*, are defined in the appropriate section of the Seismic Provisions. *hc* is the clear distance between adjacent HBE.

Figure 4. Summary of requirements for special plate shear walls.

sion resistance of the web plate. This method is recommended by the authors of the design guide for typical applications when software with this capability is available. The local axes of the elements are set to match the calculated angle of tension stress, α. The material properties in the axis aligned with α are the true material properties. The stiffness in the orthogonal direction should be assumed as zero so that the stresses calculated in the compression diagonal are essentially zero. Further recommendations for the use of the orthotropic membrane model can be found in the design guide.

Capacity Design Methods

Once the shear force in the web plates is determined from an analysis (as described above) the web plate can be designed. A capacity design is then required to determine the forces in the boundary elements and their connections based on the strength of the web plates. There are a number of analytical approaches to achieving a capacity design when determining the forces acting on the boundary elements.

The most direct method is to determine the forces associated with an earthquake by assuming the web plate has fully yielded, the HBE have formed plastic hinges, and the shear at the end of the VBE is as required by the *Seismic Provisions* Section 17.4b. This method is referred to as the direct capacity method in this article. Guidelines and recommendations on how to determine and apply these loads and combine them with gravity loads are found in the design guide. In essence, the forces determined from the full-tension yielding of the web are considered the earthquake effect, *E*, to be used in the load combinations of the applicable building code. Section 3.5.2.2 of the design guide covers HBE design. Section 3.5.2.3 covers VBE design.

Axial forces in the VBE corresponding to web-plate yielding at all levels simultaneously (as assumed in the direct capacity method) can be extremely high. For this reason, alternative methods for estimating maximum forces corresponding to the expected mechanism have been proposed. Three of these are outlined in section C17.4a of the Commentary to the *Seismic Provisions*. They are:

- **Nonlinear push-over analysis (POA).** A standard push-over analysis is done with web elements having varying stiffness properties as yielding occurs. The forces in the boundary elements that correspond to web yielding are determined. This method is especially useful to reduce the overturning moment for taller structures (as compared to direct capacity method).
- **Combined linear elastic computer programs and capacity design concept (LE+CD).** This method involves the design of the VBE at a given level by applying loads from the expected strength of the connecting web plate and adding the overturning loads from

levels above using the amplified seismic load.

- **Indirect capacity design approach (ICD).** In this method, loads in the VBE can be determined from the gravity loads combined with the seismic loads from a linear analysis increased by an amplification factor based on the overstrength of the web plate at the first level of the system.

Preliminary Design

For preliminary design, the web plates can be assumed to resist the entire shear in each frame, based on the following steps:

- The web plate thicknesses at each level can then be determined by meeting the shear strength requirements of the *Seismic Provisions* Equation 17-1, assuming a reasonable value for α. Typical designs show that the angle ranges from 30° to 55°. It is convenient to assume an angle of 45° (although 30° would be a more conservative estimate).
- Once web plates are selected, the preliminary selection of the VBE can be made based on the stiffness requirement given in the *Seismic Provisions* Section17.4g.
- For the preliminary design of the HBE, the forces imposed by the web plate can be derived from the same angle, α, as was assumed for the selection of the web plate. The selection of the HBE should be based on this load in combination with the gravity load effects.
- The preliminary sizes of the web plates and boundary elements can then be used in the analysis model as a starting point for iteration to the final design, which is based on the actual distribution of shear to the web and VBE, actual web plate thicknesses, and forces in the boundary elements based on the full yielding of the web plate.

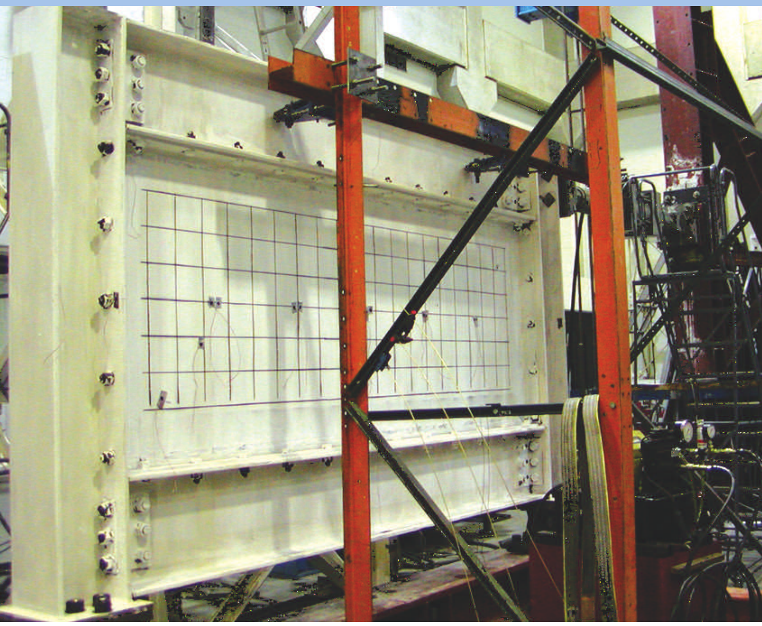
Preliminary design is discussed in more detail in the design guide, section 3.4.1 and the Commentary to *Seismic Provisions* section C17.4a. A spreadsheet to automate many of these preliminary calculations is being developed through the AISC Steel Solutions Center and will be available as a Steel Tool from the AISC web site, **www.aisc.org**.

HBE-to-VBE moment connection

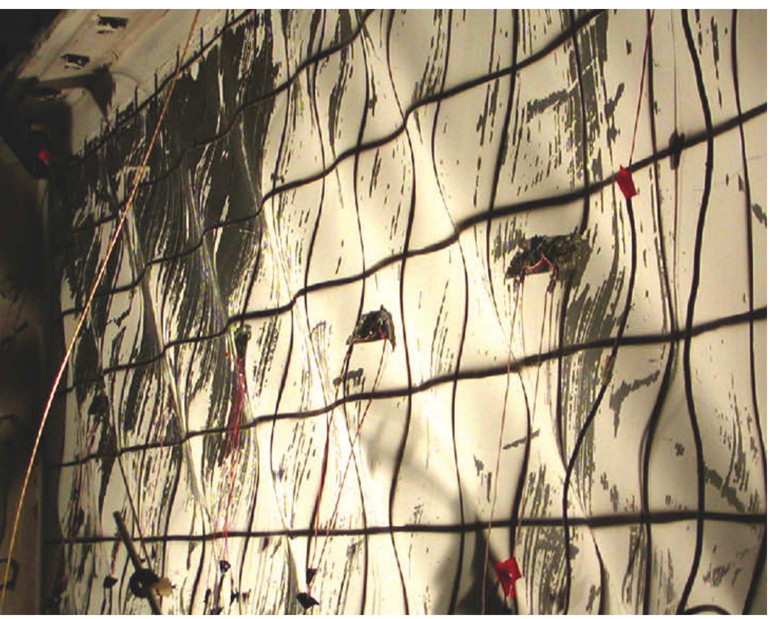
Consider two properties. First, the flexural force in the VBE due to HBE hinging is typically greater than that due to web-plate tension. In such cases, the flexure away from the connection does not govern the design of the VBE. Second, the required HBE flexural strength is governed by flexure in the mid-span due to web-plate tension (in combination with gravity loads), not at the ends. Based on these two properties, it is convenient to use a reduced beam section (RBS) connection in the HBE to limit the required flexural strength of the VBE. In addition, the RBS reduces the demand on the VBE when applying the HBE-VBE moment ratio requirements. The RBS is thus proposed for economy in the design of the VBE by the authors of the design guide. The connection only needs to meet the requirements of Section 11.2 (for OMF). The quality requirements of SMF are not applicable to the connection as these connections are not expected to undergo the same level of inelastic rotations as those expected for SMF.

Configuration

The design guide discusses the configuration options for a SPSW in section 3.5.2.5. Various configurations can be used to reduce the overturning of the system, which reduces the axial forces in the VBE as well as increases the lateral stiffness of the



Steel plate shear walls have been tested extensively. A shear wall specimen, above, is readied for testing. After testing, below, the diagonal fold lines of the buckled web are readily apparent.



system. Additional web plates or moment-connected beams can be use as outriggers or as coupling beams between walls. Remember: Using walls in irregular configurations introduces vertical irregularities that must be addressed.

Mid-span Columns

HBE at the top and bottom of the SPSW have more severe loading from the web plate because there is a web plate on only one side of the HBE (as discussed earlier). A series of mid-span columns at each level can be used to reduce the required flexural strength of the HBE at the top and bottom levels. The mid-span column resists the upward force on the bottom HBE and carries the forces to the other HBE, and helps balance the downward force at the top HBE. The sections of the web bounded by the boundary elements and the mid-span column must meet the aspect ratio requirements of section 17.2b. Therefore, the columns can also help long walls meet the aspect ratio requirements.

Horizontal Struts

Horizontal struts at the mid-height of a story can also be used to brace the VBE against the inward flexure caused by the web-plate tension and help meet the minimum stiffness requirement for VBE of section 17.4g. The struts should be designed to carry the compressive axial load and should not have rigid moment connections to the boundary elements. The sections of the web bounded by the boundary elements and the struts must meet the aspect ratio requirements of section 17.2b. Therefore, the struts can also help tall walls meet the aspect ratio requirements.

Overstrength in the Web Plate

The web plate will have some overstrength due to the fact that plates are available in discrete thicknesses and yield strengths. (The design guide has a table of commonly produced thicknesses of materials suitable for web plates in SPSW.) This overstrength can have a significant effect on the design of the boundary elements and their connections due to the fact that all elements are designed based on the strength of the web plate. In addition, having stronger stories (relative to the demand) can concentrate the inelastic deformation in "weaker" stories. Thus, it is recommended to proportion the web plates to the story shear as closely as possible and not to provide unnecessary overstrength.

Low-seismic Design

The term low-seismic, as used in this article, refers to structural systems that are not expected to undergo significant inelastic deformations, are not designed to meet the requirements of the *Seismic Provisions*, and have a redundancy factor R equal to 3. The general term for the system with steel boundary elements and web plates is the steel plate shear wall (SPW). The term special plate shear wall (SPSW) that is the main focus of this article is reserved for high-seismic applications. Low-seismic design of the system is based on the same mechanical principles as described here. However, the system is not proportioned to fully yield the web plate. Instead, the forces can come from one of two sources: Forces from the model can be used directly for sizing the web plate, HBE, and VBE; or design of those elements can be done assuming a uniform distribution of average stress in the web plate.

Resources

AISC *Design Guide 20, Steel Plate Shear Walls* has a complete discussion of the mechanics, research, and design requirements for low- and high-seismic applications, along with full design examples with preliminary and final designs. Visit **www.aisc.org/bookstore** to purchase the guide. AISC members can download the guide for free at **www.aisc.org/epubs**. The design guide also has a list of references that discusses the topics it covers in more detail.

AISC also offers a seminar on the design of steel plate shear walls for wind and seismic loading. Visit **www.aisc.org/seminars** for more information.

The spreadsheet discussed in the preliminary design section of this article will be available at a future date at **www.aisc.org/steeltools** to help with preliminary design. MSC

Jason Ericksen is the director of AISC's Steel Solutions Center. Rafael Sabelli is the director of seismic design with Walter P Moore. He is a co-author of AISC's Design Guide 20, Steel Plate Shear Walls *and the author and presenter of AISC's four-hour seminar on steel plate shear wall design.*

Shape Sense

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

Selecting the right shapes for a project involves a careful balance of **strength**, **serviceability**, and **availability**.

CHOOSING THE RIGHT SHAPE for a beam, column, or other component involves more than simply selecting a structurally adequate shape that meets serviceability requirements. Experienced engineers develop their intuition—their "shape sense"—that allows them to examine a set of plans and make sense of the myriad beam and column sizes.

How do you develop your shape sense? A few years of design and construction experience helps, but here are a few tips to get you started.

It Bears Repeating

Using more of the same shape in a project reduces structural costs by making it easier to purchase, detail, fabricate, and erect structural steel. Fewer beam and column sizes maximize the tonnage of those shapes, resulting in larger (and more economical) mill orders. Fewer shapes may simplify your designs and drawings by allowing you to standardize connections. In the shop, fewer shapes mean reduced storage and material handling costs. And in the field, repetitive members speed erection and can help other trades complete their work faster (for example, think about the benefits of uniform beam depths for the mechanical equipment installers).

Remind yourself, as well as your clients, that least weight does not equate to least cost. Far too often we get caught up in the game of reaching a targeted steel weight in pounds per square foot. Yes, steel tonnage is certainly a factor in structural costs, but it's not the only factor. Fabrication and erection are significant components too. A few extra pounds of steel can save a lot of labor costs in the shop and in the field.

Rolling Along

Choosing shapes that are readily available will make your project go more smoothly. That's where AISC's shape availability data can help. If you visit **www.aisc.org/steelavailability**,

Contact Information for Rolled Shape Producers

ArcelorMittal
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Phone: 312.899.3960
Fax: 312.899.3765
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Michael Engestrom
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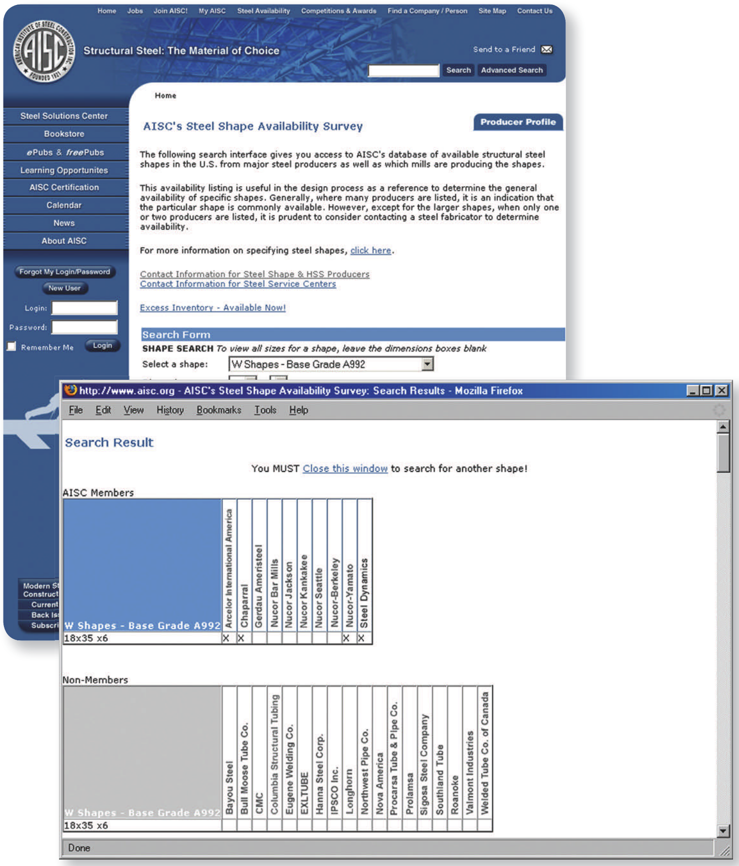
Steel Dynamics Roanoke Bar Division
Parker Arthur
parker@roanokesteel.com
Phone: 800.753.3532
Fax: 540.342.6610
www.roanokesteel.com



you'll find an online database of shape producers and their products. A shape produced by several mills is more likely to be readily available than a shape produced by only one mill.

For example, if you select W-shapes (noting that the base grade W-shape produced in the U.S. today is ASTM A992 Gr. 50), and then select a W18×35, the results indicate that W18×35s are produced by four mills. Similarly, a W18×311 is produced by only one mill. So, the W18×35 is much more readily available.

If you have questions on availability, feel free to contact a local fabricator. Also, contact information for AISC-member shape producers is listed on the previous page. Feel free to contact them with availability questions as well.

Special Shapes and More

Steel service centers are part of the steel supply chain that most engineers are still unfamiliar with. Service centers purchase bulk quantities of steel from the mills, stocking a wide range of shapes and sizes. For special shapes in small quantities, steel is often available with little or no wait. And for larger projects, service centers can provide most, if not all, of the structural steel required. For example, service centers supply approximately 70% of the structural steel for all buildings (a higher percentage on small projects and a lower percentage on larger projects).

AISC Member steel service centers are willing to help engineers with material selection issues on their upcoming building projects. Contact information for AISC Member steel service centers is listed below. MSC

Contact Information for AISC Member Steel Service Centers

Alro Steel Corporation	www.alro.com	517.787.5500
Delta Steel, LP	www.deltasteel.com	713.623.8080
DuBose Steel Inc. of NC	www.dubosesteel.com	910.525.4161
INFRA-Metals Co.	www.preussag.com	770.641.6460
Lampros Steel	www.lamprossteel.com	503.285.6667
Macsteel Service Centers USA	www.macsteelusa.com	219.933.1000
Metals Supply Company, Ltd.	www.metalssupply.com	713.330.8080
Metals USA - Plates and Shapes Group	www.metalsusa.com	800.523.3340
Namasco Corporation	www.namasco.com	678.259.8863
O'Neal Steel	www.onealsteel.com	205.599.8000
Reliance Steel & Aluminum Co.	www.reliancesteelofvt.com	323.582.2272
Saginaw Pipe Co.	www.saginawpipe.com	205.664.3670
Triad Metals International	www.triadmetals.org	215.784.0240
Triple-S Steel Supply & Subsidiaries	www.sss-steel.com	713.697.7105

Inclined towards Interoperability

EDITED BY GEOFF WEISENBERGER

MSC recently asked a handful of structural engineering software experts for their thoughts on current trends, consolidation, and ease of use with their software, as well as what the future holds for their industry. The following is a compilation of their responses in which they provide some insight on what makes their industry tick.

What's new with structural engineering software, and how is it addressing design challenges?

Bates: The general trend of more power per dollar is continuing and accelerating, as it has from the very beginning of the structural software industry. Another important trend is improving integration and interoperability. In the past "integration" meant a vendor's own products exchanged data with each other; now it means that, plus exchange of data with other vendor's products as well.

Habibullah: The ability to exchange data and information between applications appears to be of major interest at present. We are currently offering several different levels of interoperability to our users, allowing them to work in whatever manner is most comfortable for them. At the top is BIM, which integrates information from all of the disciplines, and for this we offer our two-way link to Autodesk's Revit. But we also provide CIS/2 and Application Programming Interface (API) links that allow for a more focused information exchange, such as our connection to Tekla for the detailing of steel structures. In addition, our API can be used not only by third-party developers, but also by our users as a way to control input and output between our programs and their own custom applications. The API is a powerful way to communicate with other applications because of its inherent ability to maintain data integrity; it does not rely on text or neutral files (as is the case with most BIM applications) that can become obsolete or corrupted.

Krumpen: As software packages are becoming more open, this has allowed greater access to data upstream for use by other parties in the work process. More information can be displayed graphically. We can utilize filters and coloring to denote schedules, loads, capacities, shipping information, and pretty much anything else you can think of.

Tekla: We're hearing a lot about new contract and business models that might fall under the general description of integrated project delivery, and emerging BIM technology is facilitating this trend. In practice this could mean the steel fabricator or precast manufacturer receiving an engineer's model and using it for detailing and manufacture; the Washington Nationals Stadium was a good example of this. It could mean the engineer working closely with the fabricator at the early stages of a fast-track project to provide models that generate mill orders, etc. Or, it could mean the general contractor combining the structural and M/E/P models to anticipate problems in the field and to plan erection. In short, the structural engineer is providing a data-rich, usable model to the construction phase of the project.

Lawson: In general, structural engineering software these days is allowing engineers to deliver more complete solutions, cut-

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SOFTWARE COMPANIES

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RISA Technologies	www.risatech.com	**Bruce Bates,** President
Computers & Structures, Inc.	www.csiberkeley.com	**Ashraf Habibullah,** President and CEO
Bentley Systems, Inc.	www.bentley.com	**Melanie Lawson,** Marketing Manager for Structural Engineering

SOFTWARE USER

Bechtel Power	www.bechtel.com	**Robert P. Krumpen III, P.E.,** Senior Civil Engineer, Structural Steel Coordinator

ting time off of the entire project; schedules are getting shorter and shorter.

How has structural engineering software evolved over the last few years?

Habibullah: The size of the models and the level of detail included continue to increase due to the performance enhancements offered by the software. Our current SAPFIRE analysis engine can process exceptionally large models extremely fast—orders of magnitude faster than solvers available at the beginning of the decade. Graphical displays have also greatly improved, allowing users to quickly and accurately render models in a very realistic manner, aiding not only the structural engineer in his review and verification, but also providing the owner and others on the design team a much better representation of the structure.

The use of nonlinear analysis is also becoming more common—not only for advanced technologies such as base isolators and dampers, but also for construction staging studies, where a user can see how buildings or bridges will behave as they are erected, and cable structures, where the forces in the members may be dependent upon the deflected geometry of the structure.

Bates: Structural software now is getting more design-oriented, with more direct support for building code compliance, optimization, and drawing production, either via internal features in the software itself or via links to third-party applications. Analytically, most applications still use a finite element method solution, but true sparse solvers, automatic adaptive meshing, etc. are features you can now find in programs costing $2,000 to $3,000, versus the tens of thousands you would have had to pay five years ago.

Krumpen: 3D models have changed from being just tools to create drawings to being documents in themselves. We rely on models increasingly more to coordinate vendors and within different disciplines within our own company. In many cases bid packages for work now contain a model to facilitate the vendors in making an accurate bid on the work.

Tekla: The ability to robustly integrate analysis models and physical building information models has matured greatly over the past five years. Single-source data is the cornerstone of minimizing waste in the delivery process, and the maintenance of the same data in the analysis and design process minimizes error and increases efficiency.

Are you starting to see more integration of structural engineering software with other types of software (detailing, BIM, etc.)?

Bates: Definitely. For steel, the CIS/2 standard is more important than BIM right now; BIM is still very much vendor-specific. For example, the link we develop between RISA and Revit is not the same link we would use to hook to Tekla or ArchiCAD. We have to carefully pick where we are going to spend our resources when developing links.

Krumpen: Yes, but probably at a slower pace than expected. The biggest concerns that come up with integration is how one controls ownership of information once it goes to another party, and whether all parties are properly informed when changes are made.

Tekla: The move towards BIM and an integrated workflow from conceptual design through detailing and beyond can have a number of beneficial effects outside simple productivity. One is that with the right BIM tool a young engineer can gain an appreciation of constructability and the practical implications of their design, helping them to overcome the criticism from old-timers that they unquestioningly use output from analysis and design programs.

Another, related effect is making more in-depth decisions earlier in the project that are critical to the overall decision-making process, while not sacrificing productivity. "Lean" design information in the model at early stages in the project (only seeing/querying what data is needed) is key for achieving this.

Is ease of use an ongoing battle? On that same note, what features are users asking for?

Krumpen: With the introduction of BIM—and integrating non-engineering software types such as construction, procurement, and management—ease of use becomes extremely important. It is often difficult to incorporate these new groups, especially since prior to BIM they have had limited or no interface with 3D models. So having user-friendly tools eliminates an important hurdle in getting everyone into the model. It is probably not an understatement that in order for BIM to be successful, the software tools need to be as user-friendly as possible and still provide plenty of features. Not the easiest balance to achieve.

Habibullah: Ease of use is very important, and is always a major focus with any development work that we undertake. If the user interface environment is logical and consistent, which we feel ours is, you can continue to add features and capabilities that enhance the productivity of the software without negatively impacting the ease of use. Our user environment also uses a cascading approach in that users doing simpler tasks are not necessarily exposed to the more sophisticated options. However, we do realize that a graphical user interface may not be the best solution for all of our users, so we continue to develop and improve other ways of creating models and extracting results.

One item that users recently asked for was for our software to support the ANSI/AISC 360-05 code (the 2005 AISC *Specification for Structural Steel Buildings*) utilizing the direct analysis method, which we just released. This upgrade completely automates the inclusion of second-order p-delta effects, member stiffness reductions, and the application of notional load combinations in the design of steel members. Other items that we currently have under development include a database-driven bridge modeling tool, enhanced report generation capabilities, and the ability to input a user-defined element formulation.

Bates: Ease of use has always been one of RISA's strongest selling points; we're much more accustomed to hearing compliments versus complaints, so we don't hear demands for a more user-friendly interface. For us, the real battle is continually adding new features without cluttering up the interface.

Lawson: According to a recent customer survey we conducted, the two most important attributes of a structural engineer software package are its design capabilities and ease of use. As you add more and more features, it stll needs to be easy to use. That said, we provide extensive training and documentation online and at customer sites. All of our project managers are S.E.s, so the people providing the training really know engineering.

Tekla: The challenge our interface designers enjoy is meeting the expectations of users who want software that is easier to use and continually includes more and more powerful features. Tekla has engaged the services of Georgia Tech to conduct extensive research into usability. The first fruits of that work will be seen in version 14, due this spring.

Do you think that certain features of your structural engineering software are underutilized? What is being done to promote these features?

Habibullah: Our software appeals to a very wide range of users and industries, and thus there will always be some options in the programs that are of little interest to a particular class of user. However, one area that we would like to see utilized more is the link between our structural engineering software and other BIM and detailing packages. In order to rectify this, we are trying to work closer with our development partners in order to promote these connections in a mutually beneficial manner.

Krumpen: The limiting factor in not taking advantage is the impact of the new features to the work process. We are often proceeding in incremental steps to avoid getting in over our heads. Doing too many new things at once can often cloud real process issues, so we try new things with some caution. Typically, we create a technology plan, an informal "what we want to do in the near future" list. When a new project comes up, we assess if it is appropriate to make these introductions or not.

Lawson: Some features are underutilized, but it's tough to find time to learn them during the workday. Again, that's where our training comes in.

Bates: We've tailored our products to a wide range of design challenges based primarily on user feedback, so most every feature in the software is there because a number of our clients consider it to be important.

Tekla: Sometimes, users may not realize that software offers them new ways of addressing old problems. In the case of Tekla Structures, a couple of examples come to mind:

1. The ability to model selectively both rebar and embedments at steel-concrete intersections. This enables the engineer to anticipate and avoid interferences and has the potential to eliminate expensive field fixes for one of the more common issues facing construction teams.
2. Model-based shop drawing review. The traditional process of checking shop drawings remains a significant part of the structural engineer's scope of work. Even though 3D modeling technology has improved the creation of shop drawings, the workload to review shop drawings is just as extensive as years before.

To introduce our users to new work processes we developed best practice documents that are based on the real world experience of P.E.s, detailers, and fabricators.

What effects has consolidation had on the structural software industry?

Habibullah: Interestingly enough, the consolidation in the industry brought about by large CAD companies buying smaller structural software providers appears to be (somewhat surprisingly to us) a benefit to our business. What we are finding is that a significant number of firms who previously used the acquired engineering programs are migrating to our products.

Bates: As any industry matures, consolidation is a fact of life. The cost of entry is much higher now than it was 20 years ago when I started RISA. Anyone wanting to break into the U.S. structural software market now will find it to be very difficult. It's probably more cost-effective to acquire an existing player as opposed to trying to build from scratch.

Lawson: Our goal with acquisitions is to fill in the "white space" in our expertise in an effort to provide an overall structural software solution to our customers. For example, we just acquired a bridge software program, and as such have gained several bridge experts.

Krumpen: Much like with any industry, there are multiple players at the beginning, and some will flourish while others die. This is just how it works; may the best idea win. What worries me is the concept of software packages becoming "closed systems," where in order to fully integrate your project, one must procure all the software from one entity or only work with firms that use the same software. I think this will limit the construction industry, especially smaller firms, at a crucial time when true integration is gaining momentum.

What do you see for the future of structural engineering software?

Habibullah: A primary focus in our near-term development effort is the creation of a comprehensive software package for the structural engineer that allows them to produce analysis models, designs, and production drawings from a single integrated application. This application will be able to share information with other BIM software for the purpose of coordinating and verifying data with other disciplines, but the production of all models and drawings as they relate to the structural engineer will be handled in this single structural engineering package.

Bates: We'll continue to see steady improvements and more integration in software, but I don't see any "inflection points" in the near term. The role of structural software is to automate, as much as possible, the structural engineer's workflow. The market itself will only accept change at a certain rate. Engineers are not interested in revamping their workflow every three to five years.

Krumpen: On-the-fly cost assessment of structures is one change we'll see. Any change made to a structure will give the user a clearer understanding of the financial impacts to the fabricator, erector, and owner. Changes, RFIs, and managing documents will be more automated, with the databases warning all parties when critical information is lacking. Integration with analysis and detailing packages will become more seamless—hopefully to the point that one would wonder why there were ever two models to begin with. Offices will become virtual, with software linking geographically disparate partners in a one-model environment.

Tekla: In 2008, Tekla will introduce a construction management product that will provide anyone involved in construction and erection management with a visual tool to combine and manipulate data from sources such as Excel and Primavera together with models from Tekla Structures and other BIM products. MSC

New for 2008!

We've reinvented MSC's products section for the new year to highlight a collection of exciting products each month. In general, these products have been introduced within the past six months. All products submitted are considered for publication, and we encourage submittals related to all segments of the steel industry: engineering, detailing, fabrication, and erection. Submit product information via e-mail to Keith Grubb (**grubb@modernsteel.com**) or Geoff Weisenberger (**weisenberger@modernsteel.com**).

We've also recreated the previous format of the products section (lists of products by category) online in a searchable database of product producers. You can browse producers by category or search for specific terms to find the products you need. Check it out at **www.modernsteel.com/products**. To be listed in the product directory, e-mail Lou Gurthet (**gurthet@modernsteel.com**).

Ready, Set, Anchor!

The Hilti HIT RE 500-SD Epoxy Adhesive Anchor System is the industry's first adhesive anchor to receive recognition for use with the strength design provisions for post-installed anchors found in the 2003 and 2006 International Building Code (IBC). It has been evaluated in accordance with ICC acceptance criteria AC308 and has been issued ICC ESR-2322.

The HIT RE 500-SD can be installed in the tensile zone of concrete members (cracked concrete, Ref. ESR-2322 Ch 5.8). Cracked concrete recognition allows the use of the HIT RE 500-SD in areas with any seismic design category and qualifies it for use in a wide temperature range, meaning that project location is never a concern. The system meets these requirements using a standard threaded rod with no special elements required for cracked concrete applications.

Engineers can design for any embedment between four and 20 times the rod/rebar diameter per AC308 1.2.2.4., and the system provides flexibility for various hole conditions, including hammer drilled, diamond cored, water saturated, water filled and underwater holes (ESR 2322 Fig. 3).

The anchor system has successfully passed the mandatory creep test requirements of AC308, designed to evaluate performance projected to 50 years. Only Periodic Special Inspection is required (ESR-2322, Ch. 4.4), saving valuable project time and resources.

For more information, contact Hilti Customer Service at 800.879.8000 or visit www.us.hilti.com.

Avoid an "Oops!"

You've spent hard-earned profits for electronics equipment for your business, but in a world of uncertainty, one wrong move can mean the end. Now you can help protect your investment with protective cases from OtterBox.

OtterBox offers a variety of protective covers for electronic devices such as tablet PCs, laptops, PDAs, BlackBerry devices, iPods, and other equipment. "Semi-rugged" models include a polycarbonate shell to protect the device; a clear, interactive polycarbonate membrane; and a silicone outer wrap for cushioning against drops. "Rugged" models add water resistance and additional interior cushioning, depending on the device.

For more information, visit www.otterbox.com.

Magnetic Attraction

The Magnetic Activated Ground from Western Enterprises is a new welding ground that has a built-in on/off switch. The switch activates a powerful magnet, providing an outstanding ground close to the weld. It is smaller, lighter, and more versatile than alligator clamps or traditional-style magnetic clamps. There is no need to tack a tab to the surface as with an alligator clamp, nor will the ground collect debris like an old magnetic clamp. To clean, the user simply turns it off and wipes it clean.

The ground can handle up to 450 amps continuously (100% duty cycle) on a clean, flat surface. Up to 600 amps can be handled at a 20% duty cycle on a clean, flat surface, accommodating most welding processes. The ground has a unique ergonomic curved body that permits one-handed operation, even with gloves. Additionally, two built-in scrapers can be used to help clean away rust and debris for solid contact.

The Magnetic Activated Ground allows 360° ground cable rotation when in the locked position. It does not require adapters of any kind. A built-in pipe boot allows for both inside diameter or outside diameter pipe applications.

For more information, visit www.westernenterprises.com.

Upgrade for Engineers

Bentley's RAM International Solutions Center has released version 11.0 of RAM Structural System, Bentley's modeling, analysis, and design software for engineers involved in the design of building structures of all types. Some of the new features in version 11.0 are:

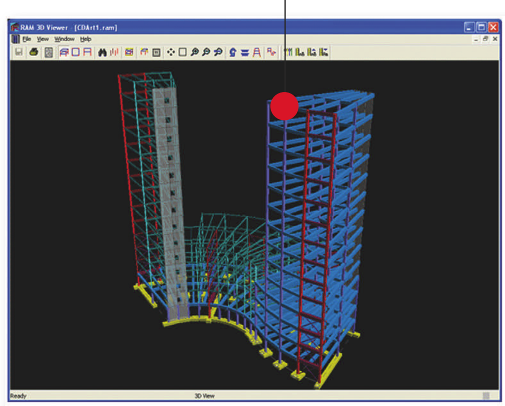
Multiple Diaphragms: This feature allows structural engineers to model, analyze, and design structures that have any number of independent, complete slab edges on a single story.

Self-Mass: This new option provides automatic calculation of mass from beams, columns, and slab/decks, if requested. Wall mass has been enhanced to give the option to either split the mass of walls between levels (half up and half down) or to apply all of the wall mass to the story above.

Steel Table Editor: A new interactive program that can be used to edit or create steel master, beam, or column tables.

Several commands have been added to ease the modeling process, including a "move column" command, improved line and point load layout commands, and enhanced data-check warnings.

In RAM Steel, the "ignore rib spacing" option has been added. Stud placement is often dictated by the spacing of the deck ribs, especially when the angle between the beam and the deck is small. This can result in an insufficient number of studs on the beam to satisfy the minimum percent composite requirements. An option is now provided to ignore the rib spacing when determining the stud placement (either because the deck is split or the ribs are flattened), thereby allowing these beams to be designed compositely, with whatever quantity of studs is required.



For more information, contact Bentley's RAM International Solutions Center at 800.726.7789 or visit www.bentley.com/structural.

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For more information, contact COMEQ, Inc. at 410.933.8500 or visit www.comeq.com.

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A well-established fabricator located in the Midwest is offering a great opportunity to an experienced detailer. Egger Steel Company is seeking a full time detailer with experience in AutoCAD and/or Tekla(X-Steel) applications. Experience with Fabtrol software and detail checking is not required but would be an advantage. The company offers competitive pay and benefits with the possibility for a company-wide bonus based on overall company performance. Candidates must be authorized to work in the United States and be willing to relocate to work on-site in Sioux Falls, SD.

Egger Steel Company offers employment in a successful family owned business supplying quality products across the country for the past 60 years. Forbes Magazine ranked Sioux Falls as the #1 Small Metro for Business and Careers for 2006 and in the top ten for the previous 4 years. Sioux Falls is a young and growing city with many entertainment, restaurant and outdoor activity options.

Please send information to:
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Applicants should have a BS degree in architectural or civil engineering with structural emphasis; MS or M. Eng. preferred. A minimum of 5 years of design experience is required, and more is better; also, having experience in construction is a plus. AISC provides a great working environment offering professional development opportunities, flexibility, excellent resources, and a competitive salary with excellent benefits.

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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.

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ARE WE MAKING ANY PROGRESS?

The business of designing and constructing buildings has changed over the years. But change doesn't necessarily mean progress.

BY BARRY ARNOLD P.E., S.E., SECB

PROGRESS, BY DEFINITION, means betterment or improvement. Change without progress is a waste of time and effort. It isn't an indication of improvement any more than shaking one's leg can be considered dancing the waltz. Moving in a clear direction doesn't necessarily mean moving in the *right* direction. And doing things faster doesn't necessarily mean doing them correctly.

Looking back over my many years in the business, I've seen a lot of change, but I'm not sure that we've made progress. Most disconcerting are some of the current trends that have infiltrated and changed the construction process.

Absence of Professionals/Craftspersons

It seems that laborers are doing most of the work these days. By laborers I mean people who, unfortunately, have little or no interest in their job beyond collecting a paycheck. Their commitment to the job is measured by a time clock.

The construction industry used to be staffed with professionals/craftspeople (P/Cs), individuals with a strong passion for their work and a commitment to make sure it was done correctly. They were educated, skilled artisans, trained in their trade and profession and dedicated to completing even the most minute, detailed tasks with enthusiasm.

The P/Cs' minds and hearts were fully engaged in their projects; they knew that problems were an inherent part of construction, something to be anticipated and minimized, not magnified. When problems arose, and they always did, there was no finger-pointing, and you could always count on the P/C to come prepared to offer solutions and ideas—to be part of the solution, not the problem. They knew that correcting a problem was a greater benefit than placing blame.

P/Cs were proud of the product they helped create; they always did their best because they knew their work reflected on them personally. They were proud—and they had a right to be.

Lack of Commitment to Continuous Education

Education doesn't only happen at a desk or in a classroom—or even working in the field. It happens continuously throughout your career. Education happens when a person is willing to learn and looks for opportunities to be taught.

Arrogance seems to have crept into the design and construction business, preventing us from learning from each other. Every problem, regardless of how small, is handled as though it was the ultimate war of right vs. wrong, good vs. evil, or life vs. death, instead of a simple comparison of mutually acceptable alternatives. Too many people believe that they have the "one and only" correct answer or solution to a problem.

We used to understand that graduating from a university or trade school was only the start of our education. We knew that there was no more prestigious school than the School of Hard Knocks, and we were eager to enroll.

Lack of Common-Sense Design—and Too Much Reliance on the Computer!

Today, I looked at shop drawings with a W12×26 beam that was 12 ft long with an 8-kip end reaction. The end connection had twelve ¾-in.-diameter bolts; the end connections weighed more than the beam. Why? Because the computer said that was what was required.

There was a time when designs were created in the engineer's head first—long before putting pencil to paper or fingers on a mouse button. Before formal design began, the designer had a "feel" for the correct answers. More important, the designer had a feel for what the wrong answers were too. No self-respecting designer or detailer would allow reams of computer printouts to create an illusion of completeness or accuracy. They used the computer as a resource tool, not as a substitute for thought and common sense.

Learning from the Past

We have opportunities every day to not only make changes, but also to make substantial strides forward in helping every person and company progress. When looking toward the future, it doesn't hurt to spend some time looking back. In doing so, we can ensure we're not just making changes but making real progress—progress that will lift every member of the construction business to a new level of commitment, dedication, education, respect, and understanding. Progress fosters respect, understanding, and real, tangible teamwork. By making progress, we make better products and better designs—and build a better industry.

Fortunately, trends aren't a predictor of things that must happen; they're only an indicator of what can happen if the trend is allowed to continue. Look back at your work experience and see if you've made progress or just changes. It's worth your time. MSC

Barry Arnold is a vice president with ARW Engineers in Ogden, Utah.

Have an opinion? Send your feedback to Keith Grubb, managing editor for MSC, at grubb@modernsteel.com.

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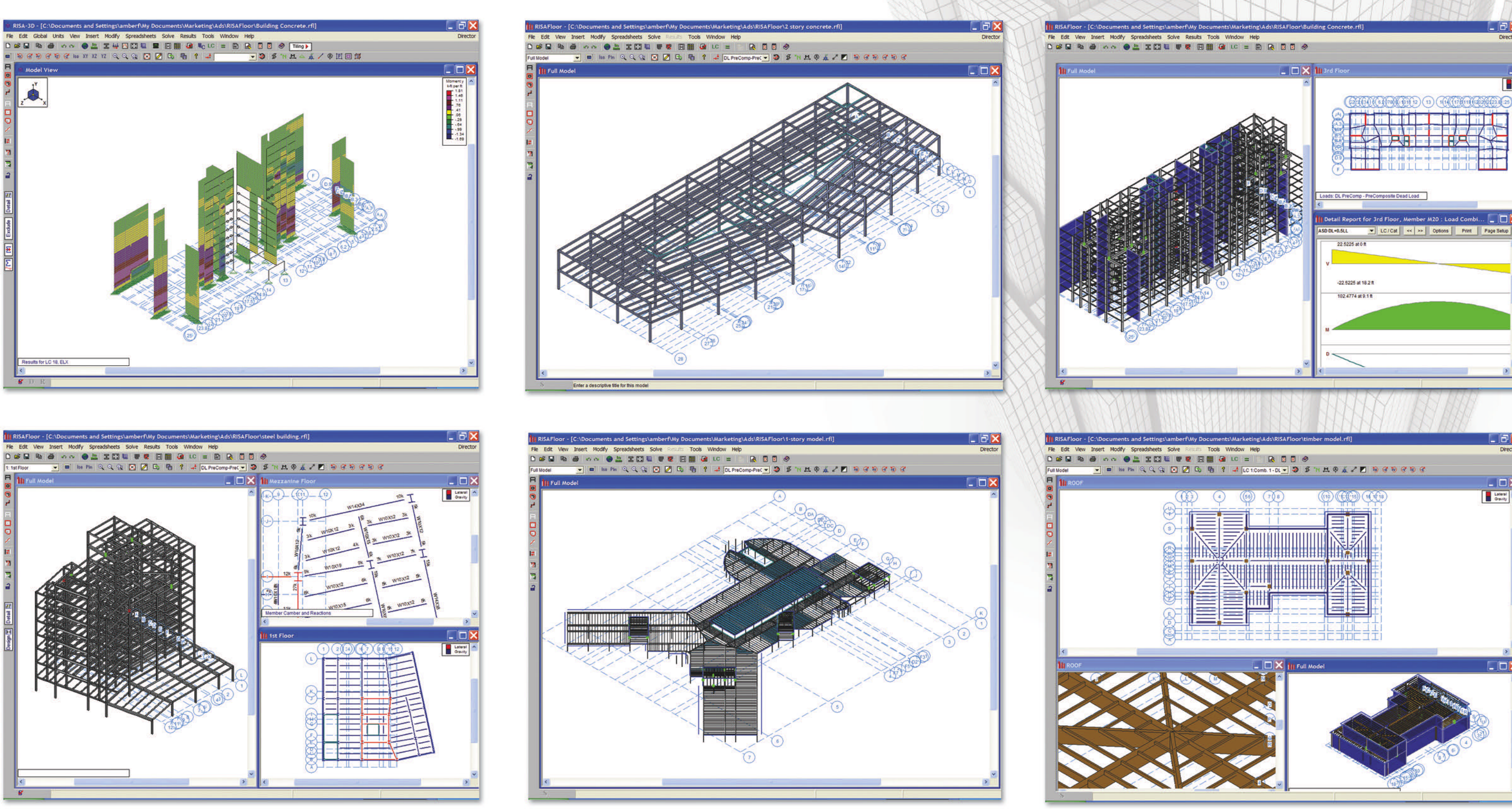

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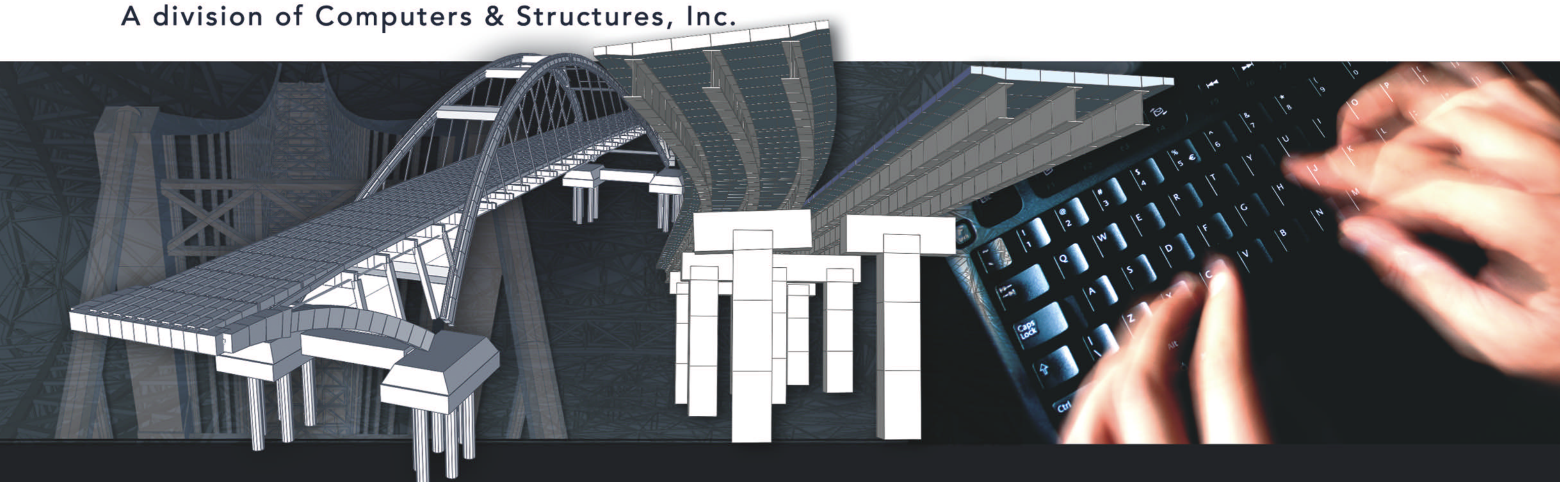

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