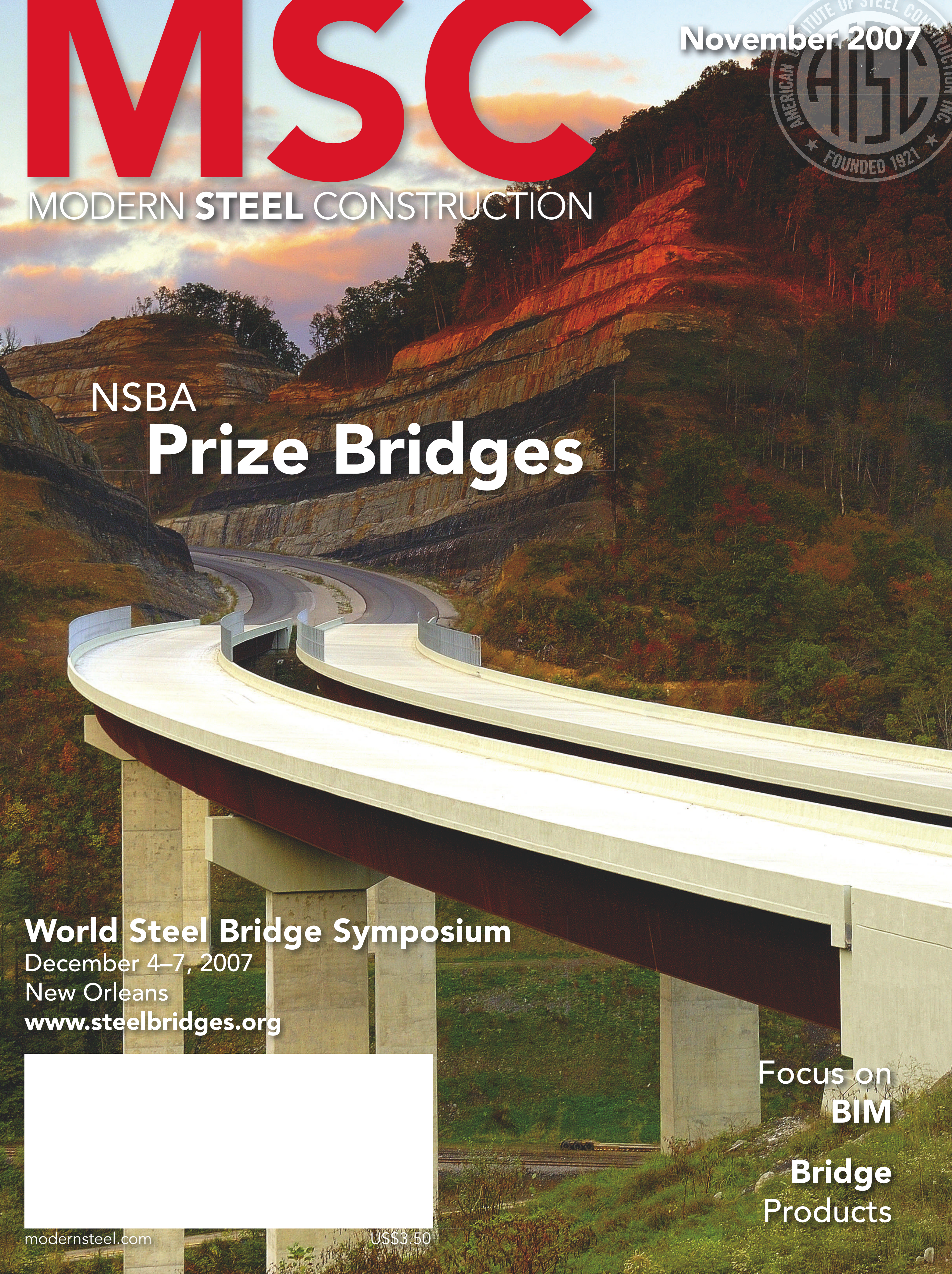

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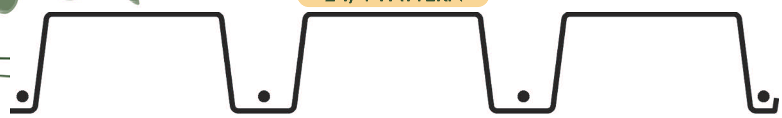
steel roof deck and WIND INTERACTION

DECK DESIGN DATA SHEET 47

24/4 PATTERN



USD TABULATES *WIND EFFECTS* ON DIAPHRAGM SHEARS.

SHEAR AND UPLIFT INTERACTION'S IMPACT ON DIAPHRAGM SHEAR CAPACITY

NS, NI 3" Roof Deck — Structure = 5/8" ϕ Welds — 24/4 Pattern — Stitch Fasteners = # 10 Screws

Allowable Shear Strength is in PLF and includes a Shear Safety Factor = 2.75.

THICKNESS	SPAN	SCREWS PER SPAN	Uplift pressure in PSF: 0	20	30	40	50	60
.0295"	9'	2	141	130	121	109	93	68
		3	167	156	146	134	118	88
		4	193	182	172	160	142	105
		5	218	207	198	185	163	119
		6	244	233	223	207	183	131
	10'	3	150	139	128	115	96	*
		4	173	162	151	138	115	*
		5	196	185	175	160	133	*
		6	219	208	198	180	150	*
	11'	3	137	124	113	98	70	*
		4	158	145	134	119	84	*
		5	179	166	155	139	96	*
		6	199	187	176	157	106	*

THICKNESS	SPAN	SCREWS PER SPAN	Uplift pressure in PSF: 0	20	30	40	50	60
.0358"	10'	3	181	171	162	150	136	116
		4	209	199	190	178	164	139
		5	237	227	218	206	190	161
		6	265	255	246	233	213	181
		7	293	283	273	257	236	199
	11'	3	165	154	144	132	115	85
		4	190	179	170	157	141	102
		5	216	205	195	183	163	116
		6	241	230	221	207	184	128
	12'	3	151	140	129	116	97	*
		4	174	163	153	139	119	*
		5	198	186	176	162	138	*
		6	221	210	199	185	156	*

THICKNESS	SPAN	SCREWS PER SPAN	Uplift pressure in PSF: 0	20	30	40	50	60
.0474"	11'	3	216	206	198	188	175	160
		4	250	240	232	222	209	194
		5	283	274	266	255	243	226
		6	317	307	299	289	276	255
		7	351	341	333	322	305	283
	12'	3	198	188	179	168	155	138
		4	229	219	210	199	186	169
		5	260	250	241	230	217	197
		6	291	281	272	261	247	223
	13'	4	211	201	192	180	166	145
		5	240	229	220	209	194	169
		6	268	258	249	237	221	192
		7	297	286	277	266	246	214

THICKNESS	SPAN	SCREWS PER SPAN	Uplift pressure in PSF: 0	20	30	40	50	60
.0598"	12'	3	247	238	230	221	210	196
		4	286	277	269	260	249	235
		5	325	316	308	299	288	274
		6	364	355	347	338	327	313
		7	403	394	386	377	365	347
	13'	4	264	255	247	237	225	210
		5	300	291	283	273	261	246
		6	336	327	318	309	297	281
		7	372	363	354	346	332	312
	14'	4	245	235	227	216	204	188
		5	278	269	260	250	237	222
		6	312	302	294	283	271	253
		7	345	336	327	317	304	282

The structural welds are loaded in both shear and uplift (tension) during wind events.
Interaction affects diaphragm shear strength. Diaphragm stiffness is independent of uplift.
Table is based on F_y = 33 ksi & F_u = 45 ksi. Table is based on a multispan application.
Additional welds and/or stitch connectors will minimize the interaction impact and increase capacity.
Capacity is not rapidly reduced from 0 to 20 psf. Interpolation is allowable.
Consult the Summit office for combinations outside this table. Spans were chosen to provide shear capacities between 100 PLF and 300 PLF using typical fasteners. These are not absolute span limits.

* The uplift capacity of the weld group is exceeded at this pressure.

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November 2007

MSC
MODERN **STEEL** CONSTRUCTION

ON THE COVER: Raccoon Creek Bridge, Pike County, Ky.

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editor's note

ABOUT FIVE YEARS AGO, I NOTICED THEY WERE BUILDING A NEW HEALTH CLUB ABOUT A MILE FROM MY HOUSE. We stopped in at Lifetime Fitness' sales office and were mightily impressed. There were acres of equipment, an indoor (and an outdoor) pool, and even a free day-care center.

Best of all, they seemed genuinely committed to customer satisfaction—so much so that they talked sincerely about having enough equipment that there'd never be a wait (and to ensure that, they even mentioned capping their membership at 10,000). And at first, everything was great. The club was sparkling clean, the towels fluffy, and the equipment always available. But slowly, membership and the club's popularity grew. Classes that were once free suddenly had a fee. Equipment was often reserved for a class (for which there was an additional fee) and unavailable to other members. Rates continually escalated. The final straw was when they added a surcharge for each child. So, I cancelled my membership.

In contrast is my bank. First Bank and Trust of Evanston/Skokie opened for business nearly two decades ago (it still only has three or four branches), and my wife and I opened charter accounts. We were promised personal service (to this day, I've almost never encountered a teller line and both the tellers and the personal bankers always seem glad to see me and my children, each of whom have opened friendly junior banker accounts). We were told they'd never nickel and dime us with those little fees for which banks are famous (and they haven't). We were given a lifetime free safety deposit box (they even let us move it to a different branch when one opened slightly closer to our house). They delivered exactly what they promised—until just a few weeks ago.

Perhaps my only complaint about the bank was that with only a limited number of branches, I occasionally was stuck with an ATM fee when I withdrew money from a bank in some other city (my bank, of course had no fees). But a few weeks ago, I received a notification that my bank would now pay the fees for me to use ATMs at other banks up to eight times a month. I love my bank. Not only do they meet my expectations—they exceed them!

Our goal at MSC is to do the same—and I hope our completely revamped web site (**www.modernsteel.com**) goes a long way to exceeding your expectations.

The first thing you'll notice is we've added a digital edition. You can page through the new online edition just like the print edition (complete with advertisements) and even click on hyperlinks to open the associated web pages. We've also added handy compilations of the most popular features (Steel Interchange, SteelWise, and Quality Corner) as well as PDFs of all MSC articles from 1996 onward. We have news and we have an interactive reader forum. We're also making it easier to reach Steel Utilities Online. This neat feature contains basic design utilities that other engineers have created (typically enhanced excel files) for things like "end plate moment connection design" or "eccentrically loaded web group analysis." Visitors can download the utilities, comment on them, or post their own.

You can search for information that has appeared in any article in MSC since 1996 or, if you click on Steel Interchange, you can search just within that section of the magazine for specific technical information.

We're also in the process of enhancing our product and job listings (have patience—building a site is complicated and we don't want to settle for just adequate). We also have a reader feedback area where you can post comments (and even comment on the postings of other readers).

I'd love it if you visited our new site (**www.modernsteel.com**) and gave us some feedback. Simply click on the "Reader Feedback" link in the top right-hand corner and write a new post. Tell us what you like (or don't like) about the site and any additional features you'd like to see. I hope you like us as much as I like my bank!

SCOTT MELNICK
EDITOR

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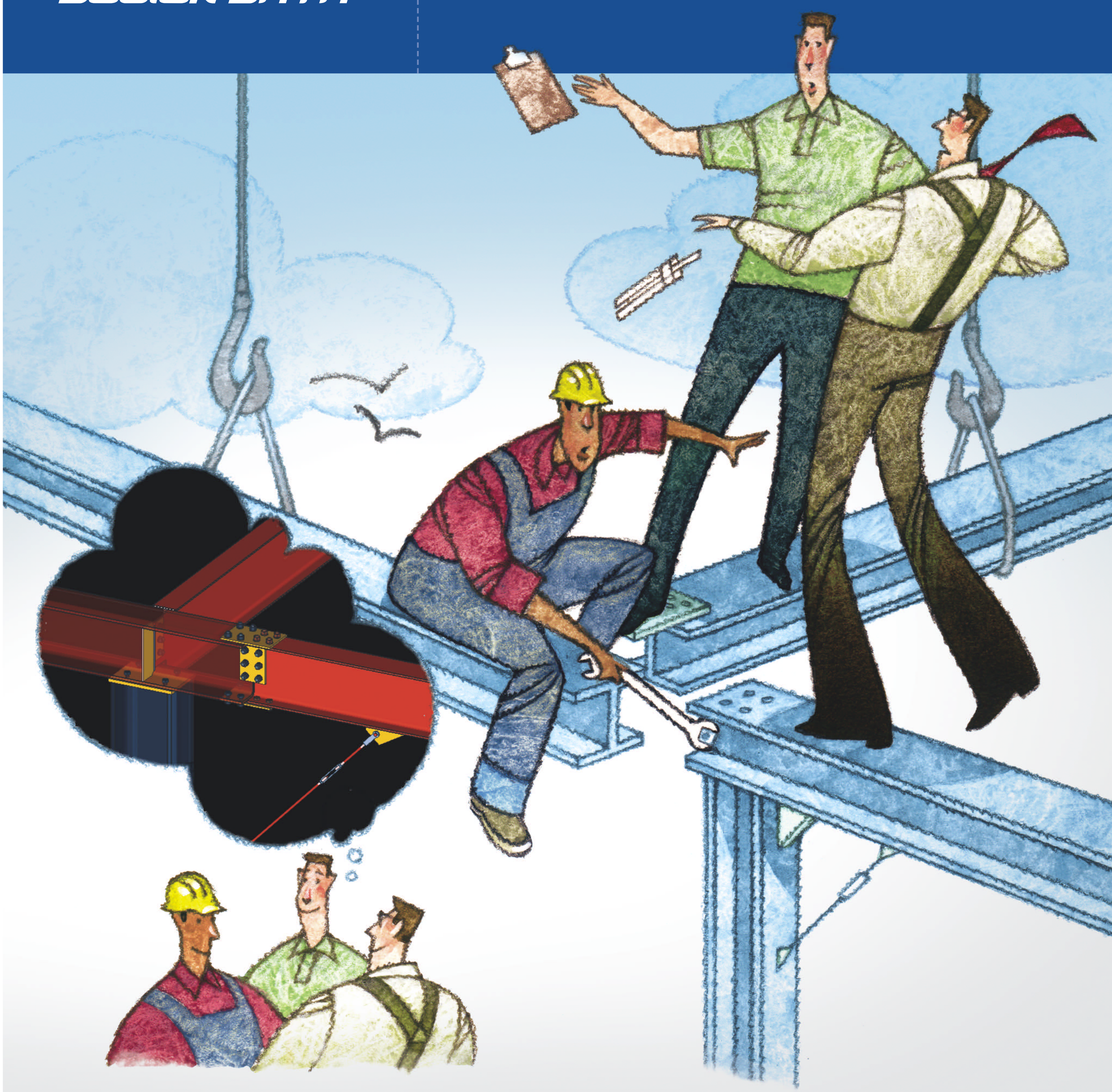

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IF YOU'VE EVER ASKED YOURSELF "WHY?" about something related to structural steel design or construction, *Modern Steel Construction*'s monthly Steel Interchange column is for you! Send your questions or comments to solutions@aisc.org.

Weak Axis Bending

I have an H-shape in bending about the weak axis. Chapter F, Section F2 of the AISC manual notes, "Lateral bracing is not required for members loaded through the shear center about their weak axis, or for members of equal strength about both axes." Do we still need to consider the lateral torsional buckling effect if the beam is bent about the weaker axis? Based on my understanding, lateral bracing prevents torsion and lateral deflection only. What is the exact relation between "lateral bracing to prevent torsion" and "lateral bracing to prevent lateral torsional buckling"?

Lateral-torsional buckling is a combination of lateral movement and twisting that can occur when a beam is not stiff in the lateral direction. But when a beam is bent about its weak axis, it can't move laterally because it is stronger in that direction, and the lateral effects cannot overcome that. Thus, lateral-torsional buckling does not apply for a member that is bent about its weak axis.

Section 6.3 of Appendix 6 in the 2005 AISC specification (a free download at **www.aisc.org/2005spec**) discusses how to brace beams to resist lateral-torsional buckling. Lateral-torsional buckling can be restrained by a torsional brace or a lateral brace. That is, the brace can either prevent twist or lateral displacement of the compression flange relative to the tension flange. Most details provide some combination of these restraint mechanisms.

Amanuel Gebremeskel, P.E.

Design Forces

A fabricator has recommended providing member end forces (for beams) and axial member forces (for braces) for economical connection design. What are "transfer forces" with regard to connection design, and how does one calculate these? What is the rationalization as to why member end forces acting transverse to the longitudinal axis (in the weak axis direction) are ignored in connection design?

Transfer forces are forces that occur across a joint where multiple members attach to the joint. An example would be in a frame with braces connected on opposite sides of a column. Some of the axial forces in the braces are transferred into the beams and column, while some go from one brace into the other brace. In the analysis, the joint was treated as a node, but the forces must have a path through the various connections in the real structure to get from brace to brace.

As for your second question, the AISC specification does not define what forces can be ignored or not. That decision needs to be made by the responsible design professional based on the particular project details. In many cases the horizontal forces perpendicular to the longitudinal axis for a beam that has an attached slab are assumed to be taken by a slab diaphragm.

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

R = 3

I understand that there is a provision that will allow me to not design steel connections per the AISC *Seismic Provisions* if I use an *R* value of 3. Can you tell me where I can find this information?

The governing building code or model code typically addresses which *R* values require compliance with the AISC *Seismic Provisions* and which ones do not. For instance, as per ASCE 7, for low and moderate seismic risk areas (Seismic Design Category C and below), you are correct that structures can be designed per item H in ASCE 7-05 Table 12.2-1, which covers steel systems not specifically detailed for seismic resistance. This option allows for the use of *R* = 3 with normal detailing, an option that is covered in detail in Part 2 of the *Seismic Design Manual*. In high seismic risk areas (Seismic Design Category D and above), however, all steel building structures must utilize one of the other systems provided in ASCE 7-05 Table 12.2-1 and comply with the corresponding requirements of the AISC *Seismic Provisions*.

The 2005 AISC *Seismic Provisions* can be found at **www.aisc.org/2005seimic**.

Amanuel Gebremeskel, P.E.

Steel Availability and Fabricator Listings

Could you suggest a resource where I can obtain mill pricing on structural shapes and information on availability? Could you also suggest a resource where I can obtain list of domestic steel distributors and major fabricators?

It is very important for structural engineers and architects to have a current understanding of the market for structural steel both in terms of price and availability. Mill pricing and the current rolling schedule for wide-flange products is available on the web sites of each of the major wide-flange producers (see **www.aisc.org/availablity** for a list of producer web sites). However, this information only provides a partial picture of the market for structural steel. Approximately 70% of all structural steel flows through local service centers that carry a significant stock of commonly used wide-flange, HSS, and miscellaneous sections. In addition, the designer should keep in mind that the mill price of the structural steel typically represents less than one-third of the erected cost of the steel. The best resources for determining what sections are stocked locally for immediate delivery and pricing trends in your area are local steel fabricators and steel service centers who are active in the market on a daily basis. AISC member fabricators can be found in your area by visiting the "Find a Company/Person" area of the **www.aisc.org** web site. A list of member service centers is available at **www.aisc.org/servicecenter**. If you need assistance locating a member mill, service center, or fabricator, please give the AISC Steel Solutions Center a call at 866.ASK.AISC (866.275.2472).

John P. Cross, P.E.
Vice President, AISC

steel interchange

Bending Radius

What is the minimum allowable bend radius for 1½-in.- and 1¾-in.-diameter bars in ASTM A572 Grade 50? When hot bending is required, are there code provisions for the temperature required?

Suggested minimum inside radii for cold bending steel material of various groups and thicknesses are given in Appendix X4 of ASTM A6. There is also guidance given based upon thickness and steel grade in AISC manual Table 10-12 (page 10-160 in the 13th edition). It suggests that the minimum radius for cold bending should be twice the diameter for the sizes you mention. For hot bending, temperature limitations for cambering, curving, and straightening of steel are discussed in Section M2.1 of the AISC specification (a free download at **www.aisc.org/2005spec**).

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

Shape Availability

I was informed by my engineering team that a W24×160 beam is commercially available. Can you tell me by whom such a beam is being produced?

This shape is not currently produced in the U.S. It is possible that your engineering team is working with outdated information, as there has not been such a shape designation in the U.S. since the early 1970s.

There is a W24×162 in the current ASTM A6 standard. You can find the producers of this shape on the AISC steel availability link at **www.aisc.org/availability**. At that link, you will find four mills that roll this particular product, as well as contact information for these mills. You will also find contact information for many steel service centers from which the shape can be obtained.

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

Historic Steel Specifications

I remember seeing a download that shows the historical steel specifications used in industry—for example, what years ASTM A7 steel was used. Can you help?

AISC's Design Guide 15 is probably the document you are looking for. You will find it at **www.aisc.org/epubs**.

You may also want to download an article that appeared in the February 2007 issue of *Modern Steel Construction* titled "Evaluation of Existing Structures." Back issues of MSC can be accessed via the "Archive" link at **www.modernsteel.com**.

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

BF in Table 3-2

Table 3-2 in the 13th edition manual has a column showing value of *BF*; however, the symbol list does not include the term *BF*. General Nomenclature (Index) indicates that *BF* is factor that can be used to calculate the flexural strength for unbraced length L_b between L_p and L_r. How is that done? Table 3-2 also lists M_{rx}. How was this calculated?

The *BF* listed in Table 3-2 is a simplification of Equation F2-2 of the AISC specification to account for the slope of the straight line between L_p and L_r. In numerical terms it represents $(M_p - M_r)/(L_r - L_p)$.

M_r is the moment capacity of the beam as it enters the elastic buckling range on the curve. Essentially, it is the moment capacity of the beam when the unbraced length is L_r and is calculated using Equation F2-6. Equations F2-3 and F2-4 are used to calculate the value of M_r.

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

Unbraced Tee in Flexure

Does the limit state of yielding apply to an unbraced tee flexural member with stem in tension? The compression flange is non-compact.

Yes. The AISC specification (a free download at **www.aisc.org/2005spec**) contains a section for the design of tees loaded in the plane of symmetry, and Section F9.1 provides for a yield check. Also, Section F9.2 provides for the lateral-torsional buckling (LTB) limit states, and Section 9.3 provides for the flange local buckling limit states; the later includes checks for non-compact and slender flanges.

Amanuel Gebremeskel, 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.

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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.

It's all about the AISC *Seismic Provisions* in this month's Steel Quiz, developed by AISC's Steel Solutions Center. Sharpen your pencils and go! You can download a copy of the AISC Seismic Provisions at no charge at www.aisc.org/2005seismic.

1 Does the AISC specification apply to steel structures other than buildings?

2 When must the AISC *Seismic Provisions* be used?

3 **True/False:** All structural steel buildings are required to meet the requirements of the AISC *Seismic Provisions*.

4 When is a non-building steel structure required to meet the requirements of the AISC *Seismic Provisions*?

5 What is the purpose of the Response Modification Coefficient (*R* factor) in relation to the lateral force resisting system?

6 **True/False:** The required *R* factor is associated with the ductility requirements of the SLRS?

7 How is the Response Modification Coefficient (*R* factor) used in the design process?

8 What are the seismic response characteristics of a moment frame system versus that of a braced frame system?

9 What is the difference between a Special Moment Frame, an Intermediate Moment Frame, and an Ordinary Moment Frame?

10 **True/False:** When determining the design forces for connections to comply with the AISC *Seismic Provisions*, the minimum specified yield strength F_y for the connected member is used.

TURN PAGE FOR ANSWERS

steel quiz

ANSWERS

1 **Yes.** Section A1 of the Specification includes the following statement of scope:

The Specification sets forth criteria for the design, fabrication, and erection of structural steel buildings and other structures, where other structures are defined as those structures designed, fabricated and erected in a manner similar to buildings, with building-like vertical and lateral load resisting elements.

2 The AISC *Seismic Provisions* are required to be used when a Seismic Load-Resisting System (SLRS) of higher ductility ($R > 3$) is used as a means to dissipate high seismic energy. The detailing requirements of the *Seismic Provisions* are correlated to the required ductility to accommodate large deformations and drift while maintaining the structural integrity of the SLRS.

3 **False.** The applicable building code or ASCE 7 standard defines which steel building frame types must be detailed in accordance with the AISC *Seismic Provisions*. See Table 12.2-1 of ASCE 7-05 for Seismic Force-Resisting System classifications, permitted applications, and design coefficients for building systems. While most steel systems in this table do require the use of the AISC *Seismic Provisions*, there is one common type permitted in Seismic Design Categories A, B, and C that does not. The so-called steel system not detailed for seismic resistance is permitted by Section H of ASCE 7-05 Table 12.2.1.

4 Many non-building steel structures are similar to buildings and are required to be detailed in accordance with the AISC *Seismic Provisions*. Chapter 15 of ASCE 7-05 provides an approach for other non-building structures. See Table 15.4-1 of ASCE 7-05 for further details.

5 The response modification coefficient R represents the ratio of elastic response to inelastic response. That is, there are elastic forces that would develop in the seismic load-resisting system (SLRS) under the specified ground motion if the structure exhibited elastic response. But the structure will behave inelastically before these forces are reached, and the R factor is used as a divisor to determine the design forces from the elastic forces.

6 **True.** A higher R factor is indicative of a system that can accommodate more deformation and ductility during a seismic event.

7 Primarily, the R factor is used in the calculation of the design base shear. The lower the R factor, the higher the bases shear.

8 In general, a moment frame system will have more lateral flexibility than that of a comparably detailed concentrically braced frame system. The ductility required in a moment frame is provided by the beam through bending. In a concentrically braced frame, the ductility is provided by tensile yielding or compressive buckling of the brace.

9 The difference between the Special, Intermediate, and Ordinary classifications of moment frames is in the level of ductility associated with each system. The connections of Special Moment Frames are expected to be capable of sustaining an interstory drift angle of at least 0.04 radians. Intermediate Moment Frames are expected to withstand limited inelastic deformations in their members and connections. Ordinary Moment Frames are expected to withstand minimal inelastic deformations in their members and connections.

Lateral systems designed for high ductility have a higher R factor associated with them, which means they are designed for less seismic load. As the members yield and the SLRS softens, the period of the structure becomes longer and lower seismic loads are attracted.

10 **False.** Because the connection designs are often based upon developing a plastic hinge or yielding in a connected member, an estimate of the actual yield strength must be used. Called the expected strength, R_yF_y is used in these cases, where R_y Factors for various steels are stipulated in Table I-6-1 of the *Seismic Provisions*.

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**.

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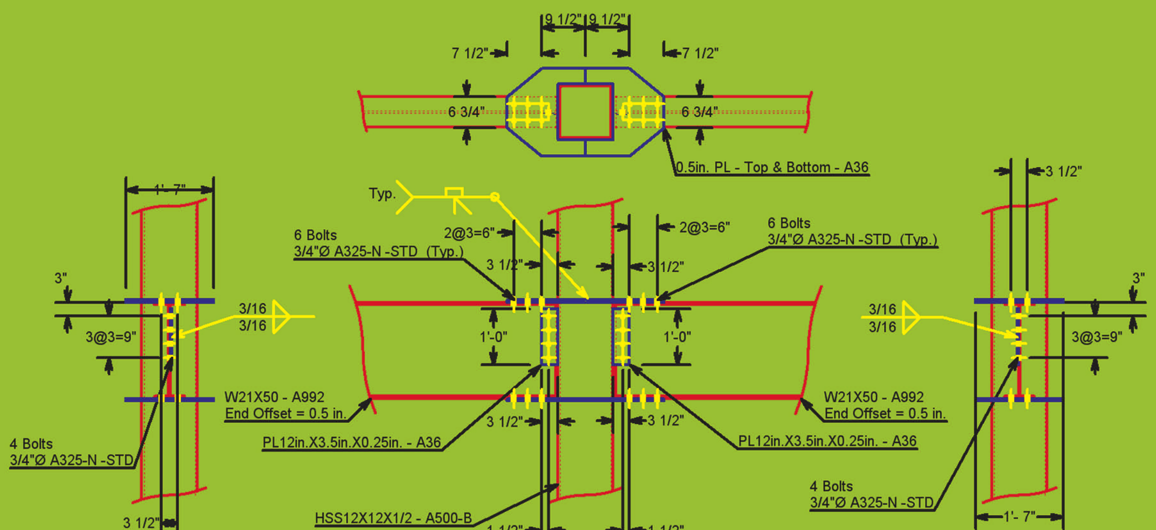

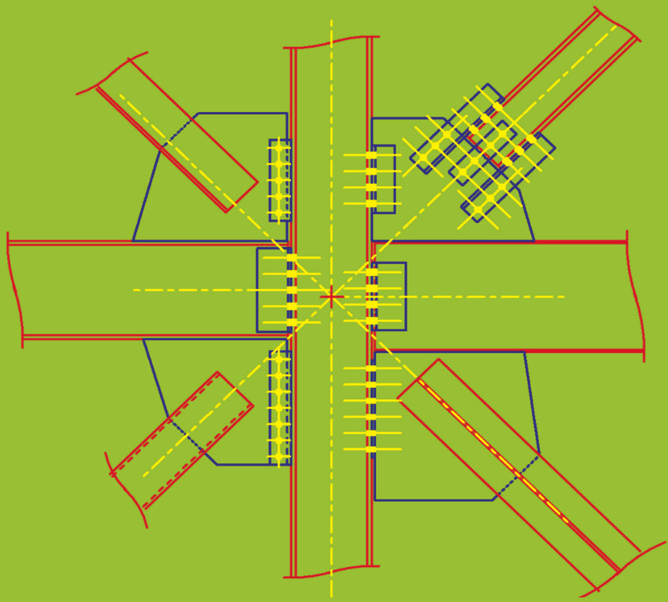

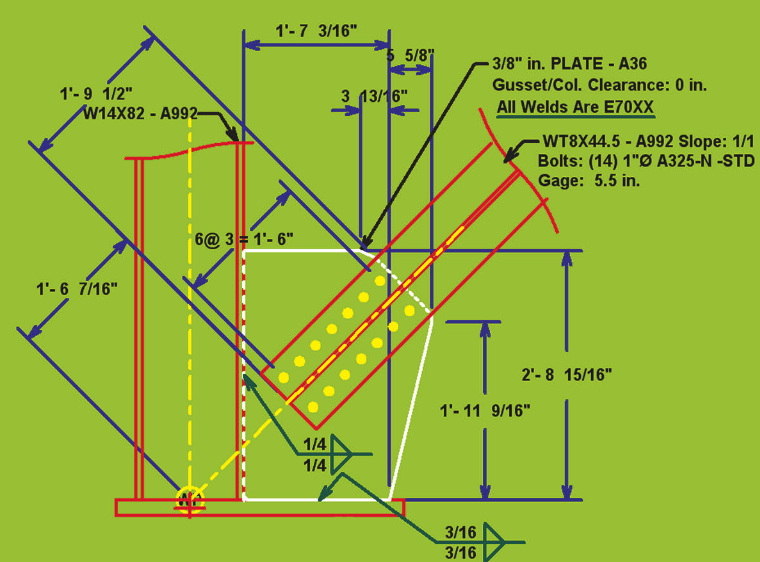

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news & events

WEB SITE

A New MSC Web Site!

If you've visited the *Modern Steel Construction* web site (**www.modernsteel.com**) lately, you may have noticed some changes. If you haven't been there in a while, take a look: We've got a new site!

Besides overhauling the appearance, the biggest change is that we now offer the current issue of the magazine in a digital e-book format. The digital version of MSC shows the magazine exactly as it appears in print, including advertisements. Also, all links and e-mail addresses (in both the text and ads) in the digital version are live links.

Each digital edition will stay live for about a month, until it's replaced by the next issue. And of course, current and past articles are always available in the familiar PDF format. (Check out our revised, easy-to-browse Archives section).

In addition, the revised About MSC section contains links for advertising, submitting articles, and managing subscriptions.

Other new features:

- ✓ Steel in the News: a regularly updated news section
- ✓ Reader Forum: an opportunity for you to provide feedback and discuss relevant topics
- ✓ A searchable Career Classified section (based on the Marketplace/Employment section of MSC)
- ✓ A searchable Product Directory
- ✓ A "What's the SSC Answering Now?" feature with live questions and answers from AISC's Steel Solutions Center
- ✓ Collections of popular articles (Quality Corner, SteelWise, and Career Resources)
- ✓ Links to the popular Steel Utilities forum site and Steel Availability information on the AISC site
- ✓ A searchable database of Steel Interchange questions

In addition, the MSC site now accepts advertisements (click the Advertising link for details).

Please give our new web presence a visit and let us know what you think! E-mail your comments to Keith Grubb at grubb@modernsteel.com.

EVENTS

2007 Bridge Symposium

"Steel Going Strong" is the theme of the 2007 World Steel Bridge Symposium, to take place December 4–7, 2007 in New Orleans.

The WSBS gathers steel bridge owners, designers, and contractors from around the world to discuss all aspects of steel bridge design and construction. The exhibit hall is full of products and services to advance the state-of-the-art of the steel bridge industry. WSBS attendees come to the symposium to learn about the latest innovations in steel bridges.

Focus areas of the symposium's many sessions include, but are not be limited to: short span bridges; intermediate span bridges; case studies featuring the use of high-performance steel; restoration, rehabilitation, and reuse; fabrication, construction, and erection; innovative bridge designs; and inspection and maintenance. In addition, this year's program features half-day workshops on AISC Certification and quality management, as well as pre-conference workshops on prefabricated bridge elements and systems and accelerated construction technologies.

The highlight of this year's symposium banquet will be the presentation of the 2007 Prize Bridge Awards.

For exhibit and sponsorship information, contact Jody Lovsness at 402.758.9099 or lovsness@nsbaweb.org. For general information, contact Elizabeth Purdy at 312.670.5421 or purdy@aisc.org. Visit **www.steelbridges.org** for the latest information.

HSS

AISC Requests HSS Data from Independent Testing

During the past few months, a number of companies in the U.S. and Canada, including producers of hollow structural sections (HSS) and steel service centers, have sponsored a limited number of tests by independent testing facilities on HSS material imported from China, as well as HSS material produced in North America. As a result of those independent tests, the companies have raised questions about the mechanical properties of the imported HSS, as well as the credibility and reliability of the documentation provided when the products entered the U.S. and Canada from some of the newer sources in our market. (For more information on HSS products, including a list of traditional suppliers to the domestic market, please visit **www.aisc.org/hss**.)

"AISC has not been involved in any of this HSS testing. Nor have we thoroughly reviewed the test data," said Roger Ferch, AISC president. "We believe it is premature to draw any conclusions from any of the tests that have been conducted." It is important to note, however, that from the data we have been provided, AISC has not concluded that there is a building code issue.

AISC is seeking to compile all available test data from its members and others in the steel industry willing to provide their test data. We request anyone who has sponsored recent tests on imported or domestic HSS to please contact Roger Ferch at ferch@aisc.org or 312.670-5401.

ASCE/SEI Requests Public Comments

The American Society of Civil Engineers' Structural Engineering Institute (ASCE/SEI) today announced it will conduct a public comment period on the second supplement to its Minimum Design Loads for Buildings and Other Structures standard (ASCE 7-05). The public comment period is now open and will run until December 4, 2007.

The purpose of the standard is to provide minimum load requirements for the design of buildings and other structures that are subject to building code requirements. This supplement addresses changes to seismic design requirements for building and non-building structures.

To participate in the public comment period, contact Phillip Mariscal, ASCE standards administrator, at pmariscal@asce.org or 703.295.6338. For more information on the standard or ASCE's standards program, please contact Karen Albers at kalbers@asce.org or 703.295.6404.

letters

Dead On, but Expensive

Todd Alwood's September 2007 MSC article "Let's Be Plank..." (p. 39) is a long-needed dissertation on the detailed intricacies of combining precast, prestressed hollow-core slabs (plank) with structural steel. Ted Hazeldine of Benchmark Fabricated Steel is also correct with his tips for fabricators in his sidebar on p. 40.

Alwood's descripton of plank and its pros and cons was extremely informative and accurate, and his caveat to "know your plank supplier" could not have been more on target. I am therefore dumbfounded by his suggestions to the steel industry on what can be done with steel to optimize the use of plank. The suggestions in his article are expensive and are the type of details that usually preclude the use of structural steel and plank. I was surprised that no mention was made of the Girder-Slab system, which received the 2007 Special Achievement Award from AISC. It is the first and only innovative system that combines the advantages of structural steel and flat plate concrete for high-rise residential construction, and has been used in 38 completed buildings comprising almost three million sq. ft of built residential construction.

We are tracking new projects totalling almost 12 million sq. ft, and the case studies on our web site (**www.girder-slab.com**) contain a partial listing of all the prominent and innovative structural engineers that have used Girder-Slab.

Daniel G. Fisher Sr.
Managing Partner
Girder-Slab Technologies, Inc.

ENGINEERING JOURNAL

Fourth Quarter 2007 Article Abstracts

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

Improved Flexural Stability Design of I-Section Members in AISC (2005) – A Case Study Comparison to AISC (1989) ASD

DONALD W. WHITE AND CHING-JEN CHANG

The provisions in the AISC 2005 *Specification for Structural Steel Buildings* for the flexural stability design of steel I-section members have been updated relative to previous specifications to simplify their logic, organization, and application, while also improving their accuracy and generality. This paper gives a brief overview of the updated provisions, and compares and contrasts their flexural resistance calculations with the corresponding calculations from the previous AISC 1989 *Specification for Structural Steel Buildings, Allowable Stress Design and Plastic Design*. The relative simplicity and accuracy of the AISC 2005 specification equations are highlighted.

Topics: Beams and flexural members, specifications

Direct Analysis and Design Using Amplified First-Order Analysis, Part 1 – Combined Braced and Gravity Framing Systems

DONALD W. WHITE, ANDREA SUROVEK, AND SANG-CHEOL KIM

In 1976 and 1977, LeMessurier published two landmark papers on practical methods of calculating second-order effects in frame structures. LeMessurier addressed the proper calculation of second-order displacements and internal forces in general rectangular framing systems based on first-order elastic analysis. He also addressed the calculation of column buckling loads or effective length factors using the results from first-order analysis. The 2005 AISC specification provides a new method of analysis and design, termed the Direct Analysis Method (or the DM). The DM involves the use of a second-order elastic analysis that includes a nominally reduced stiffness and an initial out-of-plumbness of the structure. The 1999 AISC LRFD and the 2005 AISC specifications permit this type of analysis as a fundamental alternative to their base provisions for design of stability bracing. In fact, the base 1999 AISC specification and the 2005 AISC specification stability bracing requirements are obtained from this type of analysis. This paper demonstrates how a form of LeMessurier's simplified second-order analysis equations can be combined with the 2005 AISC specification DM to achieve a particularly powerful analysis-design procedure.

Topics: Analysis, lateral systems, stability and bracing

Direct Analysis and Design Using Amplified First-Order Analysis, Part 2 – Moment Frames and General Framing Systems

DONALD W. WHITE, ANDREA SUROVEK, AND CHING-JEN CHANG

This paper presents an application of the Direct Analysis Method (DM) introduced in the 2005 AISC *Specification for Structural Steel Buildings* for moment and general combined framing systems. The DM accounts explicitly for nominal initial out-of-plumbness of the framing as well as the reduction in the stiffness of the structure at the maximum strength limit of its most critical member or members. As a result, this approach provides a more rational estimate of the internal forces at the maximum strength limit. Also, the column and beam-column strength checks in moment frames may be based on $K = 1$ by using this method. One additional modification to a conventional elastic analysis is required in general for beam-columns in moment frames; in other words, the flexural rigidity must be reduced by an additional column inelastic stiffness reduction factor, τ, for columns loaded by axial forces in excess of $0.5P_y$. This paper proposes two modifications to the underlying amplified first-order elastic analysis approach presented in Part 1 of this paper (published in the same issue), to extend this procedure to general rectangular framing involving any combination of moment, braced, and gravity systems. Suggestions are also provided for approximate handling of frames with large axial compression in the beams or rafters and/or nonrectangular geometry.

Topics: Analysis, lateral systems, stability and bracing

Limit State Response of Composite Columns and Beam-Columns, Part I: Formulation of Design Provisions for the 2005 AISC Specification

ROBERTO T. LEON, DONG KEON KIM, AND JEROME F. HAJJAR

The 2005 *Specification for Structural Steel Buildings* contains substantial changes to the design of composite members and composite columns in particular. These revisions are intended to reflect the extensive research in the area of composite steel-concrete structures during the past two decades, as the previous specifications were based on studies from the late 1960s-1970s. This paper describes the databases created and the process followed to develop the new provisions. This process includes the development of both new strength equations for encased and concrete-filled columns and new interaction equations for composite beam-columns, as well as considerable liberalization of local buckling and material limits. The paper also discusses other important areas of composite design, such as bond stress between steel HSS sections and concrete, where specification provisions are under development. This is the first of a two-part paper; the second part contains detailed design examples.

Topics: Composite construction, columns and compression members, combined loading, stability and bracing

The Behavior of Steel Permimeter Columns in a High-rise Building Under Fire

MARIA M. GARLOCK AND SPENCER E. QUIEL

The thermal response of structural steel may affect the behavior of a steel high-rise building exposed to fire. In a plane perpendicular to the exterior wall, a perimeter column is typically laterally braced by one beam. The fire-induced structural response of this beam that frames into the perimeter column (perpendicular to the exterior wall) directly affects the perimeter column behavior and the structural integrity of the frame as a whole. The objective of this research is to evaluate the behavior of perimeter columns in a steel high-rise building that is subjected to a large fire, and examine this behavior as it interacts with the beams that frame into it. This behavior is examined by several analyses that consider the inclusion of fire protection material on the beams and columns as a parameter. A two-dimensional model of eleven upper level floors of a steel-framed building subjected to fire is analyzed. The thermal expansion of the beams that frame into the perimeter column induce column lateral deformations and moments that combine with axial gravity forces to create a plastic hinge in the perimeter columns. Since these beams are partially restrained from expanding, large axial forces develop in them, which, combined with bending moments, may lead to beam failure. Once these beams, which brace the perimeter column in one plane, fail, the stability of the column, and structure as a whole, is compromised and could potentially lead to structural collapse. The results of this research confirm the design philosophy in current codes that recommends the same level of fire protection material for these beams as the columns to which they are attached, since they significantly affect perimeter column behavior and thus the overall behavior of the frame. This study also shows that the perimeter columns and beams act as beam-columns in a fire (in other words, members under combined axial load and bending), and therefore, their behavior and capacity should be evaluated as such.

Topics: Fire and temperature effects

Current Steel Structures Research

REIDAR BJORHOVDE

This regular feature of the *Engineering Journal* provides information on new and ongoing research around the world. In the 12th installment, research projects are summarized on the following topics: tests on bolted shear connections with high-strength steel, development of a hysteretic model with pinching for steel connections, estimation of cyclic characteristics for thin web plates after shear buckling, system behavior factors for composite and mixed structural systems, practical design methods for steel and composite frames with semi-rigid connections, and storage racks in seismic areas.

Topics: Research

CERTIFICATION

Kentucky Fabricator Wins Free QMC Audit

Since October 2006, Quality Management Company, LLC, provider of quality audits for the AISC Certification program, has been administering a voluntary customer satisfaction survey of AISC Certified Fabricators and Erectors upon receipt of their certificate. Companies that complete the survey are automatically entered into a semi-annual drawing for a free QMC audit. **Harry Gordon Steel Company, Inc.**, a fabricator in Lexington, Ky., has won QMC's most recent drawing for a free audit.

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

A Virtual Success

BY ATUL KHANZODE, DEAN REED, AND BLAKE W. DILSWORTH, S.E.

Using BIM, combined with lean construction techniques, results in enhanced field productivity for a California medical campus project.

WHEN IT COMES TO OVERALL PROJECT COMPLEXITY, FEW MARKETS RIVAL HEALTH-CARE. Intricate medical gas systems and the vast mechanical, electrical, plumbing, and fire protection systems needed for acute care facilities and many medical office buildings require project teams that are highly experienced and knowledgeable in this specialized market sector. In California (and other states), design and construction teams also must navigate a cumbersome regulatory environment for hospital projects, overseen by the Office of Statewide Health and Planning Department.

Additionally, the current boom in California's health-care market—driven by a state law that has set graduated deadlines for hospitals to comply with current seismic standards by 2008 (or 2013 if an extension has been granted) and even more stringent standards by 2030—has further stretched resources, severely limiting the pool of qualified subcontractors. And, owners' demands for their projects to be brought to market faster than ever, to meet their own customers' needs, adds yet another layer to the complexity.

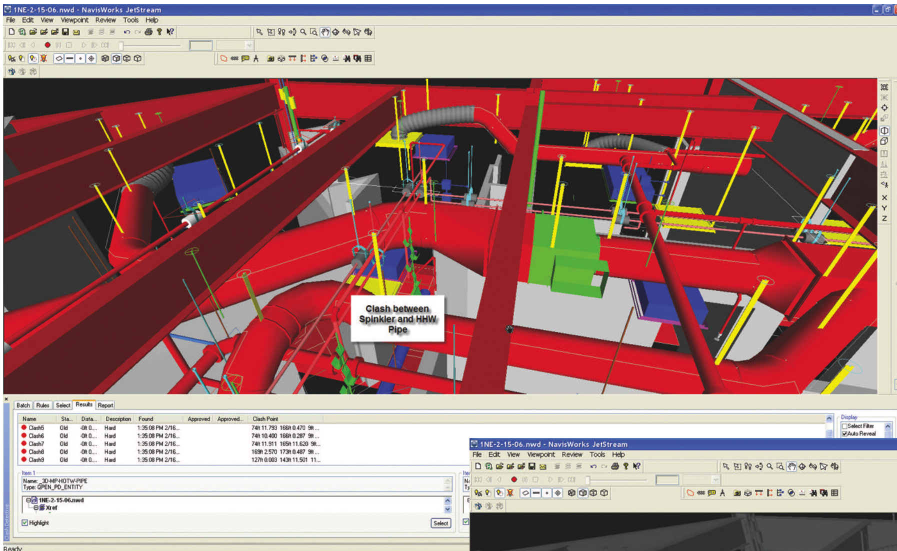
One trend helping to ease the challenges of project delivery is that of traditional 2D drawings and light tables being replaced with robust building information modeling systems. By modeling the design and construction process in 3D and 4D before construction actually begins, BIM enables teams to resolve clashes in building systems before they ever get to the point of field installation, and has proven particularly helpful in the design and installation of the highly complex mechanical systems found in health-care facilities. Virtual design and construction is also helping project teams achieve a far greater level of prefabrication on their jobs, leading to shortened field installation times and improved productivity and safety, among a host of other benefits.

Building Better with BIM

The combination of BIM and lean construction techniques is a powerful one; the idea of "lean construction" centers around maximizing value, increasing productivity, and reducing waste throughout the project delivery process. A great example of what can be accomplished when a team employs this combination is a newly opened, $98 million medical campus in Mountain View, Calif. Completed in March, the Camino Medical Group medical office building project included a 250,000-sq.-ft medical office building and a 420,000-sq.-ft parking structure.

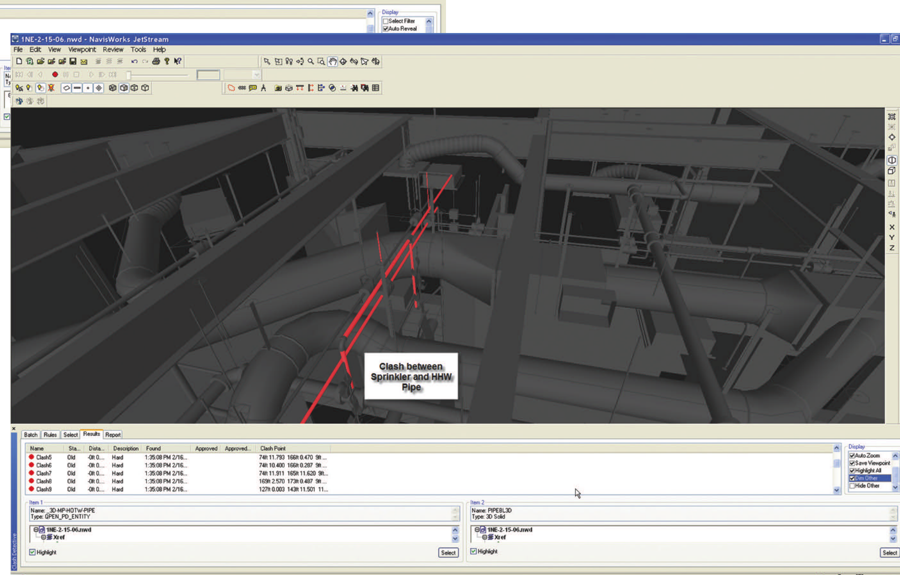
As with a majority of large-scale medical facilities, steel was selected as the structural system for this project. Special moment resisting frames (SMRFs) and special concentric braced frames (SCBFs) were used for the lateral force resisting elements. This combined system helped keep the overall steel weight and costs down and also allowed for more open and flexible work space plans. The structural steel skeleton also served as a key element of the overall virtual mechanical systems coordination in 3D.

The project was completed in March, an estimated six months earlier than would have been achieved using the traditional design-



DPR Construction

Based off the structural drawings, the 3D model also included the building's mechanical systems.



DPR Construction

Rien van Rijthoven

Clash-detection routines highlighted instances of interference between the various building systems, including the structure.

bid-build project delivery method without BIM and lean techniques. The owner's primary goal of shortening the overall project duration—in order to have the facility operational as quickly as possible—meant that the team needed to start construction before the design was complete. The general contractor, along with the key mechanical subcontractors, came on board very early in the design process with the structural engineer and architect. They formed multidisciplinary teams of designers and contractors, who worked together to model and coordinate building systems on computers located in an open office area of the field office complex called the "Big Room" before breaking ground on site.

Collaborate, Really Collaborate

A strong collaborative environment was cultivated on the Camino Medical project. The spirit and enthusiasm to drive true change, shared by all the major players, helped to overcome the lack of experience some parties had in using 3D modeling tools and lean construction processes. Co-locating the design and detailing teams in the Big Room, where detailers worked side by side to construct designs virtually and were able to resolve conflicts and issues immediately, further facilitated a highly integrated project delivery. The detailers used shared resources, including a network server, printers and plotters. All the construction documents were generated from this one room. Weekly meetings were held to review progress and analyze and correct clashes using the 3D model.

As with all BIM projects, the Camino project team also addressed a number of questions from the beginning to guide the project coordination process, including:

- How should the project be organized to best implement BIM?
- What roles should each project team member play in the coordination process?
- What common protocols should be established for the technical logistics of the coordination process (i.e., establishing how files would be shared and updated, etc.)?
- What level of detail should be included in the architectural, structural, and mechanical models?

From the outset, the team determined it would use BIM for the coordination of mechanical systems. The steel, modeled in 3D by the structural engineer, formed the foundation for the coordinated 3D mechanical systems model.

Lessons Learned

One of the key lessons from previous projects in the 2D world was that the structural model should include connections like gusset plates for the SCBF connections. The Camino Medical 3D model did show all of the gusset plates, but they were based on the structural engineer's design and not the actual steel-shop-fabricated gusset plates. While this disconnect did not cause any issues on the Camino project, the possibility of field clashes will remain at large gusset plate connections until a direct digital exchange exists between the structural steel detailer and structural engineer.

Models should also feature all the miscellaneous metal supports and connection points to external building elements like façade panels and medical equipment supports. All of these details play a crucial role in the modeling of mechanical systems. The lack of detail of some of the objects proved to be the sole source of field errors, where clashes had not been detected by the model. This clearly illustrates the need for structural engineers, steel detailers, and steel fabricators to work toward greater integration.

It also became clear that it is far more preferable to initially model in 3D than to convert a 2D drawing to 3D. Converting 2D models to 3D after the design is largely completed caused some issues, as design changes required a significant amount of additional detailing effort.

While the use of BIM and lean construction requires more time and involvement from contractors much earlier in the process than usual, the payoff comes in greater value achieved during construction. Savings on the Camino Medical project were accrued through a significantly higher level of prefabrication of mechanical components, the elimination of conflicts between the various systems, reduction in change orders, and an increase in field productivity due to reduced field conflicts.

Exceptional Results

In the end, despite some issues working through inexperience with 3D modeling and a few minor field issues, the Camino Medical project remains an unqualified success of what can be accomplished through a collaborative virtual building process:

- ➜ Labor productivity was 15% to 30% better than industry standards.
- ➜ Less than 0.2% re-work was required on the HVAC system.
- ➜ There were no change orders related to field conflict issues, and only two field issues related to RFIs.
- ➜ There were no field conflicts between the systems that were modeled and coordinated using BIM. Normally, on comparable projects, an estimated 100 to 200 conflicts must be resolved in the field using traditional coordination methods.

Clearly, the use of BIM technology and the lean construction methodology proved important to overall project success. Equally important, however, was how the team used those tools within the context of a highly collaborative environment, establishing overall goals, developing models, and gathering and sharing information to create a breakthrough in enhanced project delivery. MSC

Dean Reed and Atul Khanzode are collaborative virtual building group leaders with DPR Construction, Inc. Blake Dilsworth is a principal with KPFF Consulting Engineers.

Owner
Camino Medical Group, Mountain View, Calif.

Architect
Hawley, Peterson and Snyder, Mountain View

Structural Engineer
KPFF Consulting Engineers, San Francisco

Steel Fabricator/Detailer
W & W Steel LLC, Oklahoma City (AISC Member)

Steel Erector
Eagle Iron Erectors, Inc., Fontana, Calif. (AISC Member)

General Contractor
DPR Construction, Redwood City, Calif.

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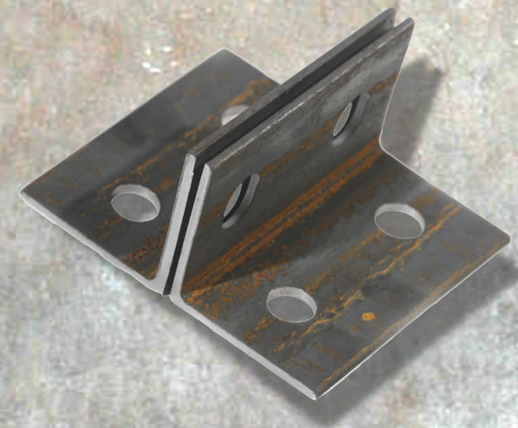

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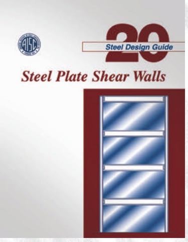
Designed to help working professionals enhance and grow their skills in a productive training environment, the American Institute of Steel Construction (AISC) is dedicated to providing you with focused seminars on relevant, timely topics designed to meet your continuing education needs.

Attend an AISC seminar and discover how to get the most value from your professional development and earn credits from courses taught by leading industry minds.



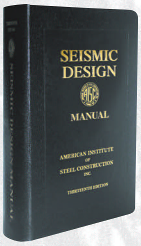
NEW! Design of Steel Plate Shear

Steel Plate Shear Walls for Wind and Seismic Loading

This short course introduces engineers to steel plate shear walls, a new system for resisting lateral forces. The system provides significant benefits over other types of shear walls, including construction speed and cost, reduced weight, and very little loss of useable floor area. The course covers the basic mechanics of the system and simple methods for its design as well as the additional detailing, proportioning, and design requirements necessary for use of steel plate shear walls as a seismic system with $R > 3$. Design examples include both wind (low-seismic) and high-seismic design.

NEW! Façade Attachments to Steel Frames

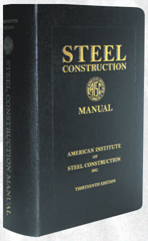
Perhaps the most complicated details in a building occur where the façade and structural frame meet. The details of this interface have a significant impact on the cost of the project. The performance issues that affect the façade attachment details include: proper support of the façade elements, structural anchorage to the frame, relative movements, fire protection, waterproofing, thermal and moisture migration, air infiltration, and sound transmission. Just as these details need to integrate all the above performance issues, the design team needs to coordinate responsibilities between the architect, base building engineer, façade engineer, general contractor, steel fabricator, steel erector, and façade subcontractor(s).



AISC Seismic Provisions/Manual

AISC Seismic Design – Updates and Resources for the 21st Century

Structural engineers across the country have appealed to AISC for good resources and continuing education seminars on seismic design. In response, Dr. Thomas Sabol – referencing AISC's extensive Seismic Design resources – has developed a seminar to meet those needs. If you are a practicing structural engineer looking to increase your knowledge of seismic design of structural steel – make sure you attend this seminar!



AISC Specification/Manual

Design Steel Your Way with the 2005 AISC Specification

This is your final opportunity to attend this very popular AISC Seminar. Don't Miss It!

Whether you design in ASD or LRFD, this seminar will accelerate your ability to design steel buildings according to the 2005 Specification for Structural Steel Buildings. The 13th Edition AISC Steel Construction Manual will provide valuable insight into the 2005 AISC Specification, which unifies ASD and LRFD and includes the specifications for single angles and hollow structural sections.

AISC Fall 2007 Seminar Schedule

Seismic Manual
- ☐ 09/18 Los Angeles (Area), CA
- ☐ 09/20 San Francisco (Area), CA
- ☐ 10/03 Memphis, TN
- ☐ 10/04 Chicago, IL
- ☐ 10/09 Charlotte, NC
- ☐ 10/11 Oakland, CA
- ☐ 10/23 Portland, OR
- ☐ 10/23 Atlanta, GA
- ☐ 10/24 Seattle, WA
- ☐ 10/25 Portland, ME
- ☐ 10/30 Denver, CO
- ☐ 11/01 Albuquerque, NM
- ☐ 11/06 Boston, MA
- ☐ 11/06 Oklahoma City, OK
- ☐ 11/07 New York City
- ☐ 11/08 Nashville, TN
- ☐ 11/09 Philadelphia, PA
- ☐ 11/13 Hartford, CT
- ☐ 11/13 Indianapolis, IN
- ☐ 11/27 St. Louis, MO
- ☐ 11/28 Spokane, WA
- ☐ 11/29 Phoenix, AZ
- ☐ 12/06 Birmingham, AL
- ☐ 12/06 Boise, ID

Specification/Manual
- ☐ 09/20 Dallas, TX
- ☐ 09/26 Los Angeles (Area), CA
- ☐ 10/25 New York City
- ☐ 11/13 Chicago, IL

Steel Plate Shear Walls
- ☐ 10/17 Los Angeles (Area), CA
- ☐ 10/18 San Francisco (Area), CA
- ☐ 11/27 Seattle, WA
- ☐ 12/11 Portland, OR

Façade Attachments
- ☐ 09/19 Boston, MA
- ☐ 09/20 Pittsburgh, PA
- ☐ 10/10 Minneapolis, MN
- ☐ 10/11 Kansas City, KS
- ☐ 11/07 Washington DC
- ☐ 11/08 Raleigh, NC
- ☐ 12/12 Houston, TX
- ☐ 12/13 Tampa, FL

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Practical BIM

BY JEFFREY SMILOW, P.E.

How are engineers and architects implementing and using this developing technology?

BUILDING INFORMATION MODELING CONTINUES TO BE A BUZZ WORD IN THE INDUSTRY. But how are engineers and architects implementing and using this developing technology? And what benefits does it deliver to the document preparation process and to the project itself?

To answer these questions, let's take a brief look at the document process itself and how it has evolved. The building consultant team, composed of architects and engineers, typically strives to produce complete contract documents, which usually take the form of two-dimensional paper documents. On typical projects each consultant produces their own set of documents associated with their respective trade. The contract documents reflect the design and engineering plus the results of an extensive coordination process between consultants.

The design team strives to provide economically efficient designs within the project constraints and fully coordinated amongst all the consultants. The coordination process takes place continuously via an exchange of preliminary documents between consultants, culminating in a final package that hopefully reflects and considers the final design of all the team members. Complex projects such as hospitals, stadiums, concert halls, and major high-rise towers require significant effort in coordination to achieve the project goals. A poorly coordinated project results when consultant coordination efforts are not kept up to date with the final design or engineering conclusions of the entire consultant team.

Until recently the dominant software used by architects and engineers in the development of project documents for building structures was AutoCAD. Although AutoCAD has a variety of three-dimensional drawing tools, it has been used primarily as a 2D drawing device. As such, AutoCAD has greatly expedited the process of drawing production and significantly improved the accuracy of drawings over hand methods, which are basically extinct at this time.

However, AutoCAD documents have their limitations, primarily in that they are not "intelligent" documents. Intelligent documents store information about the building systems and/or components. For example, a beam as drawn on a 2D AutoCAD document would be symbolized as a single line. The beam size information would be shown in text adjacent to the drawn line. Internally, within the computer memory, no information about the beam is known or compiled.

In contrast, an intelligent document can also present 2D drawings and can show the beam as a single line, with the beam size information adjacent to the drawn line. However, this is where the similarities end. The intelligent document internally saves the structural information associated with the drawn beam—the beam size, length, weight, and other relevant information including all the 3D properties. As a result a full 3D picture can be created, if desired. Consequently, an intelligent drawing of the structural, building system, and architectural components would have the ability to draw the full 3D representation of the building. In addition, since the actual geometric properties are available, areas where building components clash can be picked up by the software. Intelligent documents have the ability to provide material quantity data for the project. Relative to the structural components, the project tonnage, piece count, and material types can be tracked continuously through the document preparation phase, thereby aiding the budgeting process.

The combined integration of the full architectural, building system, and structural components into one BIM database for the project is typically not being done for most projects at this time. Although a valuable feature, most consultant teams involved with conventional building types have not developed the knowledge and sophistication to implement this feature on such a global scale.

> We have found that providing the digital model to the detailers significantly reduces dimension RFIs.

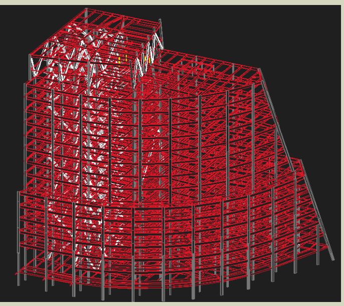
Current Practice

What used to be a tedious computational method working with 2D segments of a building is partially becoming a visual process working with pictorial representations of the structure, building systems, and architecture. Although this new process is taking shape, it is far from being fully implemented in the current building design practice. Many architects and design professionals are now implementing one or more of the available BIM software packages. But there is a significant learning curve associated with any BIM package. Consequently, as architects implement BIM they are usually beginning solely with the architectural components and perfecting their use of BIM before requiring it of the entire design team. It has become somewhat common to implement the structural components within the BIM model prior to incorporating building systems.

At WSP Cantor Seinuk, we have been using intelligent modeling of structures on a select basis for over 10 years. Although expensive to implement, and not seeing initial use by the architects or mechanical engineers, we found intelligent modeling a very beneficial drafting and coordination tool. For example, with our initial foray into the world of BIM, our plans showed all beam framing as double lines, thereby conveying the true width of beams and girders. Coordination around the building core areas was greatly improved. Elevations of bracing systems were easily coordinated with corridors, doorways, core walls, and ceilings. The structural plans also reflected the actual column sizes as compared

Citigroup's "Court Square Two" Office Building Queens, New York

As the structural engineer for this project, WSP Cantor Seinuk decided early on that developing a full three-dimensional model of the steel framing would be beneficial. At the time, we had been using a program called ProSteel for four years and chose to continue with it for this project. The full 3D structural model was developed and continued to grow with the respective phases of the project. Conventional paper documents were issued at every phase during project development. However, internally the 3D model was utilized to present and coordinate the complex areas of the project. Since the architect was not using ProSteel, but instead was working with conventional AutoCAD, we issued AutoCAD-compatible information that was exported from the ProSteel model. The exported files were overlain on top of the AutoCAD drawing in order to coordinate the structure and architecture. Coordination with the building systems was done via conventional methods, with the exception that ProSteel shows active member widths and depths in 2D plans and bracing elevations.



Courtesy of WSP Cantor Seinuk

During the later stages of the construction documents phase, we began preparing a Tekla Structures (then X-steel) model of the structure. The Tekla Structures model was prepared via a combination of exported information from the ProSteel model and conventional hand input. This resulting model proved to be highly beneficial. First and foremost it formed the basis of the bidding documents; all steel bidders were given the Tekla Structures file, and the tonnage and piece count was as defined in the Tekla Structures model. The feedback from the bidders was very positive, and they confirmed that this process expedited the bidding. In addition, upon the steel contract being awarded, the selected steel fabricator used the provided model and claimed the process was extremely helpful, saving them one month of work.

to a generic one-size-fits-all picture. Overlays with architectural finishes, walls, and façade elements became possible.

Although not common yet, we are now beginning to see collaborative coordination efforts that use a single 3D model where the structure and architecture is shown in the same model. In complex geometric building shapes, working with intelligent 3D models is imperative. This is especially true in stadiums and other non-orthogonal structures.

Communication with Contractors

Working with BIM software tools has opened up new methods of communication with contractors and subcontractors that were unheard of just a few years ago.

Within the steel industry the vast majority of fabricators and detailers use 3D detailing software for the preparation of steel shop drawings. As a result of an AISC initiative a few years ago, a digital standard for electronic communication, CIS/2, was established. Consequently, the primary detailing software packages have a unified standard for electronic transfer of data, and the structural steel framework that was developed and presented in one of the primary BIM software packages can be exported into the steel detailing packages.

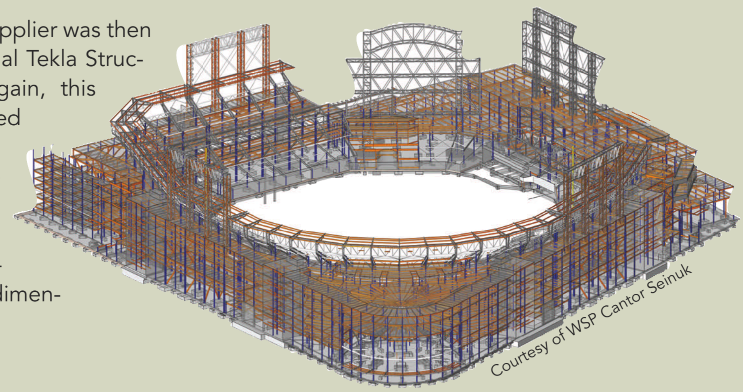
This method of data transfer has now become commonplace for steel-framed structures and has resulted in significant time savings. A typical project scenario would entail the following process: At the final stages of completion of the construction document, the conversion process of our BIM model into one of the primary steel detailing software formats would commence, either the Tekla Structures (formerly X-steel) format or the SDS-2 format. The steel bid documents would include the paper documents and the digital model. Providing the digital model in one of these two formats enables the steel bidders to avoid the time-consuming process of recreating the building digital model. By using the model provided to them, the time for the bidding process is shortened significantly, and there is uniformity in the bids. The confusion of bidders presenting differing steel tonnages is eliminated; the digital model clearly defines the piece count and tonnage. The only variation in material quantities is the allocation to connections, and with this process owners can clearly see the tonnage associated with connection

New York Mets Stadium—Citi Field Queens, New York

For this project, WSP Cantor Seinuk decided to use Revit, the newest BIM software from AutoDesk. The architect, HOK Sport, took full advantage of the 3D modeling features in Revit and the compatibility between both AutoDesk products. They combined both models into one and performed the structural and architectural coordination using the 3D features. Considering the highly complex nature of the stadium, 3D overlay and coordination was a necessity—especially considering the highly fast-track nature of the project.

When it came to the bidding and construction phase of the project, WSP Cantor Seinuk prepared a Tekla Structures model for use by the steel bidders. Preparing the model from the Revit 3D model was a relatively smooth process. The Revit structure was exported into Tekla Structures, and the feedback from all the bidders was extremely positive. In addition, as we issued addendums to the bidders working with the completed Tekla Structures model, it saved them significant time and expenses.

The selected steel supplier was then provided with the final Tekla Structures model and again, this enabled an expedited shop drawing process to proceed—without waiting for the model creation and without the delay of numerous dimensional RFIs.


Courtesy of WSP Cantor Seinuk

material. Furthermore, changes to the steel structure for bid alternates and updates are easily communicated via changes to the digital model.

Finally, upon project award, the updated detailing model in either Tekla Structures or SDS-2 format is provided. Shop drawing creation begins immediately with no lag time for model preparation. Upon a recently completed WSP project in New York, the steel fabricator stated that this process easily reduced the shop drawing process by one month, facilitating the early start of steel fabrication and erection.

We have also found that providing the digital model to the detailers significantly reduced the dimensional RFIs, which often plague the shop drawing review process. The dimensional gaps that usually occur upon paper documents are nearly eliminated on digital documents unless deliberately included.

Although the benefits of BIM are many, there are drawbacks and challenges to overcome:

- BIM standards are not fully defined. The multiple BIM products do not have the ability to communicate with one another.
- New methods of team collaboration require new definitions for individual responsibility and liability.
- Legal ownership of collaborative digital models must be defined.
- Increased dimensional responsibility for the design team results in additional legal liability.
- Expedited processes reduce the time for the customary process of “checks and balances.”
- How does the new BIM process change financial compensation for the design team?

It’s a new world out there when it comes to BIM. We are only in the infancy stage of development and usage. Much remains to be developed and defined. As with everything else in the free market world, time and market conditions will determine the general direction and final form. It’s up to the innovative design professionals, engineers, and architects to test and implement these new products. And it’s up to the owners and developers to encourage their consultants to pursue and utilize these new techniques and products. MSC

Jeffrey Smilow is the executive vice president of WSP Cantor Seinuk.

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Driving Toward an Integrated Solution

BY LUKE FAULKNER

Analyzing the obstacles that an industry must address to implement BIM.

THE A/E/C WORLD CONTINUES TO PROMOTE BUILDING INFORMATION MODELING (BIM) AS A REALISTIC CONTRACTING AND CONSTRUCTION METHODOLOGY FOR THE NEAR FUTURE AND BEYOND. But those tasked with standardizing the BIM process find themselves facing some very intimidating questions. Primary among them: What are the major obstacles that must be addressed and overcome so that BIM may be more readily deployed? The most common response includes a combination of technical and relationship issues, all of which will have to be addressed in order to promote a wider implementation of BIM.

Issue 1: There isn't a BIM-specific standard contract form.

For many, a standardized BIM contract is the most important facet of BIM implementation. A standardized BIM form is recognized by many as the most logical starting point in the integration of BIM as a standard contracting method. The need for a standardized agreement has the attention of several organizations, each of whom are making progress toward the development of agreements.

For example, AISC has published appendix A to the Code of Standard Practice, allowing a model to govern a project; AGC has produced AGC XML for project document exchange as well as the Contractors Guide to BIM, and continues to progress with contract agreements (some companies are even creating their own BIM agreements); and AIA has produced an exhibit to their standard contract form allowing for the use of direct digital exchange in projects. Meanwhile, the AIA California Council has developed its own guide to integrated project delivery.

To some extent, though, the industry is still struggling to get its hands around what BIM really is and what its contractual implications are. Is BIM a completely different way of contracting, wherein all the project stakeholders collaborate and give input, with the lines of design and construction methods slightly blurred? Or is BIM really a technological tool to help do the same thing we have been doing for decades? That is, is a 3D model simply a newer version of the shop drawing that allows for more complex comparisons among disciplines?

Issue 2: Legal help is needed to write BIM contracts.

To sort out these questions the A/E/C industry will have to enlist the help of construction lawyers. While not contributing to a project in the traditional sense (designing or building), the importance of the legal community should not be overlooked or overstated when discussing BIM. In fact, the American College of Construction Lawyers (ACCL) co-sponsored (with AISC) this year's eConstruction Roundtable—a positive step in the relationship between the construction industry and the legal community.

Besides fending off a constant barrage of lawyer jokes, construction attorneys are tasked with a unique challenge: bridging the gap between legal and technical knowledge required to create agreements that sufficiently cover both areas. There is no easy way to do this; construction lawyers will point out that many of the contracts used are based on forms thirty years old. And these forms are written around case law based on decisions 100 years old. While there is a great body of legal knowledge regarding traditional delivery methods, the case history for BIM is almost nonexistent and will have to be built nearly from scratch.

In addition to building a body of BIM-relevant legal knowledge, construction attorneys will have to assess what level of technical knowledge is needed to write a BIM contract. A usable agreement probably can't be created without significant input from the legal community, but is it necessary for the legal community to understand all the ins and outs of the various software packages that may be encountered during the design and construction of a building? Might it only be necessary to have an understanding of the process known as BIM? It might be reasoned that software and technology evolve at such a quick pace that standard contract forms may be woefully outdated by the time they are made public. This would indicate that even with a passing technical knowledge, construction lawyers can make a useful contribution to BIM development.

Issue 3: BIM contracts are still difficult to insure.

Contracting parties are not the only ones affected by a lack of standard agreements. Contract insurers and sureties need more certainty and an accurate gauge of their exposure when writing insurance policies and bonds. Generally, they feel that this comes in the form of standard agreements and historical data. While they are very positive about BIM, there are currently too many unknowns for them to write BIM policies.

Further clouding the issue, the most common place to see BIM in use is on design-build projects. These projects are generally known to significantly reduce the gross number of claims on a project. However, claims that are paid out tend to be three to four times higher that of the average construction claim.

As excited as the A/E/C community has become over BIM, it is still a somewhat intimidating process to the insurance industry. Called a "black hole" at the eConstruction Roundtable, the insurance industry feels that the BIM process blurs the design responsibility lines, which is an additional added risk for an industry that likes to know exactly what its exposure is and where it is coming from. Make no mistake: The insurance industry is going to eventually write BIM policies, but only as they become comfortable doing it, and it's the responsibility of the A/E/C industry to engage the insurers and help them get the information that is needed to write these policies.

Issue 4: The lack of a BIM umbrella group has left BIM without a rudder.

There are many well-intentioned groups that are busy trying to get their hands around BIM. Some are professional organizations, some are trade groups, and some are conglomerate groups. Most have slightly different missions and slightly different membership, and almost all have some cross-pollination with other groups. Of course, each of these groups has its own interests and agenda to pursue. This is not a bad thing, per se; it allows groups to examine what their particular BIM strategy is and forces an evaluation of their place in the industry. What it doesn't do, though, is foster an environment that includes all the parties needed to advance the use of BIM.

Any large-scale increase in BIM usage is going to be dependent on the industry's ability to unite and bring in all those that have in interest in it. To reach that end, the industry desperately needs one large umbrella group that can oversee the large-scale deployment of BIM and regulate the standards that will dictate how it is used. An umbrella group offers the further advantage of being able to pursue an end goal free of the constraints and concerns that more specific industry groups are forced to take on.

In addition to creating a more united industry, an umbrella group has the potential to end what has become known as the "traveling circus" phenomenon—the tendency for many of the same influential people to travel around the country attending BIM seminars and re-treading similar ground, rather than making a progress towards implementing BIM. This momentum could be better organized and channeled with and umbrella group to monitor progress.

This umbrella organization may evolve from a current group working on a more integrated solution, or it may be an entirely new group generated with the express intent of overseeing BIM development and deployment. How an umbrella group develops will ultimately be secondary to how quickly it develops—and how quickly it can organize the industry.

What is Interoperability?

In the simplest terms, interoperability is one program's ability to communicate with another. When we talk about interoperability, though, what we really strive for—what our ultimate goal as an industry should be—is a robust, mature, open-source, neutral file format. This, as opposed to proprietary data exchanges, is really what the industry is referring to when we talk about interoperability. Stated more concisely, interoperability is the ability of project stakeholders to exchange digital building information in an open-source, vendor-neutral, standard format.

Issue 5: Interoperability has come a long way, but it's still lacking.

There should be no doubt about the importance of interoperability as it relates to the success of BIM. While there have been degrees of success creating models within single software suites, the level of exchange we truly aspire to achieve will come from exchanges based on neutral file formats, not proprietary data exchanges. The degree of interoperability that is achieved will very much depend on three things: the software industry's willingness and ability to implement neutral file formats; their discipline in staying away from proprietary exchanges; and the A/E/C industry's ability to engage and help them with this.

As an example, the software industry has been a willing and active participant in development of CIS/2 translators, but the lack of an oversight body and certification process has left a patchwork of import and export capabilities among varying programs.

A translator can only work as well as the two entities for which it is translating. Many, if not most, commercial software applications that are CIS/2 capable have incomplete translators. There are specific functions they can perform, but not to CIS/2's full capabilities. This is due in large part to the lack of a certification process, and to a lesser extent the lack of customer demand for more robust translators.

Rectifying this situation means increased interoperability and a more efficient steel industry. One will have a hard time finding anyone that disagrees in principle with the need for interoperability. Anyone who has read the NIST report on interoperability knows that it's costing the capital construction industry money on all fronts. Bringing about increased interoperability is easier said than done, though. For the industry to get to a point where the expectations of interoperability are standardized, several steps have to be taken. For example, AISC has broadly identified the following steps to be taken to further implement CIS/2:

➜ Map and define the exchange process. It is important that we truly understand what steps are taken at given points in the steel design process.

➜ Validate the process with a users group that can verify the process.

➜ Bring together a users group to ascertain the software shortcomings and gaps relative to the exchange process

➜ Work with the software developers to address and close holes that remain in the implementations of CIS/2.

➜ Eventually, establish a CIS/2 certification process based on the exchange maps. A certification program will result in more thorough industry-wide implementations and more direct digital exchange.

Will addressing CIS/2 implementations solve all interoperability issues for the entire A/E/C industry? Certainly not, but a broad implementation of CIS/2 can serve as an example for the rest of the industry, and a more efficient steel supply chain will have a positive impact on the BIM world.

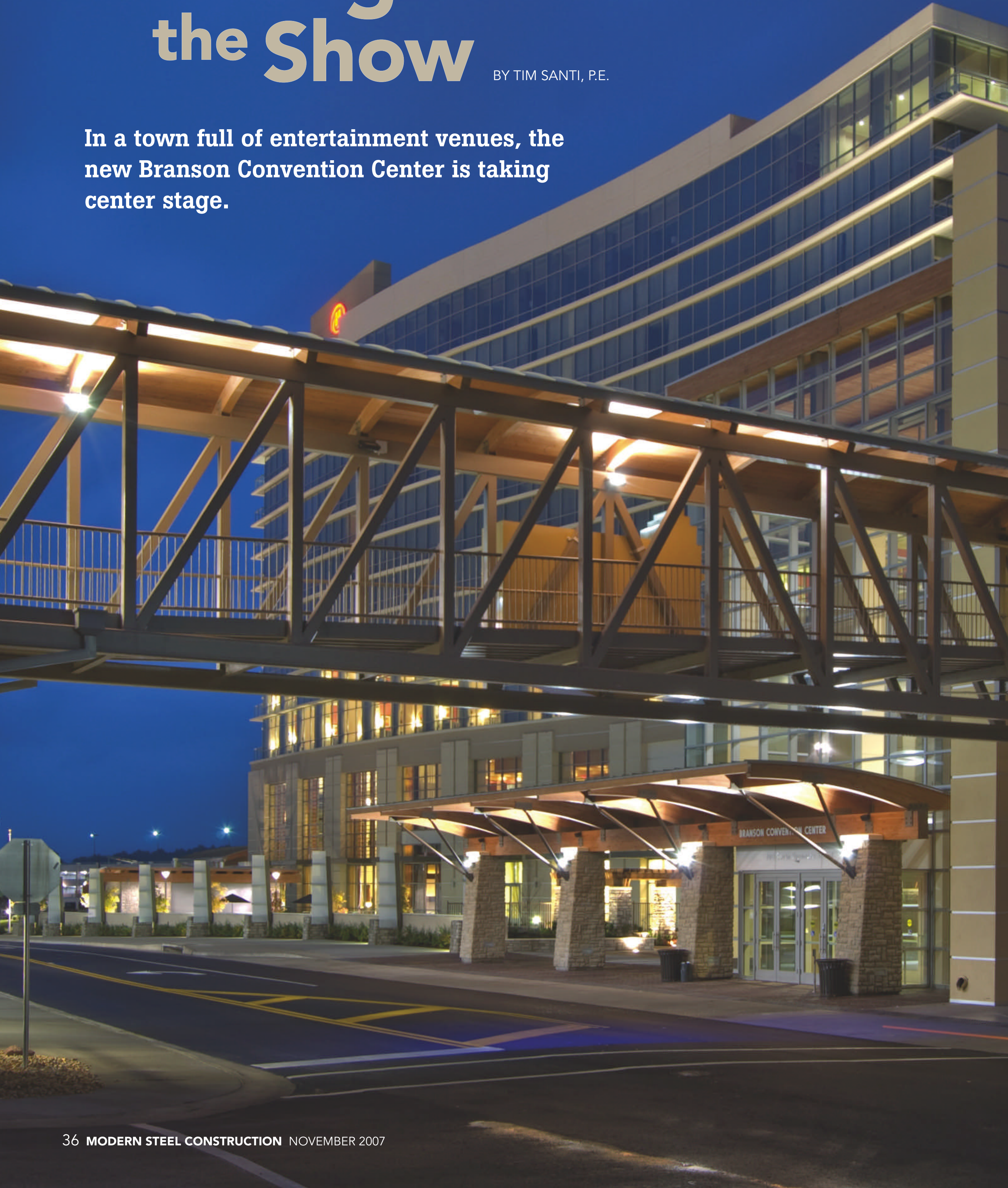
A Long-Term Outlook

The impediments to BIM implementation don't stop here. There are myriad factors affecting the use of BIM, from ingrained institutional opinions, to modified compensation structures, to the ability of companies to find proficient BIM users. It's important to realize, though, that the most common project delivery methods are far from perfect themselves; in over a century, we still haven't found the perfect method for delivering a complete built environment. It will take time for BIM to come to the masses—at least in a form that the average user can manipulate. MSC

Steeling the Show

BY TIM SANTI, P.E.

In a town full of entertainment venues, the new Branson Convention Center is taking center stage.



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MORE THAN 7 MILLION TOURISTS A YEAR COME TO BRANSON, MO., known by many as the "Live Entertainment Capital of the World." The city boasts having more theater seats than New York City's Broadway District. However, a different type of venue has just opened its doors in this dynamic entertainment destination: The Branson Convention Center, Hilton Branson Convention Center Hotel and Parking Deck. The complex, which opened in August, comprises the latest components of the $420 million Branson Landing mixed-use development, which covers 1.5 miles of Branson's downtown Lake Taneycomo waterfront.

A meeting planner's dream, the new 220,000-sq.-ft convention center includes popular amenities such as a 50,000-sq.-ft exhibit hall, a 23,000-sq.-ft ballroom, and spacious conference and meeting rooms on the upper level. Interconnectivity and flow are vital to a successful mixed-use facility, which was at the forefront of the design team's vision. A dramatic concourse component ties the many amenities together and extends into the adjacent 12-story, 294-room luxury hotel. A 73-ft-long pedestrian bridge connects the convention center and hotel to the 475-car parking deck.

Long spans and cantilevers, knife-edge eave framing, and soaring monumental entrances in the convention center demanded a material with great strength, versatility, and construction economy. Structural steel, essentially unparalleled for such challenges, was the unrivaled choice.

Long-span Efficiency and Economy

Functional requirements of exhibit halls and ballrooms typically restrict column locations to the building perimeters and back-of-house zones, and a convention center in this city—where performance and gathering space is paramount—would be no exception.

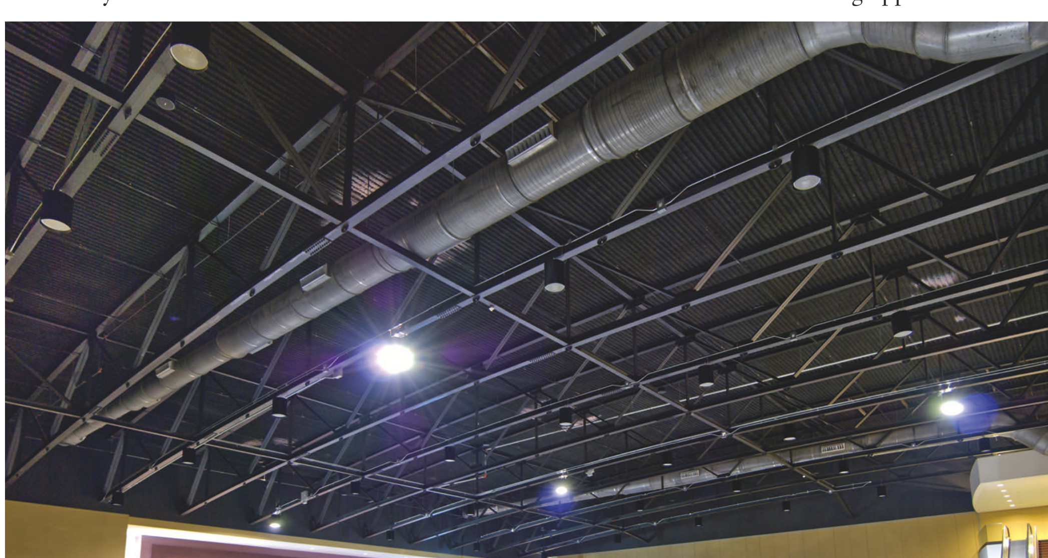
The barrel-vaulted roof over the exhibit hall and ballroom clear span between 156 ft and 165 ft. Twenty-nine structural steel roof trusses are spaced at 15 ft on center across the exhibit hall and ballroom. This truss spacing was selected to maintain the architectural 30-ft module, but more importantly to permit the 3-in.-deep metal roof deck to span truss to truss, thereby precluding the need for additional roof filler beams. Every other truss is supported by a W30 transfer girder to carry the gravity loads to the main 30-ft column grid. Four sets of truss-to-truss bracing are located at quarter points across the space to provide erection and stability bracing. To provide further economy, continuous bottom chord bracing is located only at third points along the truss spans.

Several truss geometries and member shapes and orientations were studied to derive the most economical design. W12 top and bottom chords and double-angle web members yielded the lightest truss weights and are amenable to simple, straightforward connections. The geometry of the double-angle web members were coordinated closely with the architect to align throughout the exhibit hall and ballroom and to provide panel points at rigging locations.

The W12 top and bottom truss chords are curved and parallel to match the shape of the barrel-vaulted roof. Aligning the bottom chord with the curved top chord minimized the truss depth at each section along the span. The shallow truss depths offered two advantages: The maximum clear height below was achieved for the exhibit hall and ballroom usage; and truss components could be shop assembled by keeping the total truss depth below the regional maximum shipping depth of 14 ft. Shop assembly of the truss components shortened erection time by reducing transportation time and costs, reducing the quantity of field connections, and capitalizing on the steel fabricator's shop efficiency in welding and bolting.

Backbones of Steel

The edges of the barrel-vaulted exhibit hall and ballroom roof create a striking appearance as they



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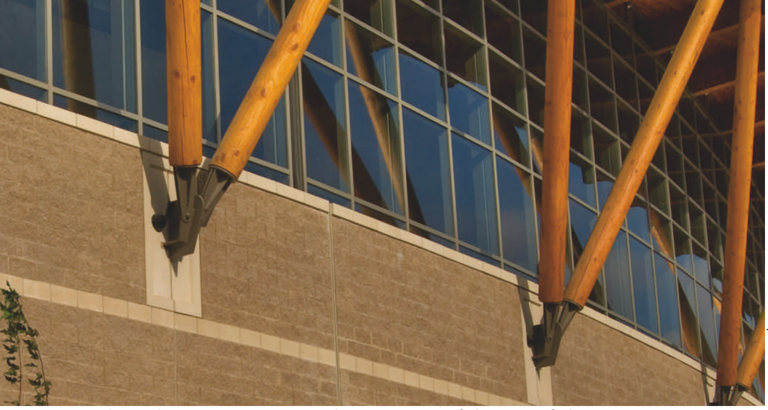
Barrel-vaulted trusses clear span between 156 ft and 165 ft over the exhibit hall and ballroom.



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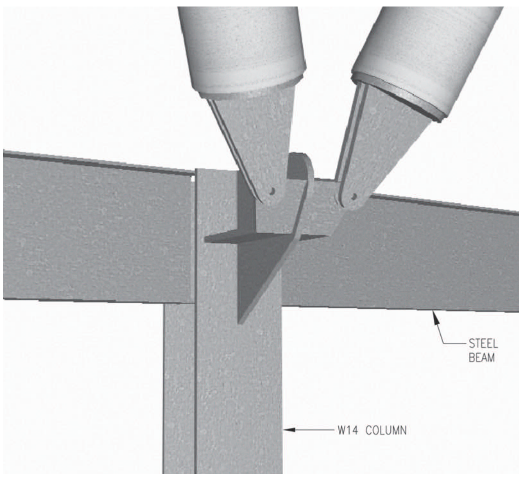
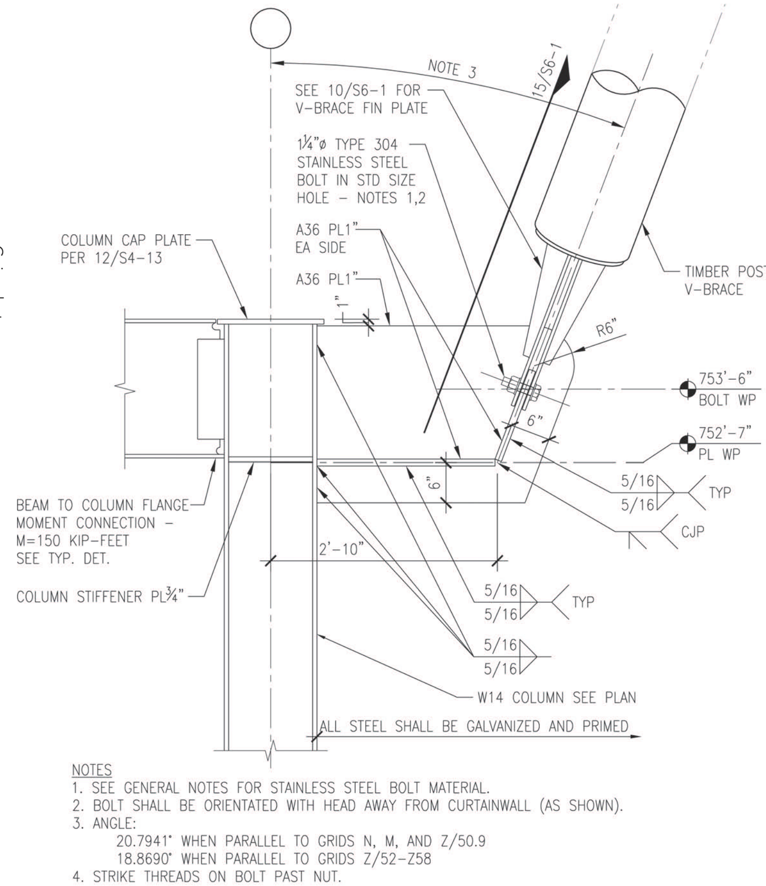
The V-braces punctuate the exterior of the 900-ft-long serpentine concourse.



Perspective view of the timber-to-steel connection at the base of the V-braces.



Relatively simple timber-to-steel connections were carefully detailed.

cantilever several feet beyond the building cladding to a crisp point. The long-span truss top chords cantilever over the supporting columns to suspend the knife edge channel framing assembly.

Four “wing wall” elements, curved in plan to match the shape of the concourse, knife out of the building at various points to communicate entrance and exit locations. The wing walls are tiered, or stepped down, in elevation to ease users from the elevated concourse down to grade as they exit the building. Wide-flange columns interlaced with curved wind girts serve as the backbone of the stepped wing walls in a simple yet effective solution to brace the walls for out-of-plane wind loading.

The monumental south lobby and prefunction entrances required 60-ft-high unbraced steel columns and wind girts for curtain wall support. Back-to-back HSS 10×4 columns are exposed and stitch-welded together with weld locations specified to match the curtain wall horizontal mullions. To complete the impressive prefunction space, steel pipe posts and two ASTM A36 1-in.-diameter rods attach to the top timber chord of queen post roof trusses that are spaced at 15 ft on center overhead.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Queen post trusses of glu-lam and steel form the ceiling in the prefunction area.

Structural steel also proved to be the only viable material for many of the project's other architectural expressions, including the hotel lobby's grand stair. Uniquely configured, this segmented half-spiral staircase spans around the twisting corner with no supporting columns. The built-up 36-ksi box stair stringers, carefully detailed to support the treads and handrails with minimal obstruction into the lobby space below, won out over concrete stringers due to formwork and placement challenges. The strength and versatility of steel was put to use yet again for support of other various hotel features such as the cantilevered wood-clad canopies, a massive rooftop billboard, and an iconic rooftop "eyebrow."

Mixing Metal and Wood

Steel and timber construction, when well-thought out and carefully planned between architect and engineer, can create a bold and enchanting blend of construction materials. The concourse of the convention center is such a statement, owing to thoughtful design. Serpentine in plan, the focal concourse extends roughly 900 ft along the convention center and hotel. HSS 8×4 posts provide lateral support for the 25-ft-tall curtain wall. Glulam decking is supported on glulam roof beams spaced at 10 ft on center. Twenty-nine sloping V-braces march along the serpentine concourse to support the glulam beams.

The V-braces were erected quickly and easily with an innovative system. Fifteen-in.-diameter timber poles are attached to the structural frame with an exposed adjustable steel tie-rod assembly and built-up steel apex assembly. Simple steel-to-timber connections were vital to maintain an efficient and cost-effective design solution. Each V-brace apex node is "pinned" with one ASTM A304 stainless steel bolt per pole, while each tie rod assembly above is adjustable to accommodate various roof slopes and erection tolerances. The V-brace system shows creativity at its best by fusing two very diverse materials into a unified, warm composite, with neither material overpowering the other.

Gravity and Lateral System

Composite steel framing is used throughout the second level to support the concourse, meeting rooms, and other program areas. Widespread cantilever conditions due to restricted column locations were no problem for the flexibility afforded by steel framing. A combination of wide-flange and double-angle braced frames and moment frames provide lateral resistance to wind and seismic loads induced on the convention center. Strategically located, the various frames provide the most economical means of transferring lateral loads to the foundations.

At a total project cost of $81 million and with 2,100 tons of structural steel, the Branson Convention Center and Hilton Hotel will undoubtedly be a big hit in this city of entertainment. MSC

Tim Santi is a principal and senior project manager with Walter P Moore's Atlanta office.

Convention Center Architect
Thompson, Ventulett, Stainback & Associates, Inc., Atlanta

Structural Engineer
Walter P Moore, Houston

Contractor
Turner Construction Company

Steel Erector and Fabricator
Doherty Ornamental Iron, Paola, Kan. (AISC Member)

Steel Detailer
Datadraft Structural Detailing Systems, Montreal, Canada (AISC Member)

Software
SAP2000 v9, ETABS v8, IntelliBeam

National Steel Bridge Alliance

2007 PRIZE BRIDGE *Competition*

The NSBA Prize Bridge Competition honors significant and innovative steel bridges constructed in the United States. Awards are presented in a variety of categories, including long span, medium span, short span, movable span, major span, reconstructed, and special purpose.

The National Steel Bridge Alliance thanks the submitters of all of the outstanding entries for their participation in the 2007 Prize Bridge Competition. The projects were judged on:

- Innovation
- Aesthetics
- Design and engineering solutions

Designers of the winning Prize Bridge projects will receive award plaques during a dinner banquet at the 2007 World Steel Bridge Symposium in New Orleans, December 4–7, 2007. Owners of winning bridges will receive award plaques at a dinner banquet during the 2008 AASHTO Bridge Subcommittee meeting.

Jurors for this year's competition were:

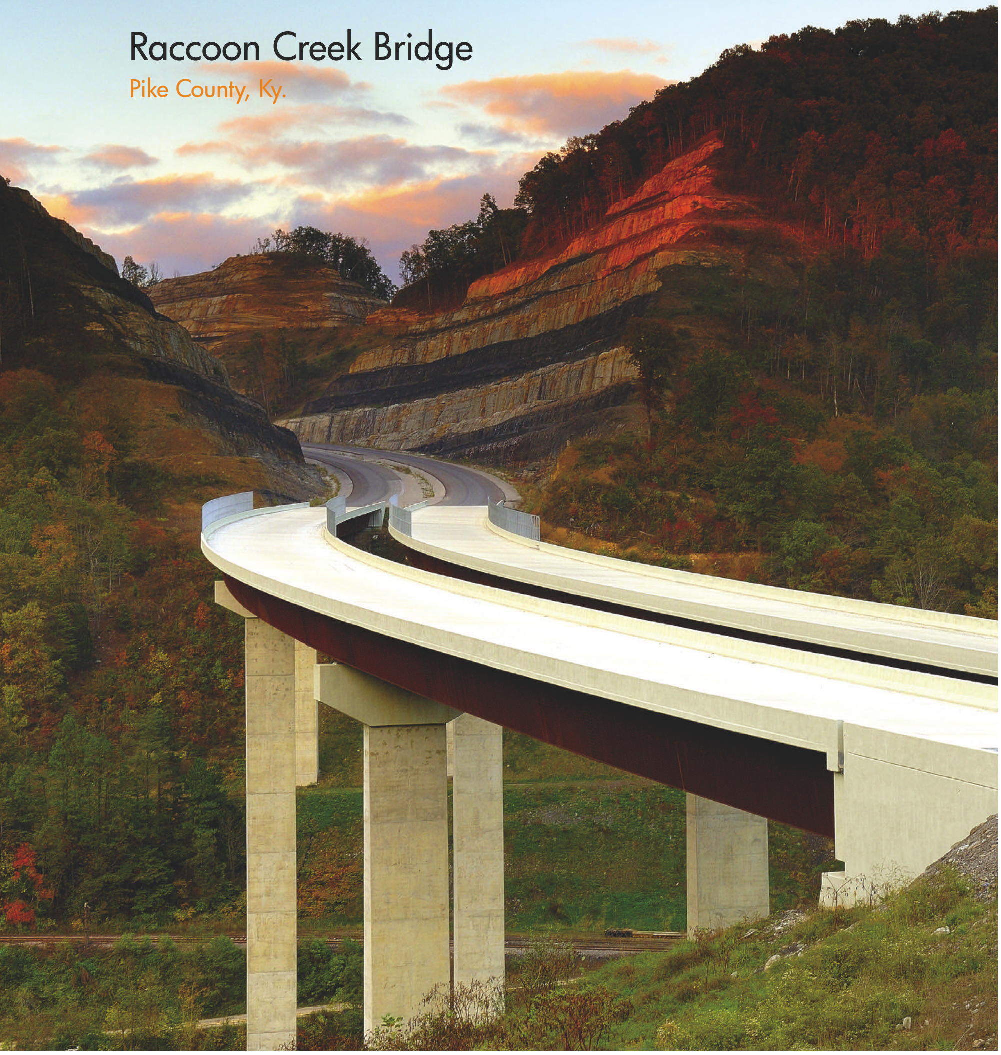
- Thomas Lulay
  CH2M Hill, Salem, Ore.
- Matthew Farrar, State Bridge Engineer
  Idaho Department of Transportation, Boise
- Myint Lwin, Director
  FHWA Office of Bridge Technology, Washington, D.C.
- Andrew Herrmann, Managing Partner
  Hardesty and Hanover, New York

NATIONAL AWARD

LONG SPAN

Raccoon Creek Bridge

Pike County, Ky.



Owner
Kentucky Transportation Cabinet, Pikeville, Ky.

Designer
Palmer Engineering, Winchester, Ky.

Fabricator
High Steel Structures, Inc., Lancaster, Pa. (AISC Member)

Detailer
Tensor Engineering Co., Indian Harbour Beach, Fla. (AISC Member)

General Contractor
Bush & Burchett, Allen, Ky.

Raccoon Creek Bridge is part of U.S. Route 119 in Pike County, Ky. This section of relocated U.S. 119 is a four-lane divided highway through mountainous terrain and is one of the last sections of Corridor G of the Appalachian Development Highway System, a network established by the Appalachian Regional Commission to support economic and social development in the region.

The $20 million bridge consists of twin structures that begin in a 3,280-ft radius curve with a 4.8% superelevation, transition through a spiral, and end in a tangent section of roadway. The bridges are 1,275-ft-long four-span structures with maximum 380-ft spans crossing 212 ft above Raccoon Creek. Three piers ranging from 140 to 210 ft tall support each bridge.

Design

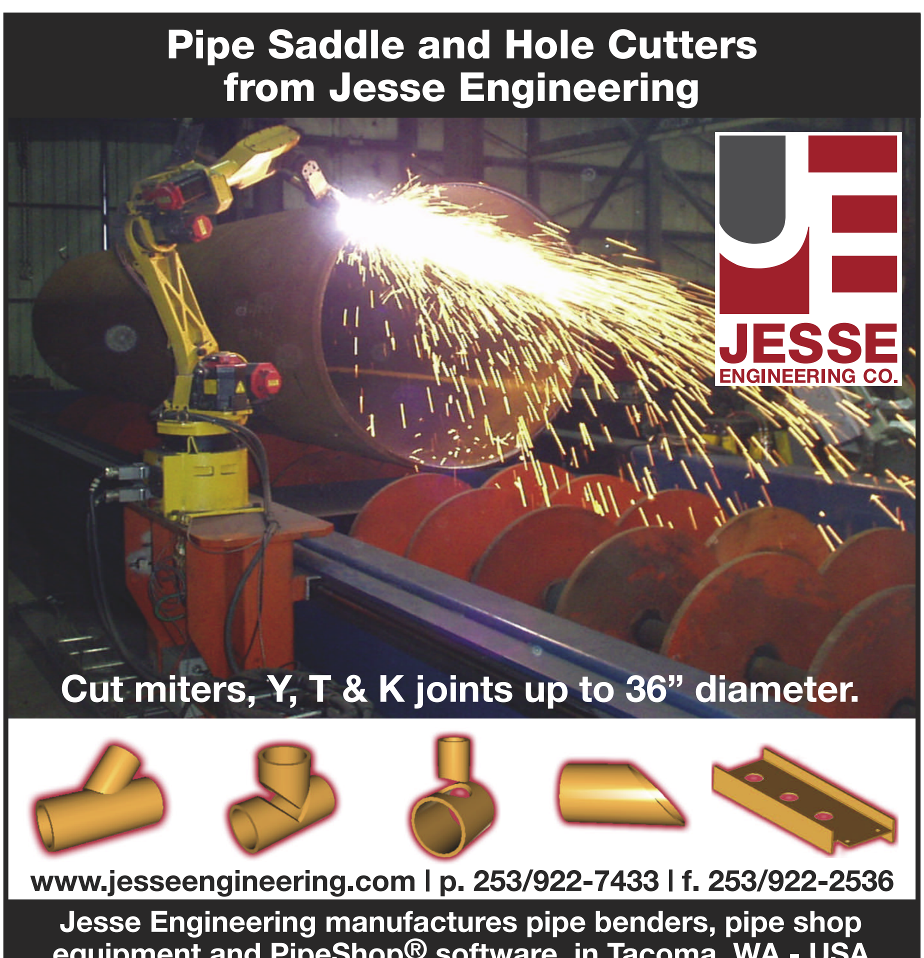
Long spans were required for this curved mountain road as the third span crosses Raccoon Creek Road, Raccoon Creek, two railroad tracks plus a spur track, and a coal mine's entrance and access roads. These same constraints that dictated long spans also restricted the contractor while building the bridge. Limited workspace, combined with the 200-ft height of the bridge and the weight of the box girder segments, truly created a one-of-a-kind construction job.

During preliminary design of the bridge, welded steel plate girders were sized for the long, curved spans. The design met the owner's load requirement (AASHTO HS25 design), but showed large differential deflections under truck loading—i.e., the deck rotated because the beams on the outside of the curve deflected 8 in. more than the beams on the inside. This inherent flexibility of the I-girder bridge type was an even greater concern because Kentucky has a legal load limit of 126,000 lb for trucks hauling coal.

In addition to in-depth evaluation of the bridge's in-service performance under traffic loading, constructability of the bridge was also investigated. Instability of the flexible I-girders during erection and installation of cross frames could have caused considerable problems. Even if construction were accomplished with the necessary, extraordinary measures, the traveling public would likely be able to sense deck rotation and not be at ease with this crossing.

The design team met with the owner to discuss these concerns. After a discussion of possible mitigation measures, all parties agreed that a different bridge type was needed to overcome the deck rotation problem and construction challenges. Although steel box girders had not been used before in the state, the design team decided on this girder type as it is much stiffer torsionally and is well suited for curved bridges.

Even once the decision was made to switch



the bridges to steel box girders, building within the constrained site remained a challenge. To address this matter, a partnering meeting between the owner, the consultant, and potential contractors was held to obtain suggestions aimed at preventing problems during construction. Contractors were shown design concepts and asked for comments on constructability concerns. Main comments were: 1) beam segment weight should be minimized to allow for smaller, more economical cranes; and 2) a possible construction sequence should be developed and included in the contract plans.

Including a detailed construction sequence in the plans is typically done for very large, complex, or segmentally constructed bridges where the method and sequence of construction can greatly affect stresses within the bridge. Recognizing the uniqueness of the Raccoon Creek Bridge situation, the owner agreed to include a suggested erection scheme in the contract plans. Presenting a sequence where construction stresses remained within allowable limits ensured a biddable project, although alternate schemes would be allowed if the contractor desired.

Construction

The erection sequence suggested in the design plans utilized temporary girder supports sometimes called "angel wings." These supports were fastened near the top of the tall piers and created stable platforms for the girders. Once a girder segment over a pier was secured in place, the temporary supports allowed for balanced cantilever construction. After completing the balanced cantilever portions from the piers, construction progressed with simultaneous drop-in girder sections, resulting in efficient erection.

Early Warning

By designing the Raccoon Creek Twin Bridges with their construction complexities in mind, engineers encountered and conquered obstacles in the preliminary phase, allowing the owner to avoid costly changes before or during construction. The project demonstrates a way to reduce differential deflections if the combination of span length and curvature create problems. A very difficult bridge construction project was improved by using more stable box girders in combination with temporary supports attached to the tall piers. MSC

NATIONAL AWARD

MAJOR SPAN

Burro Creek Canyon Bridge

U.S. Highway 93 between Phoenix and Las Vegas

Owner/Designer
Arizona Department of Transportation, Phoenix

Consultant
URS, Phoenix

Fabricator
PDM Bridge, Eau Claire, Wisc. (AISC Member)

Detailer
Tensor Engineering Co., Indian Harbour Beach, Fla. (AISC Member)

Erector
Traylor Brothers, Irvine, Calif.

General Contractor
R.E. Monks, Fountain Hills, Ariz.

Arizona U.S. Highway 93 runs north to south through central Arizona and is the primary transportation corridor between Phoenix and Las Vegas. Transportation growth through this corridor and related safety concerns have necessitated an expansion of the corridor—and a second Burro Creek Bridge.

The existing Burro Creek Bridge, which carried two-way auto traffic, is a truss arch structure with spandrel columns supporting the roadway deck and plate girder approach spans. The final design for the new bridge design was also a truss arch, but using weathering steel for future maintenance reasons. The existing Burro Creek Bridge will be painted in the future to blend aesthetically with its new sister.

The location is environmentally sensitive, part of a wilderness recreation and campground area, and owned by U.S. Bureau of Land Management (BLM). This federal agency, as steward and custodian of the unique canyon area, had set a higher level of environmental restraints for this new bridge crossing over the canyon. Major constraints included: minimal damage and disturbance to the canyon, preservation of the natural settings and compatibility, no construction access to the canyon base, and maintaining a scenic view from the nearby campground. The Arizona Department of Transportation (ADOT) developed a partnering relationship with BLM early in the planning and design process, and BLM concerns and priorities were included in the layout and bridge type selection.

Learning from Lessons Past

The existing Burro Creek Bridge offered insight as to how to deal with the challenge of erecting a structure—that would not be internally stable until it was complete—over a significant opening. A cable high line was used with the first bridge to deliver material and erect the structural steel. A cable-stay tower was also used for temporary erection support, as the truss arch stretched out from the abutments and ultimately closed at center span. The spandrel columns and decking were then erected with the high line once the main arch truss was complete.

This erection method was suggested by ADOT

in the original project bid documents for the new bridge. However, the erector concluded that this method was slow and not competitive. Experience within the estimating team was drawn upon and lessons learned from previous projects were brought to the table. One such bridge project, in Washington state, was erected "over the top" with a light crawler crane. A bogie cart system was used to ferry materials to the erection crane as it walked forward to erect the truss bridge until the cantilevered halves closed at center span. But the New Burro Creek Bridge design, by itself, was not capable of self-support, nor was it capable of supporting an erection crane.

Another previous bridge project, in Michigan, was also considered. This through-arch structure, which was also erected with a crane over the top, used a temporary support tower with cable stays to support the arch erection and crane loads until the arch was completed. This erection method appeared to be adaptable to the New Burro Creek Bridge, and the tower components used for this bridge still existed and were available. As such, this was the chosen method for the new Burro Creek Bridge.

Laying the Groundwork

Extensive geotechnical investigation and iterative bridge foundation studies were performed to optimize the location of the bridge. A computer-based visual simulation study presented the impact and compatibility of the various feasible bridge structure types on the scenic view of the canyon.

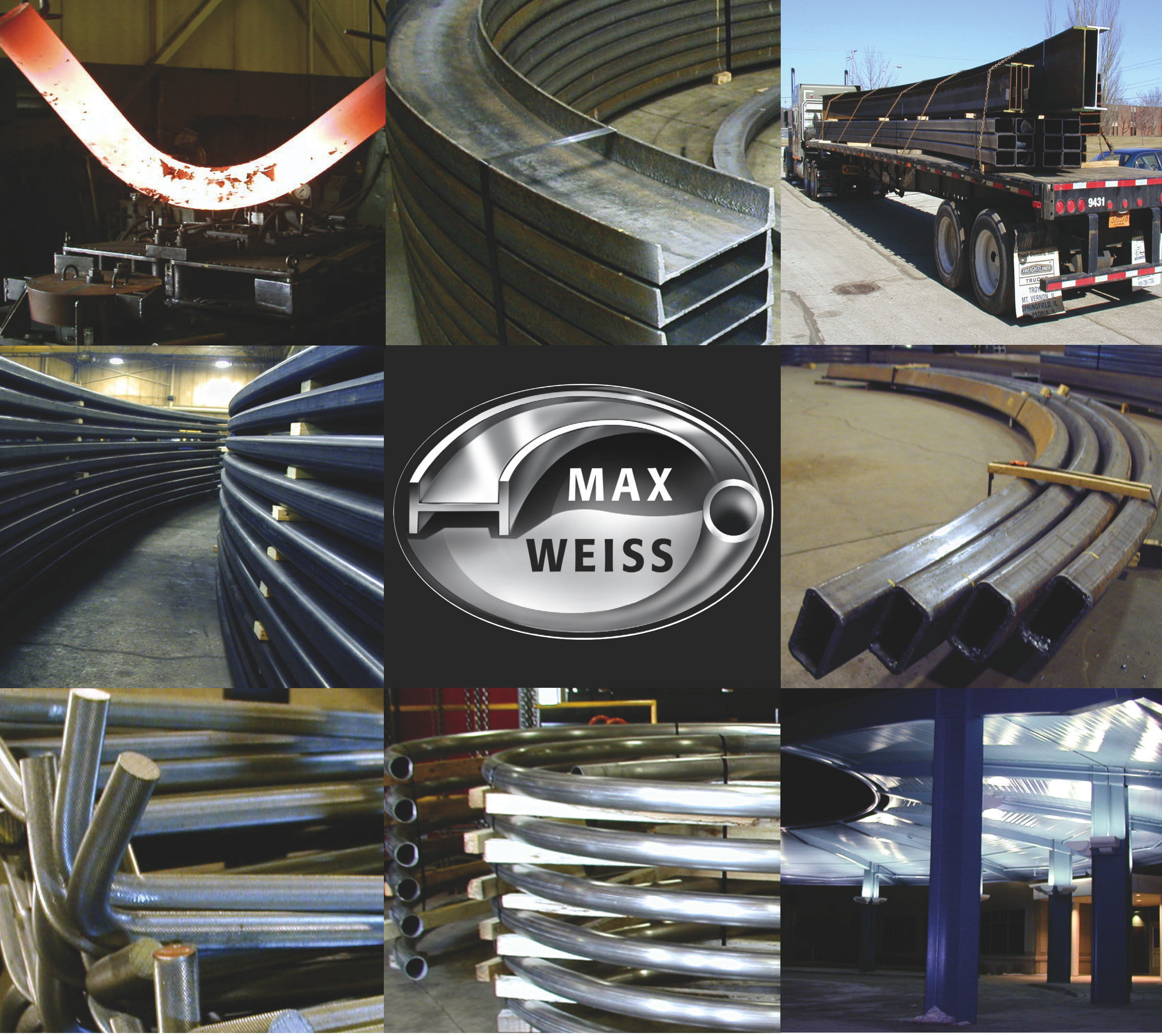
Three-dimensional simulation models were developed to make comparative evaluation of alternative bridge types over the canyon setting and to aid in selection of bridge structure type. Innovative connection designs were developed to improve fabrication and erection methods and enhance construction safety. High-strength weathering steel was used to protect the environment and blend with the natural setting and rock types of the canyon. Special types of wind bracing and anchoring details at skewbacks were developed to streamline steel erection. In addition, special provisions and dynamic control parameters were specified in design to control rock-blasting effects.

The Right Fit

A steel truss arch bridge layout was selected as the best fit for the canyon. Arch skewback foundation layout and excavation limits were refined in order to reduce rock excavation and rock fall in the canyon.

Constructability issues of the steel arch over the canyon, with minimal disturbance and in close proximity of the existing Burro Creek Canyon Bridge with heavy traffic, were major criteria in the design development process. Several innovative and optimized design features were included to achieve these goals. Skewback piers were designed to provide support and anchorage for the cantilever launch of the steel arch over the canyon. Flexible connection details were provided for ease of fabrication, transport, and field erection.

Erection productivity and worker safety were addressed using an access platform system. The contract specifications originally called for the use of safety nets, but the access platform system prompted the elimination of this requirement and afforded a heightened level of worker safety. This in turn resulted in improved erection productivity. A bottom platform extended across the lower chord joints, from which the lower arch truss members could be erected and bolted. The platforms were moved forward with the erection in a trapeze fashion. Upper erection platforms were smaller and specific to a single joint, and also served to provide erection access and later, a secure means to complete the joint bolting process. MSC


MAX
WEISS

NATIONAL AWARD

MEDIUM SPAN

Gateway Bridges

Taylor, Mich.

Owner
Michigan Department of Transportation, Lansing

Designer
Alfred Benesch & Company, Lansing

Fabricator
PDM Bridge, Eau Claire, Wis. (AISC Member)

Erector
Whaley Steel Corporation, Mio, Mich. (AISC Member)

General Contractor
C.A. Hull, Inc., Walled Lake, Mich.

Unequal arch lengths, pressurized ribs, hidden arch ties, and even Super Bowl-inspired football-shaped braces characterize a new set of bridges in suburban Detroit.

The Gateway Bridges are part of a $55 million project to improve Interstate 94 between Detroit's airport and downtown. They replace a previous four-span struture and carry westbound and southbound I-94 traffic over a redesigned single-point urban exchange. The structures are twin 246-ft single-span inclined through arches, with the interior and exterior arch ribs inclined 25° toward each other in order to maintain the desirable vertical clearance over the roadway. The ribs are braced together using five football-shaped braces.

The unique physical appearance of the bridge incorporates innovative functional aspects, and several progressive engineering concepts were developed to aid in maintenance and provide longevity for the structures. The following are notable unique characteristics:

➜ This is the first tied arch with its longitudinal ties buried under the road (modified tied arch). The modified tied arch solves the redundancy issue with tied arch bridges.

➜ The arch ribs are not the same length, satisfying the desire to match the existing horizontal alignment of I-94 east and west of the Telegraph Road interchange. The base of the interior arch ribs is located at the level of I-94, while the base of the exterior arch ribs is located at the level of Telegraph Road. This caused the length of the exterior and interior ribs to be different—296 ft and 257 ft, respectively.

➜ The rib sections of the two arches are varied to achieve the same stiffness in each arch. This is done to ensure that the arch deflections will be the same.

➜ In order to reduce the size of the arch ribs, the shape of the arch is optimized to produce axial stresses in the rib with a minimum moment from dead load. Most of the bending stress comes from live load acting over a part of the span.

➜ The arch ribs are 3-ft by 4-ft box sections. Due to the small size of the ribs, future inspection and maintenance of the inside portion of the box

will be difficult. Therefore, the arch ribs are pressurized with air to prevent any internal moisture in an effort to prevent corrosion.

➜ The framing of the bridge deck is a series of floor beams, stringers, and stiffening girders. The transverse floor beams support a 9-in.-thick concrete deck, which in turn is supported by hangers. The longitudinal stringers and stiffening girders reduce the deck deflection due to live load. The stiffening girders also distribute the live load between the adjacent hangers. This resulted in lighter hangers.

➜ The hanger assembly has two strands per assembly. In the event of losing one strand per assembly, each strand within the assembly is designed to carry the total load of the adjacent failed strand with an impact factor of two. To reduce the possibility of wake galloping for the hangers, one separator is used to connect the two strands together.

➜ The transverse beams are haunched I-beams with portions of the beam extending outside the deck. These extended portions are boxed, using two additional outer webs, and then pressurized with air. The boxed-sections improve aesthetics and increase the torsional resistance of the beams in case one strand within the hanger assembly is lost or replaced.

➜ In true arches, the longitudinal arch thrust is taken by the foundation supports, such as the piles. In a tied arch, the thrust is taken internally by the tie. In both cases, there is no redundancy in case of a failure of the thrust resistance. For this bridge, the longitudinal arch thrust is resisted by multiple foundation elements—battered piles, longitudinal reinforced foundation ties, and the transverse foundation ties.

Cost-effective Aspects

Cost was a major concern of MDOT, and was therefore considered with highest regard. Design decisions were guided by cost implications resulting in significant savings from the original estimate. Each of the following was significant to the realized cost savings:

Optimizing arch ribs. A perfect arch would carry only compression under applied dead load. In order to reach the shape of the arch that will result in a minimum bending stresses under dead loads, the shape of the ribs was optimized to closely approximate the equilibrium thrust line, which corresponds to the applied dead loads. A compound circular curve was chosen to approximate the equilibrium thrust line. Starting from a basic circular profile with constant radius, the bridge was analyzed under dead loads, then the equilibrium thrust line was determined, and a compound circular curve was fitted through the thrust lines. The structural model was then re-analyzed with the new shape of the ribs. This iterative process was carried, in which the resulting dead loads from the previous analysis were used to generate a new shape for the ribs. The final shape of the arch ribs was reached when the bending stresses were negligible. This process resulted in a lighter arch ribs and small arch rib deflections under dead load.

The arches were optimized, making the most efficient use of materials while achieving the desired aesthetic result. This effort saved $500,000 in material costs.

Bridge assembly technique. Design specification required per-assembly of the arch, which contributed to the efficiency of construction. The first bridge took one month to construct. Having learned from the first erection, the second bridge was erected in 10 days.

Sealing and pressurizing the arch ribs ensures that maintenance will be minimized and traffic flow optimized during routine inspection, making the bridges cost-effective over time.

Transverse Beams. The transverse beams are 100-ft 2¾-in.-long haunched I-beams with portions of the beam extending beyond the deck. These portions are boxed sections using two additional outer webs. The boxed sections of the beams increase the torsional resistance of the beams in case one strand within the hanger assembly is lost or being replaced. Cost savings were realized by incorporating the I-beams as opposed to using complete box girders. The stringers act compositely with the deck through ¾-in.-diameter shear studs. MSC

NATIONAL AWARD

MOVABLE SPAN

Louisa Bridge

Louisa, La.

Louisiana's longest steel girder double-leaf bascule bridge spans the Intracoastal Waterway in remote Louisa, St. Mary Parish, La. The main navigational span is a semi-high-level, two-steel-girder, double-leaf, fixed-trunnion bascule bridge. The longitudinal bridge, with a trunnion-to-trunnion distance of 275.6 ft and a width of 40 ft, is one of the longest spans of its type in the United States. In the closed position, it provides a minimum vertical clearance of 73 ft and a horizontal navigation clearance of 200 ft.

The superstructure design for both the bascule and adjacent approach spans uses two shallow-depth parabolic-shaped welded steel plate girders for each span. These girders were selected for their efficient use of steel, light weight, durability, cost-effectiveness and aesthetic characteristics.

The bascule girder tail end utilizes a unique short and compact style counterweight. Special innovative steel counterweights were efficiently positioned in this tail end in order to minimize the overall counterweight size for aesthetic purposes. In the fully closed position, the bascule tail end seamlessly disappears within the adjacent approach spans, resulting in a pleasing three-span haunched girder-shaped superstructure. In the fully open position, the tail end disappears within the open-type bascule pier.

The very long and narrow bascule leafs required the floor system to be as light as possible. The floor system design, using steel stringers and steel floor beams supporting a light-weight open steel grating for the roadway deck, was selected for its efficient use of steel.

Louisa Bridge's shallow-depth parabolic bascule girders vary in depth from 7.5 ft to 17.3 ft and are spaced at 27.6 ft. The two adjoining steel girder spans vary in depth from 8.3 ft to 16.4 ft and are spaced at 33.5 ft.

Each leaf of the bascule is driven using curved racks mounted on each girder. The 73-ft vertical clearance means that the bridge will open infrequently. Therefore, a very basic drive system is used in each leaf; a single enclosed gear drive is driven by two 25-horsepower two-speed alternating current motors. MSC

Owner
Louisiana Department of Transportation, Baton Rouge, La.

Designer
HNTB Corporation, Baton Rouge

Fabricator/Detailer
Carolina Steel Corporation, Greensboro, N.C. (AISC Member)

Fabricator/Detailer – Movable Span
Steward Machine Co., Inc., Birmingham, Ala. (AISC Member)

Erector
Huval & Associates, Inc., Lafayette, La. (AISC Member)

General Contractor
Coastal Bridge Co., LLC, Baton Rouge


BETTER. FASTER.
EASIER.

NATIONAL AWARD

RECONSTRUCTED

St. Johns Bridge

Portland, Ore.

Owner
Oregon Department of Transportation, Salem

Designers
OBEC Consulting Engineers, Eugene, Ore.
Oregon Department of Transportation, Salem

Fabricator/Detailer
Hogan Fabrication, Inc., Portland, Ore. (AISC Member)

General Contractor
Max J. Kuney Construction, Spokane, Wash.

After more than 70 years of weathering the Pacific Northwest elements and a comprehensive inspection in the late 20th century, the historic St. Johns Bridge in Portland, Ore. recently underwent a $37 million restoration. Major work items on this 3,600-ft bridge included restoration of deteriorated steel, new deck, painting, main cable rehabilitation, suspender replacement, new railing, and seismic retrofitting.

St. Johns Bridge was designed by the famous bridge engineer David B. Steinman and was constructed in 1931 at a cost of $800,000. From west to east, the four-lane bridge consists of 255 ft of conventional steel deck truss approach spans; a 2,067-ft suspension bridge segment with suspended spans of 430 ft, 1,207 ft, and 430 ft; and 1,285 ft of conventional steel deck truss approach spans up to 180 ft in length. The bridge is the only large suspension bridge on the Oregon State Highway System and spans the Willamette River in Portland, providing more than 200 vertical ft of navigation clearance.

The Oregon Department of Transporation completed some of the design work in-house and used an outside engineering consultant for the remainder of the project. The rehabilitation included $16 million of painting, $11million for cable restoration work, a new $4 million concrete deck, and $5 million in miscellaneous rehab work including deteriorated steel restoration, bridge rail strengthening and rehabilitation, and seismic retrofitting. All work was staged to allow a continuous single-lane of traffic to be maintained in each direction at all times on the bridge.

Stiffening and other Factors

Stiffening was a major consideration for the renovation, and the design team performed extensive finite element and non-linear analysis on the bridge to determine areas of concern. The results indicated that the bridge was very close to excitation by wind and vulnerable to seismic events. The critical component was the slender stiffening trusses of the suspended main span, which have a span/depth ratio of L/67, well above most other suspension bridges of this size.

The typical deck section was modified by the addition of two tie braces between the deck and the floor beams, which allowed the concrete deck to become the fourth side of the "torsional box" deck section. This concept stiffened the bridge against wind excitation without changing the historic look of the structure, while using existing components of the bridge to the maximum extent.

Another method used to stiffen the bridge against wind excitation without changing the historic look of the bridge was the use of "traction rod" ties between the existing stiffening trusses and the main cables. The traction rods had an additional benefit of providing seismic restraint for longitudinal "slapping" of the superstructure into the seismically vulnerable towers supporting the main cables at deck level. The main cables were exposed and fitted for new traction rod clamps. The total weight of the new traction rod clamp castings was 38,000 lb, with the mid-span casting being the heaviest at 9,000 lb.

Justified Replacement

Out of 204 suspender cables, more than half were found to have enough broken wires to warrant replacement in kind with 1⅝-in.-diameter ASTM 603 wire ropes. The contractor provided the jacking scheme based on the designers' requirements and installed the ropes to the specified tension so as to maintain the distribution of forces in adjacent suspenders and prevent undesirable deflection in the structure.

The original main cables of the suspended span consisted of ninety-one 1½-in.-diameter bridge strands—each fabricated from individual wires—compacted into a hexagon shape with shaped Port Orford cedar used to form a circular shape, which was then wire-wrapped. Alternating rows of strands are fabricated with left-hand and right-hand lay to prevent rotation under loading. Sealing the main cable consisted of the use of a proprietary continuous Hypalon cable wrapping system. The wrapping is sealed at each cable band, splay cable, cable bent, and saddle and anchor house shroud. At low points in the main cable, inspection ports were installed with direct visual access to the bridge strands. These inspection ports can also be used for future cable corrosion control using the state-of-the-art dry air injection method.

The longitudinal steel stringers were originally constructed to be non-composite with the concrete deck. In order to replace the deck with a new concrete deck of similar thickness—combined with the need to strengthen the existing deck stringers to handle current vehicle loading—the new deck was made composite by the addition of shear studs to the top flanges. Approximately 7.5 miles of stringers were strengthened using approximately 60,000 shear studs. MSC

NATIONAL AWARD

SHORT SPAN

Box Elder Creek Bridge

Watkins, Colo.

Just a few miles east of Denver, an innovative six-span bridge crosses Box Elder Creek on U.S. Highway 36 in Watkins, Colo. The new bridge, which replaces a previous one, is 470 ft long and 44 ft wide, and carries two lanes of traffic. The project's total cost of $2.1 million includes removal of the old bridge, construction detour, and landscaping.

The superstructure is composed of 77-ft-long W33x152 rolled steel girders. The bridge has six girder lines of grade 50 weathering steel spaced at 7 ft 4 in. The bridge deck is 8-in.-thick cast-in-place concrete. The girders are simple span for non-composite dead load and were made continuous at the piers for composite dead load and live load.

A Competitive Alternative

Highway 36 highway makes a low crossing at Box Elder Creek, demanding a shallow superstructure. During the design stage the Colorado Department of Transportation considered precast prestressed concrete side-by-side box girders and structural steel girders; precast side-by-side box girders are the most common CDOT solution to the low-depth issue, due to the very competitive local precast industry. However, Colorado's standard precast concrete bulb-T shapes were too deep for the site, and steel was eventually chosen. The designers applied solutions generally reserved for precast concrete to this material alternative. These included:

- ➜ Simple-span girder sections made continuous at the piers for composite dead loads and lives loads.
- ➜ Simple, easily constructed details to obtain continuity at the piers.
- ➜ Using the deck to carry the tension component of the negative moment at the pier.
- ➜ Low-cost standard girder sections.
- ➜ Minimizing the number of diaphragms.
- ➜ Simple fabrication details.
- ➜ Simple construction details.

Although the Box Elder Bridge is not necessarily the first use of these innovative solutions for steel girders, by using them creatively and in concert the designers provided an alternative that was competitive with the normal precast concrete solution; project estimates showed the rolled W33×152 solution to be less costly than the precast concrete box girder solution. In addition, the W33×152 solution, as designed, was easy to build quickly.

To optimize the use of standard rolled steel sections, a simple yet unique compression plate detail was used at the piers. To carry the negative moment at the piers, the designers used a compression plate welded to the bottom flanges. This plate carried the compression component of the negative moment, and the composite bridge deck, with its rebar, carried the tension component.

Longitudinally adjacent girders sit on one 30-in. by 14-in. by 1-in. compression plate bolted to the pier cap and resting on an elastomeric leveling pad. One of the girders is shop-welded to the plate, and the other welded in the field. Consequently, the only field actions needed to obtain girder continuity were bolting the plate to the pier, field-welding one girder to the plate, and placing the bridge deck.

Rapidly Constructable Steel Details

To optimize the use of standard rolled steel sections, the "simple-span-made-continuous" technique (simple span for non-composite dead load and continuous for composite dead load and live load) was used to minimize both steel and fabrication costs. Making the girder continuous shared the live loads between spans, allowing a shallower girder section.

To save steel costs and construction time, intermediate diaphragms were not used between all the girders. Instead, they were placed in only three of the five girder bays between the six girder lines. All girder compression flanges were supported by a diaphragm, and all exterior girders were supported by a diaphragm—especially important during deck placement.

Single W27×84 rolled shapes were used for the diaphragms as opposed to multiple cross-bracing pieces. The diaphragms are spaced at 12 ft 8 in. in the two external bays and at about 19 ft in the internal bay. Similar diaphragms in all bays connect the girders at the piers and abutments.

Owner/Designer/Detailer
Colorado Department of Transportation, Denver

Fabricator
Big R Manufacturing, LLC, Greeley, Colo. (AISC Member)

General Contractor
Structures, Inc., Englewood, Colo.

The advantages of employing these details and using rolled beams were numerous:

➜ Fabrication costs were low, and therefore total steel costs were much lower than for welded plate girders.

➜ All pier cap compression plates and all diaphragm details were similar.

➜ After developing shop drawing for one rolled beam, all other drawings were the same or similar.

➜ With this bridge, continuity was obtained without any bolted girder splices.

➜ The girders were designed so that additional transverse stiffeners were not needed, other than those used for bearing stiffeners and to connect the diaphragms.

➜ Concrete diaphragms between the girders were not used at the piers or the abutments. This provided cost and construction time savings over the concrete diaphragms typically used for precast concrete girders.

➜ Using weathering steel eliminated the need for maintenance painting.

➜ Lifting the rolled beams was handled by relatively small cranes; the prime contractor was able to perform the steel erection.

➜ The total amount of structural steel needed for this bridge was only 20.7 lb per square foot of deck area!

Pier Details

The piers are founded on five steel pipe piles—which are ideally suited for the rather loose alluvial material making up the foundation soils—as opposed to the much longer pile lengths that would have been required for end-bearing piles or drilled shafts. The steel pipe piles were also less costly and quicker to construct.

The designers accomplished the most significant cost savings by using the pipe piles to create the five aesthetically pleasing round columns supporting the pier cap. The pipe piles were left extending out of the ground—with no pile caps or fussy transition details—and filled with concrete. Then, projecting reinforcing steel was inserted and the pier cap was constructed on top. Not only was this cost-effective, but it also removed several weeks from the construction schedule that would have been required had reinforced concrete columns been used.

Good Competition

The innovative six span steel bridge crossing Box Elder Creek in Colorado showcases the viability of standard rolled steel sections as a competitive alternative to precast concrete. The simple-span-made-continuous technique, although not new, was used with an innovative continuity detail and in concert with several other thoughtful design considerations, providing an especially economical, low-maintenance, and visually appealing bridge that was easy to fabricate and constuct. MSC

NATIONAL AWARD

SPECIAL PURPOSE

Highland Bridge

Denver

The new Highland Bridge restores a vital link between downtown Denver and the revitalized Highland neighborhood to the northwest. It replaces the 16th Street viaduct, a reinforced concrete viaduct that was failing when it was demolished in 1993, with a user-friendly pedway. It is the third in a family of three signature pedestrian bridges extending the city's downtown 16th Street Pedestrian Mall alignment across the Central Platte Valley.

Similar to the first two crossings, the Highland Bridge utilizes structural steel tubing and a cable-stay system for a dramatic structure. Rising 70 ft above the ground, the triple-rib steel arch spans 320 ft over Interstate 25. The flared cross-hanger arrangement provides a sweeping support system for the suspended bridge deck.

Design Vision

During the project's design, many structural steel options were evaluated, ranging from 200 ft to 350 ft long: single-rib arches, trussed arches, and bifurcated arches. Renderings were used during the design process by the architects, urban designers, and structural designers to share design concepts and solicit input from stakeholders and the public. Input from businesses, residents, and special interests, such as bicyclist groups, helped steer the project design. Critical to the urban design concept was the creation of a vertical circulation area to traverse a 13-ft change in grade from the structure deck down to the existing Platte Street elevation on the east side of I-25. The need for both long ramp access and stair access drove the design toward an architecturally sophisticated and urban solution. A circular ramp solution minimized impact on surrounding property while creating a plaza area with theater seating and direct access to nearby shops and a park.

The west end of the triple-rib arch anchors into a single-thrust block foundation. As pedestrians and bicyclists travel east across the bridge, the arch rib spacing increases, opening up and framing the downtown skyline, with each arch rib anchoring into a separate foundation.

Input from fabricators and contractors was solicited during the design to provide efficient and economic details. To facilitate construction over I-25, the arch fabrication was broken into four sections. Temporary splice plate connections between the arch pieces were designed for ease of erection and were removed once the arch steel pipe welds were completed.

Innovative Construction

To facilitate fabrication, the arch sections were fabricated upside down and fitted up to adjacent pieces for geometry control. The pieces were painted in the shop and shipped to the field, where each section was reassembled in a staging area north of the bridge site in preparation for erection. The arch sections were erected by crane during two consecutive night closures of I-25. The contractor's step-by-step sequence included a rolling procedure to orient the arch section upright and provide temporary falsework support for the end sections.

Design allowances during construction included sleeving the individual anchor bolts for each arch piece in the foundation, allowing up to one inch of adjustment in any direction. The sleeves and under-the-arch base plates were grouted after placement.

After the arch erection, the steel deck girders

Owner
City and County of Denver

Sturctural Engineer
Hartwig & Associates, Inc., Englewood, Colo.

Designer
Carter & Burgess, Denver

Fabricator
King Fabrication, Houston (AISC Member)

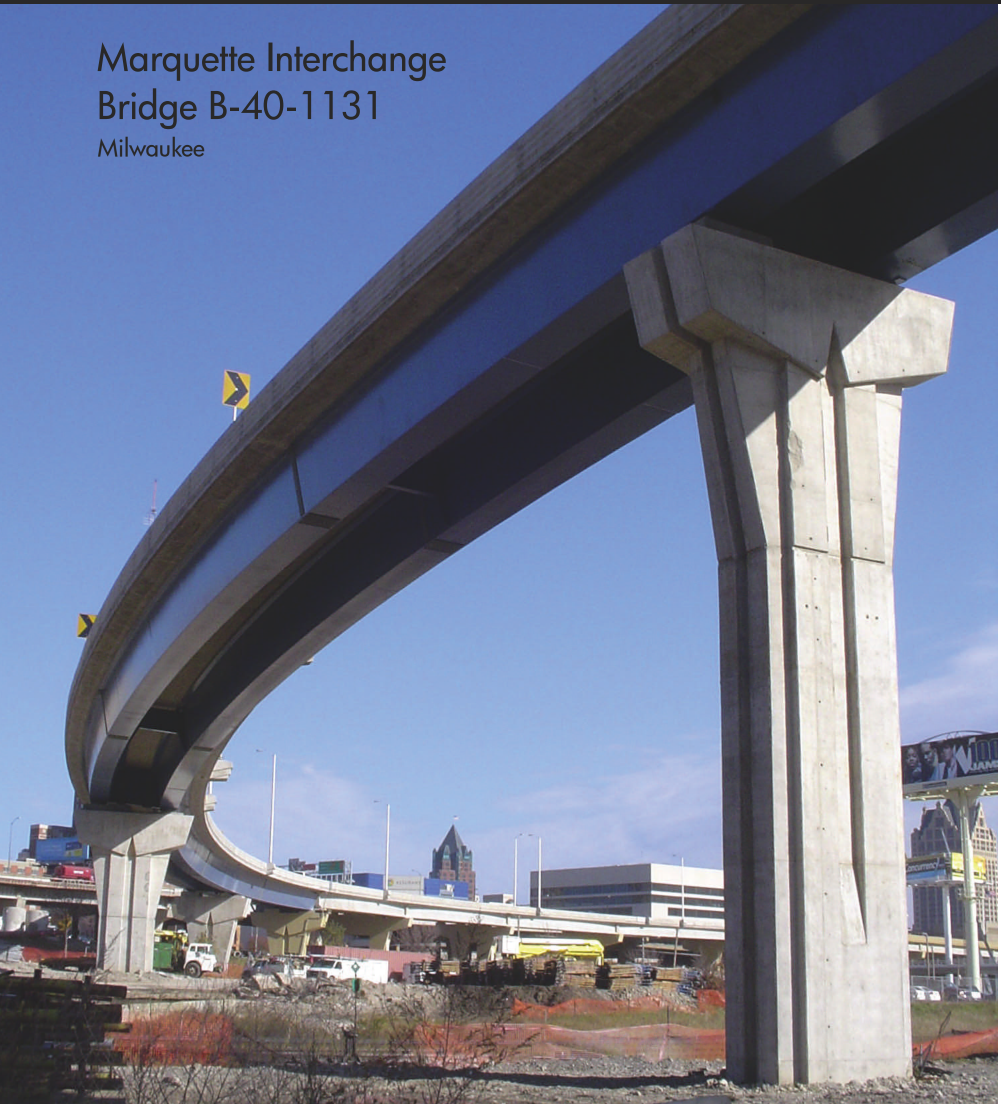
Construction and Erection Engineering
GES Tech Group - Consulting Engineers, Calhan, Colo. (AISC Member)

General Contractor
Hamon Constructors, Inc., Denver

were suspended with temporary cables prior to installation of the permanent 1.5-in.- to 1.75- in.-diameter cables. Because of the asymmetric layout and varying lengths and angles of the permanent cables, the deck girder geometry was set with a cambered twist, so that once the deck was poured it would match the proper geometry. The cable forces were monitored during the construction by measuring the cable vibration frequency. With the use of an accelerometer, the cable forces were calculated from the cable frequency, length, and weight. This method of measuring the cable forces was non-intrusive and can be used to conduct future routine inspections of the bridge. MSC

MERIT AWARDS

LONG SPAN



Marquette Interchange Bridge B-40-1131

Milwaukee

Owner
Wisconsin Department of Transportation, Madison

Designer
Milwaukee Transportation Partners, LLC, Milwaukee

Fabricator
PDM Bridge, Eau Claire, Wis. (AISC Member)

Detailer
Tensor Engineering Co., Indian Harbour Beach, Fla. (AISC Member)

General Contractor
Marquette Constructors, LLC, Black River Falls, Wis.

The Marquette Interchange in downtown Milwaukee includes three Interstate highways—I-94, I-794, and I-43—and is the cornerstone of the southeastern Wisconsin freeway system. The $810 million reconstruction and reconfiguration of this interchange includes a five-level system interchange, five miles of Interstate highway, 28 ramps, more than 60 bridges—totaling 2.1 million sq. ft of bridge deck—and five miles of retaining wall.

The preliminary engineering phase identified two feasible bridge types for the system ramps: trapezoidal steel box girders and concrete segmental box girders. After 14 months of engineering and cost analysis, the decision was made to move forward with the steel option.

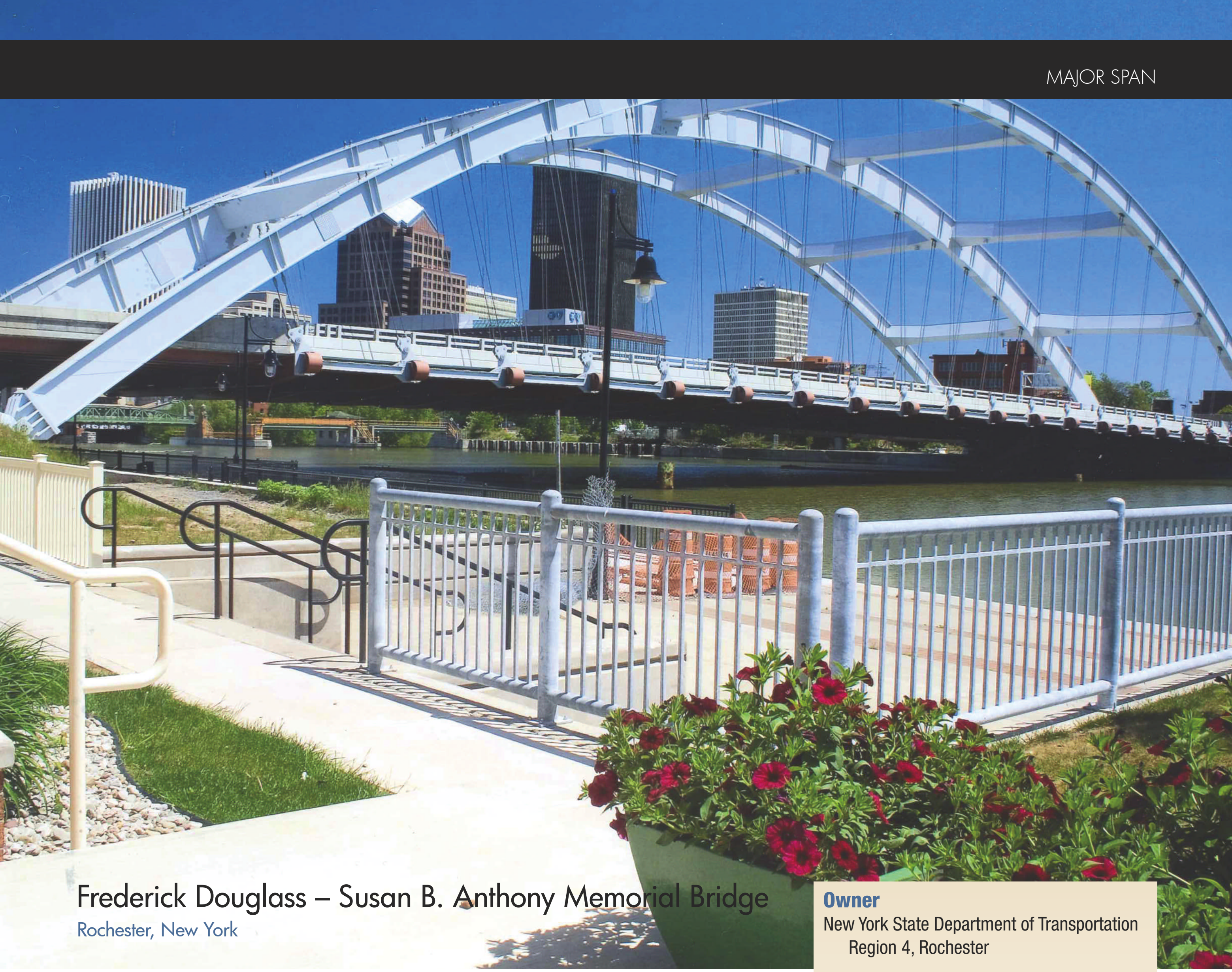
The centerpiece of the project consists of eight high-level system ramps, all of which are curved multispan twin steel composite box-girder bridges up to 2,400 ft long. Individual bents range up to 1,600 ft long between movement joints.

So far, several bridges have been completed and opened to traffic. One of these bridges is the South-to-Plankinton Structure B-40-1131, with a main span of 250 ft over active railroad tracks.

Unique HPS Use

High-performance steel is a superior product with higher yield strength, improved weldability and weathering resistance, and greater levels of toughness, all of which can lead to more economical bridges than conventional 50W designs. However, at the time, the *Guide Specifications* would not allow use of hybrid section designs. As such, for Bridge No. 1131 and other tub girder designs in the project, a design using HPS 70W and HPS 50W for adjacent field section elements provided both the function and cost benefits needed on a large project like the Marquette Interchange. This hybrid element approach involved using the higher strength HPS 70W material in the pier units, where strength mattered the most due to higher moments, and HPS 50W in the mid-span sections to take advantage of its superior material toughness.

With the Marquette Interchange project being 75% comprised of bridge structure, delays in steel delivery—and especially of the HPS steel for the bridges—would have spelled disaster. A key to the success and time savings realized on the project was getting the steel ordered as soon as possible, especially for the early bridges on the critical path. Typically, it takes several weeks or even months from the time of award to placing a steel order with the mills. To avoid this delay and expedite the steel order, all structures on the critical path were identified, and shop drawings were prepared in sufficient detail to place a mill order immediately upon award to the successful contractor. This advance order ensured delivery of the HPS steel to the fabricator in a timely manner and drastically reduced the risk of project delays. To date the project is nearing completion and is about six months ahead of schedule. MSC



Frederick Douglass – Susan B. Anthony Memorial Bridge

Rochester, New York

Owner
New York State Department of Transportation Region 4, Rochester

Designer
Erdman Anthony and Associates, Inc., Rochester

Fabricator
High Steel Structures, Inc., Lancaster, Pa. (AISC Member)

Detailer
Upstate Detailing Inc., Burnt Hills, N.Y. (AISC Member)

General Contractor
Edward Kraemer and Son, Inc., Plain, Wis.

The Troup Howell Bridge in Rochester, N.Y. was originally constructed in 1954 as an urban boulevard, and was eventually reconfigured to become part of the Federal Interstate system. After enduring decades of heavy truck traffic, the New York State Department of Transportation decided it was time to replace the bridge, and in 1999 a bridge replacement type study was performed.

Six different bridge types were evaluated: short-span steel multi-girder, long-span steel multi-girder, prestressed concrete box girder, steel box girder, steel through arch, and cable stayed. After considering the bridge type options at a public hearing, the community overwhelmingly chose the steel arch. There was consensus on a fundamental point: The site deserved a “gateway” or “signature” span that would frame the river as well as the city skyline. The new eight-span structure, the Frederick Douglass - Susan B. Anthony Memorial Bridge, is 1,194 ft long. The “centerpiece” is a 433-ft-long through arch span crossing the Genesee River in downtown Rochester.

It was decided to support both eastbound and westbound travelways by only three ribs. Precedent for three-rib construction was found in Berlin, Germany with the arch bridge over the Britz Canal, which opened to traffic in 2001. Ribs for the Troup Howell Bridge are steel boxes. The center rib is 9.8 ft by 3.8 ft, and the exterior rib is 5.8 ft by 3.8 ft. The ribs are spaced at 65.3 ft. The boxes are made with a wider top flange than bottom, and aesthetic stiffener plates are added at each hanger location. This overhang geometry provides the illusion of a trapezoid and promotes the creation of shadows, which enhances visual interest.

The arch rib bracing is Vierendeel-type to maximize the view to open sky. Six brace lines connect the ribs. The braces are also steel boxes and are dog bone-shaped in plan view. The braces are also used to support expressway lighting. Fixtures are mounted within bottom flange penetrations at each brace. This arrangement eliminates the need for conventional lighting poles mounted on the bridge deck, which the design committee believed would visually conflict with the hanger layout.

Provisions to assist future bridge inspectors were also added to the ribs and braces. Six access doors were added to each rib, and two doors were added to the top of each brace. Hand rails were added to the longitudinal stiffeners in each member, and steps were placed in the steeper portions of the bottom flange on the inside of the box. All boxes are made with ASTM A709M Grade 345W (A588) steel and were not designed to be airtight. Experience on other bridges has shown that interior condensation can create conditions that accelerate corrosion, so the Troup Howell design incorporates ventilation and drains. In addition, the interior of each box is painted white to facilitate future biennial inspections. MSC

Ramp B, Interstate 40

Nashville

Ramp "B" spans Briley Parkway and Ramp "A" on the east side of Nashville, Tennessee. This structure replaces the old at-grade intersection with a flyover from I-40 west to southbound Briley Parkway.

A major concern at this location is Nashville International Airport, which has a runway terminating in the proximity of this interchange. Since there's a flight path directly over the interchange, numerous configurations of both the bridge and interchange were considered. A minimum vertical clearance for I-40 below and maximum vertical height restrictions for air traffic above resulted in a shallow zone of air space being allocated to accommodate the bridge. The shallow steel girder and integral cap ultimately employed by the Tennessee Department of Transportation effortlessly conformed to the constricted and winding corridor of space prescribed for passage of the superstructure. The 45:1 span to girder depth ratio imparts a slender line to the bridge as it courses gracefully without intrusion across the skyline.

Each of the bent caps utilized in this structure consists of a steel box with access doors for inspection. The box connection to the curved plate girders is accomplished using bolted field splices. The novel aspect of the longitudinal top and bottom flange splice plates is that they bridge uninterrupted over and under the bent cap providing a direct connection of opposing girders. This configuration mitigates transverse stresses in the bent cap flanges. The flange splice plates are bolted to the bent cap only minimally to satisfy seal and stitch requirements. Neoprene sheets are sandwiched between flange splice and filler plates to further isolate the cap from girder longitudinal stresses. The webs of the plate girder are bolted to a transverse stiffener on the outside of the box. The inside of the box has a transverse stiffener between opposing girders, which provided a continuous web connection across the box as well. The fracture-critical steel box girder was fabricated using high performance Grade 50 steel on the top tension flange and each web plate. The steel caps bear on a single bearing pin, which allows rotation of the super structure and restrains uplift attributed to unbalanced load conditions. The lugs supporting the bearing pins are field-welded to the concrete-filled steel column casing. Access ports are placed on the ends of the caps to provide worker accessibility during erection and for future inspection of the caps. The access ports have hinged doors that promote both ease of entry/egress and safety.

During construction, scaffolding was placed at each pier to stabilize the steel cap. Scaffolding was also placed near each field splice to stabilize the curved girder which has a degree of curve of 12° 30'. MSC

Owner/Designer
Tennessee Department of Transportation, Nashville

Fabricator
AFCO Steel, LLC, Little Rock, Ark. (AISC Member)

Detailer
ABS Structural Detailing, Melbourne, Fla. (AISC Member)

General Contractor
Dement Construction, Jackson, Tenn.

Owner
Miami-Dade Expressway Authority, Miami

Designer
HNTB Corporation, Lake Mary, Fla.

Fabricator
Tampa Steel Erecting Company, Tampa (AISC Member)

Detailer
Tensor Engineering Co., Indian Harbour Beach, Fla. (AISC Member)

General Contractor
Condotte America, Inc., Miami

The Miami-Dade Expressway Authority (MDX), in order to address increased vehicular traffic, has embarked on an expressway expansion program that consists of three design-build contracts. The first project of these contracts is approximately 2.6 miles long and contains the SR 836 Flyover bridges (over the Homestead Extension of Florida's Turnpike, or HEFT).

One of the largest of these bridges, Bridge No. 11, is a long-span steel box girder superstructure with post-tensioned integral concrete diaphragms, aesthetically enhanced piers founded on spread footing foundations, and spread footing abutments.

This curved flyover replaces the existing bridge over the HEFT by carrying the expanded three lanes of Westbound SR 836 traffic over the mainline HEFT lanes. The bridge is located just south of the existing bridge and is 543 ft long with a span arrangement of 140 ft by 249 ft by 154 ft and a baseline radius of 1,146 ft. These spans are configured such that the bridge piers are located between the mainline HEFT lanes and the respective future HEFTC/D roadways.

MDX's proposal package recommended that a concrete segmental box girder bridge be used for this structure. However, because the proposal package did not restrict the design-build team to the recommended bridge type—nor to the recommended span arrangement—the team chose very early in the proposal process to change some of the bridge parameters.

First, the team performed a cost analysis and decided that a steel box girder would be a more cost-effective solution. Second, they fine-tuned the bridge length by slightly shortening the main span and one of the end spans to optimize the span arrangements. Because each of the two selected pier locations will ultimately be located between the HEFT mainline lanes and the HEFT collector/distributor lanes, the available space for a pier was limited to approximately 9 ft. Because the HEFT roadways are skewed to the bridge axis by nearly 54°, use of the flared pier would extend the top of the pier out into the traffic lanes and violate the vertical clearance of the roadway. In order for this pier type to work, the piers would have to be rotated to match the skew of the roadway. However, this would have resulted in skewed box girder framing. And early team discussions indicated that the contractor preferred not to fabricate or erect skewed box girders because of the added costs due to fabrication complexities, as well as the difficulties that often occur during deck casting as a result of differential deformations. Therefore, a single round column was selected to be used in concert with non-skewed supports. Use of a traditional pier cap with the round column was not possible due to the vertical clearance requirements over the HEFT lanes adjacent to the pier, so the team elected to go with a concrete diaphragm that would work well with the box girders. MSC

MERIT AWARDS

Canyon Creek Bridge

East of Rexburg, Idaho

Owner/Designer
Idaho Transportation Department, Boise

General Contractor
Sletten Construction Company, Great Falls, Mont.

The original Canyon Creek Bridge, built in 1932, is a three-span deck truss with steel girder approach spans. Due to its narrow width of 24 ft and various functional and structural issues, including a badly deteriorated concrete-filled steel grid deck, the decision was made to create a new canyon crossing while retaining this existing historic bridge.

Access to the environmentally sensitive canyon presented a significant challenge to constructing the new bridge. There is no access available below the rim of this 375-ft-wide, 117-ft-deep canyon, and very minimal disturbance to the canyon was allowed. Four options were considered during the planning stages:

➜ A prestressed concrete girder bridge with approximately three equal spans of about 125 ft.

➜ A concrete arch with a main span of about 275 ft.

➜ A three-span steel slant-leg.

➜ An unbalanced three-span steel girder bridge with spans of 79 ft by 217 ft by 79 ft.

After the foundation investigation was completed, the arch and slant-leg options were ruled out because solid rock was over 70 ft below the skewback locations. Any horizontal thrust would be difficult to resist in the native volcanic ash. In order to construct and erect the concrete girder option, temporary access roads would be required in the canyon, which would be both expensive and disruptive to the environment. However, the unbalanced three-span steel option offered a couple of key advantages:

➜ The unbalanced geometry of short end spans would allow the pier locations on the side of the canyon to be accessed by cranes operating from the canyon rim with no need for access roads. Construction activities to build the two 58-ft-tall piers would include excavation, shoring, micropile installation, rebar placement, forming, and concrete delivery. All these activities could be carried out by placing cranes on the canyon rim.

➜ The advantage of using steel girders for the unbalanced span configuration was that these girders could easily span the relatively long center span of 217 feet and yet be light enough to be erected with cranes sitting on the end span.

The plans specifically stated that no large equipment would be allowed below the rim of the canyon. However, the end segments, once they were in place, could be used as erection platforms for the cranes setting the center drop-in segments. So, the Canyon Creek Bridge became the first steel bridge built in Idaho with the girders being used as a platform to complete the erection. The sequence of the erection was to:

➜ Set the 120-ft girder end segments first—which cantilevered 41 ft beyond the piers—from cranes operating at the canyon rims.

➜ Place a temporary wood deck on these girders, allowing the cranes to move onto the end spans out to the piers.

➜ From there the cranes could lift the 135-ft center span drop-in girders from trucks positioned on the old bridge, adjacent to the new bridge, and set them in place with only minimal traffic interference.

The team used this proposed method with one modification: The end girder segments were set just far enough out to rest the end of the segments on the piers, and then were rolled 40 ft into place. This allowed for the use of a smaller crane than had originally been anticipated. MSC

RUBY ON INTEROPERABILITY

DAVID I. RUBY, P.E., S.E., Structural Engineer. Principal, Ruby & Associates P.C., in Farmington Hills, Michigan. Specializing in steel designs that speed and ease constructability. Recently consulted on a community college project where his design and use of Interoperability resulted in a hyper-fast and efficient design—and a six-figure rebate from the fabricator to the school.

INTEROPERABILITY is the ability to manage and communicate electronic product and project data between collaborating firms. It allows the exchange and management of electronic information, where individuals and systems are able to identify, access, and integrate information across multiple systems. The goal of interoperability is to create greater efficiencies by eliminating the manual reentry of data, duplication of business functions, and the continued reliance on paper-based information management systems. The steel design and construction industry uses the CIMSteel (CIS/2) neutral file format to enable interoperability.

CONSTRUCTABILITY "When doing the pricing on a recent project, Douglas Steel Fabricating Corporation asked us to review the job to enhance constructability. It was a community college project that originally called for fully welded moment connections and knee-braced frames. The number of pieces and amount of field welding made the project uneconomical. Douglas Steel sent us the original design documents. We put together an alternative design that satisfied the intents of the owner and architect. We then transferred our CIS/2-compliant model back to Douglas Steel, enabling them to process the model in SDS/2 so they could bid both the original and alternative designs on time. Without CIS/2 Interoperability — or what used to be called Electronic Data Interchange — we couldn't have turned it around fast enough to keep the job on schedule."

VALUE "The architect's drawings, the site constraints, points of access, equipment — there are so many different things to consider to come up with the most economical product that meets a client's needs. A lot of people talk about value engineering. What that really means is examining a set of decisions that have already been made, and going from there. You're talking inside the envelope. But when you design for constructability and value, outside-the-envelope thinking leads to things like speed to market and achieving budgets. CIS/2 Interoperability is a tool that lets us think like this."

EFFICIENCY "For the community college, the floor beams were spaced at about 3-foot, center-to-center, with a very light metal deck and a reasonably thin slab. As a rough count, we eliminated over 700 members, as well as 11,000 shear studs from the floor system and it was designed so everything could be field bolted. We ended up with a metal deck system and a thicker slab that added a little dead load to the structure, but increased the strength of the composite beams. Basically, we made it easier to build, stronger and much more economical. Plus, we stayed on schedule because the design only took four days thanks to CIS/2 Interoperability."

PERSPECTIVE "Working with Fazlur Khan to design the Hancock Building early in my career gave me a different feel for construction. One thing about the Hancock: the steel out-raced concrete to the roof. In fact, steel was 25 floors ahead at one point! We even had to design temporary braces to keep the structure together because we were so far ahead. Faz was such a great concept engineer. I learned you can't just look at a building as a design — it has to be built too! Piece by piece, stability is an issue during construction. But once it's done, the issue goes away and you let the building act as it should."

COMMUNICATION "The advantage of Interoperability is speed through the elimination of paperwork and many layers of communication. Typically, a detailer would verbalize a problem to the fabricator who would submit a request for information to the contractor who'd send it to the architect. A response from the structural engineer would be communicated through the contractor to the fabricator and ultimately, back to the detailer. And many times the detailer would respond, 'That's not the question I asked.' This happens time and time again when you're trying to explain a three-dimensional problem in 50 words or less. CIS/2 Interoperability means the pertinent decision-makers — the engineer, detailer and fabricator — can look at the model in real-time, discuss the problem and collaborate on a solution. Better, faster communication is the value of Interoperability."

INTERACTION "With Interoperability, I work with the fabricator and detailer directly. We receive their files over the Internet, pull them into our system, make comments and send them back in just a couple of hours. This saves a tremendous amount of time and keeps us on schedule. Let's say there's a connection issue, or perhaps the fabricator has a question. We're not waiting because the drawings are in the mail. They just send us their three-dimensional models and we solve the problem today. That's what Interoperability is all about."

UNIVERSAL "The files a fabricator works on are generated from the RAM model we send them. So when they pull our models into the system for detailing, they have the most current designs. There is less paperwork to keep track of and that's a significant advantage. If I send files at noon, by 3 o'clock the fabricator has his bill of materials. Manually, this process took a week. And we're not talking just 40 hours — but two or three people putting in 40 hours to pull that all together. Those extra hours are an expense completely eliminated due to Interoperability."

INTEROPERABILITY "The primary reason for Interoperability is to integrate design and construction processes by eliminating the need for manual re-entry of data. The advantage for steel is that the CIS/2 standard enables compliant software—Tekla, SDS/2, Bentley, RAM, FabTrol and others—to exchange data electronically with accuracy and speed. In fact, CIS/2 makes most structural steel design, detailing and manufacturing applications interoperable."

STEEL "Steel already gave us a much quicker delivery time. And that's now clearly enhanced by CIS/2 Interoperability. Steel lets me build a structure that can be modified, easily reinforced, adapted to another use and has overall economy from start to finish. Unless you're building sidewalks, there's never a reason not to use steel."

MERIT AWARDS

MEDIUM SPAN

Upper Perry Bridge

Interstate 84 near La Grande, Ore.

The new Upper Perry Bridge, near La Grande, Ore., spans the Grande Ronde River and carries Interstate 84 traffic through a 1,000-foot radius curve. The original design for the bridge was envisioned as twin cast-in-place concrete box girder structures, tied together at the supports and with a deck closure pour.

However, after successfully bidding the job, the contractor, Holm II, Inc., decided that it would be difficult to complete all of the work, including casting all of the concrete required for the 8-cell box girder and the closure pour, in the contract time allowed. Faced with penalties if any poor weather or unforeseen events delayed the casting sequence, they began thinking of alternatives that better fit the project schedule even before the contract was awarded.

As construction began, the contractor immediately had the support of the owner's project manager for a value engineering proposal. In the end, both agreed that a steel structure was better suited for the project.

Through the value engineering process, the contractor proposed a curved, steel-plate I-girder bridge. A consulting engineer, steel fabricator, and steel detailer were brought into the discussion to help evaluate the costs of the preliminary design. The result was more of a design-build environment, with conference calls soliciting everyone's input. Even at a time of rapid price increases, the steel alternative was the structure of choice due to the relative ease and efficiency of construction.

During preliminary design, the engineer suggested independent structures that could be made different lengths to better accommodate the terrain at one end of the bridges. Additionally, the engineer suggested single, hammer-head piers instead of a two-column bent, utilizing the foundations already cast in solid rock. Due to the lower seismic mass of structural steel, the single-column substructures were sufficient for the controlling lateral load. Independent structures also eliminated the need to schedule the closure pour before a permanent traffic barrier was placed on top of the deck.

Once erection began, the contractor, who also served as the erector, worked 18-hour days in overlapping shifts to place 475 tons of steel in four days. The deck was cast five days after erection began, and the rails two weeks after the deck. The Interstate was opened for the winter as scheduled.

The design of the second bridge was completed on the heels of the first. The westbound bridge was also completed on time, with a little less stress, and the interstate was permanently opened to two lanes of traffic each way in time to meet the project deadline. In the minds of all involved, the original concrete plan would have never been completed on time. This would have created traffic delays and impacts to the traveling public, both in terms of safety and mobility. In addition, the amount of falsework required to cast the concrete for the box girder bridge would have resulted in more impact to the sensitive river environment. MSC

Owner
Oregon Department of Transportation, Salem

Designer
OBEC Consulting Engineers, Eugene, Ore.

Fabricator
Fought & Company, Inc., Tigard, Ore. (AISC Member)

Detailer
Tensor Engineering Co., Indian Harbour Beach, Fla.

General Contractor
Holm II, Inc., Stayton, Ore.

MERIT AWARDS

MEDIUM SPAN

Ravenna Viaduct

Ravenna, Neb.

Ravenna viaduct is located on Highway 68 at the southern edge of downtown Ravenna, Neb. and spans a major route of the Burlington Northern Santa Fe Railroad. The original viaduct, built in 1937, was a five-span 265.5-ft.-long bridge with a 24-ft.-wide roadway and a 5-ft.-wide sidewalk. Thanks to structural deficiency and functional obsolescence, it was replaced with a new 174-ft. single-span parallel tied arch viaduct with a 43-ft.-wide roadway and 8-ft.-wide sidewalk.

The parallel arch system offers a unique solution to the problem, providing a structural depth including slab of less than 35 in., and does not require the use of a pier. This slender arch system is only possible because of high-performance steel and concrete, as well as new theories recognizing the increased strength of confined concrete. The main structural components of the parallel arch system are: tie beams, arch pipes, floor beams, hangers, and deck. The system allows for a minimum structural depth by using the tie beam as a tension tie and the arch pipes as a compression strut. In this way, the moment in the girder is reduced by this tie beam/arch couple.

The critical member is the tie beam. By using a concrete-filled, post-tensioned beam, it was possible to limit the beam depth to only 2 ft. The tie beams are 24-in. by 24-in. box beams fabricated from ½-in.-thick Grade 50W steel. Each beam is filled with 8-ksi high-strength concrete and post-tensioned with 38 fully tensioned 0.6-in.-diameter strands. The tie beam is the most innovative feature of the system. The post-tensioning eliminates the concern over fatigue by keeping the section in net compression during loading.

The arch is the primary compression member in the system. Each arch consists of two 12-in.-diameter, ½-in.-thick extra-strong, ASTM A 500, Grade C steel pipes. The pipes were bent to the proper radius prior to being delivered to the fabricator and are filled with 8-ksi high-strength concrete. There is no transverse bracing connecting the top chords. This is highly desirable for aesthetic reasons. The lack of transverse horizontal braces also provides unlimited overhead clearance. At their peak, the arches are 25 ft. above the roadway grade. The independent arches were accomplished by placing the two concrete-filled pipes parallel to each other with one foot of space between them. This greatly increased the moment of inertia of the arch in the lateral direction, and provided an ideal space for the top connection of the hanger rods. High-strength 1¾-in. threaded rods serve has hangers. The rods extend from a bracket between the arch pipes and pass through the tie beam.

W24×250 Grade 50W wideflange floor beams connect the two tie beams. The floor beams are bolted to double angles, which are in turn bolted to the tie beam. MSC

Owner/Designer/Detailer
Nebraska Department of Roads, Lincoln

Fabricator
Capital Contractors, Inc., Lincoln (AISC Member)

General Contractor
Christensen Bros., Inc., Cherokee, Iowa

The Murray Baker Bridge truss is 180 ft shorter than it was only months ago as a result of the first known cantilevered truss shortening of its kind.

The Murray Baker Bridge carries four lanes of I-74 traffic over the Illinois River in Peoria, Ill. and is 3,250 ft long. Plans for reconfiguring a hazardous interchange on the north end of the bridge were at a standstill, largely because the truss posed a significant site constraint. Shortening the truss was an ideal, yet complex, solution utilizing unique load transfer devices and synchronized operations.

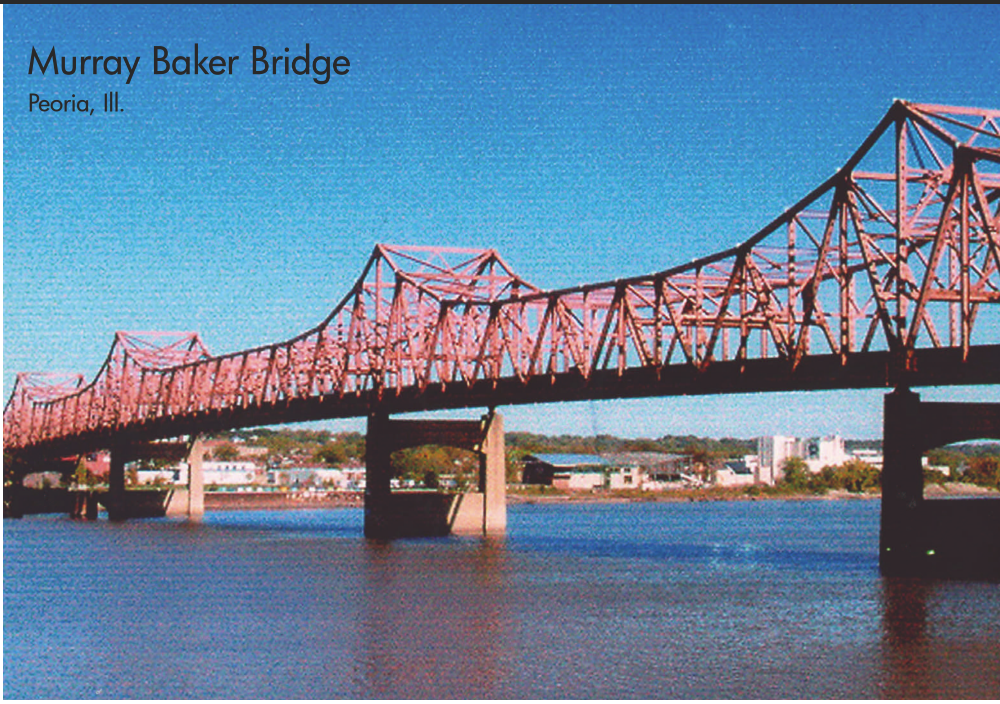
The designer conducted several workshops with the client that addressed all detailed engineering aspects involved with the project. Shortening the truss was the pivotal component of economical bridge rehabilitation, as well as the key to designing an interchange that improved the connection between I-74 and Peoria and also enhanced public safety.

The Murray Baker Bridge project contains several innovative features. The project represents the first known attempt to shorten a cantilevered through truss, making the entire concept and process truly original. The concept of shortening the truss proved to be a unique facet in the rehabilitation of a major structure, as well as an innovative solution where geometric constraints were halting the design progress of a problematic interchange to the north of the truss. Numerous obstacles had to be overcome in order to take the concept of shortening the truss from idea to reality.

In order to accomplish the truss shortening, the designer used a custom-designed load transfer device. This device was designed to be placed on the lower cord of the truss to transfer 2.2 million lb from the truss member so that it could be cut without any load on it. The device was comprised of twelve 150-ksi high-tension steel rods and four 500-ton hydraulic jacks on each of the two trusses that make up the bridge. The high-tension rods were fitted with load cells to monitor the transfer of the load.

Another unusual feat implemented to facilitate the truss work was closing I-74 to traffic for six months. This is the first time in Illinois that a major Interstate has been closed for a significant period of time for this type of work. This was a key factor in allowing work to progress quickly and safely. An incredible amount of traffic analysis and study was required to assure officials that the traffic diverted from the Interstate could be successfully accommodated by the local road system. Additionally, the staged implementation of the reconstruction of the entire 11-mile segment of I-74 was dictated by the shortening of this structure.

The cantilevered trusses have 16 major pins. The pins are 12-in.-diameter, steel cylinders located at four places on the trusses. All pins were completely replaced prior to shortening the truss. The decision to replace the pins was predicated on concerns that, after 50 years, these pins may not have the ability to rotate when the north section of the truss was removed and the entire bridge adjusted, deflected and rotated. Replacing them first gave the assurance that the pins would perform without introducing cracks once the truss was shortened. MSC



Murray Baker Bridge

Peoria, Ill.

Owner/Designer
Illinois Department of Transportation, Peoria

Fabricator
Steward Machine Company, Inc., Birmingham, Ala. (AISC Member)
Industrial Steel Construction, Hodkins, Ill. (AISC Member)

General Contractor/Erector
Halverson Construction Company, Inc., Springfield, Ill. (AISC Member)

Beveridge Suspension Bridge

San Saba County, Texas

Owner
County of San Saba ,Texas

Designer
Texas Department of Transportation, Bridge Division, Austin

The Beveridge Bridge is an historic parallel wire suspension bridge located in San Saba County, Texas on China Creek Road over the San Saba River, just northwest of the city of San Saba.

Built in the late 1800s, the bridge was eventually closed due primarily to the deteriorating main cable. The Texas Department of Transportation (TxDOT), while recognizing the need for a transportation crossing more suitable to the area's agricultural community, also recognized the uniqueness of the historic suspension bridge and developed a plan to preserve it. TxDOT initiated a preservation plan to remove the structure from vehicular service permanently, restore it as nearly as possible to its 1938 condition, and leave it in its original location as a pedestrian access structure.

The Beveridge Bridge is a stayed catenary bridge with parallel wire cables. The suspended span is 133 ft. The ground-anchored cables dated from a 1938 reconstruction, and the site investigation revealed that the cables were severely corroded at the ground line. In addition, approximately 40% of the wires at mid-span were severed from vehicular impact.

The original pier towers dated from 1896. The piers consist of a metal pipe tripod, trussed by a through-bolted framing system designed by the original builder. From contemporary newspaper accounts, the tripod is thought to be founded on a sandstone block footing approximately 18 ft below the ground line. At the ground line the metal pipes exhibited localized pinhole corrosion.

Complete replacement of the main cables was necessary to restore the suspended span. A new cable anchorage was designed to be placed below ground, founded on drilled shafts that straddled the existing anchorage. The straddle cap was designed for torsion and situated so that only the upper surface was out of the ground. Welded steel, cable link plates were attached to the upper surface of the anchorage. This allowed the anchorage to be as visually unobtrusive as the original, but kept the new cables out of the ground and subject to less corrosion.

To stabilize the 1886 pipe towers, concrete footings founded on drilled shafts were designed. The drilled shafts were placed outside the limits of the existing stone footings. The new footings were designed to cantilever from the drilled shafts and wrap around the existing pipe towers. Steel shoes were designed to be welded to the tower legs so as to transmit any added tower load to the new footing. The original piers and footings were left intact and functional through the footing and below the ground line.

A new cable layout was prepared, which allowed the cable and deck stays to be pre-spun as a single prefabricated unit. Sample cables were prepared and tested to verify the ability of the socket to develop the strength of the wire. The cables were spun and banded at a remote location and shipped to the job site. MSC

Wall Street Bridge

Fargo, N.D. / Moorhead, Minn.

The 1960s-era, two-lane, precast concrete Wall Street Bridge—over the Red River of the North between Fargo, N.D. and Moorhead, Minn.—was designed to overtop during major flood events. However, the lightweight, open steel middle span required frequent repairs, and residents complained of the noise it made when vehicles passed over it. County and state officials determined that the bridge was structurally, hydraulically, and geometrically deficient, and made the decision to replace it.

Continuous steel construction provides the geometric and span capabilities to complete the new crossing, maximizing clearance over potential flood elevations, while minimizing approach transitions as well as disturbance to the existing residential areas. The deck profile is a single vertical curve, centered about the middle of the channel. The 12-span continuous steel beam structure, symmetrical about the center of the channel, is proportioned and sited at the original crossing location. Two continuous welded plate girder spans were used over the river, and five continuous spans of rolled steel beams were used for the approaches. Hinged expansion joints separate the approach spans from the main river spans. Eight composite beam lines comprise the superstructure.

During construction, with approximately two-thirds of the beams set, the crossing experienced its third-greatest flood on record. With no interruption to construction, residents and officials were reassured the new bridge would offer a safe crossing even through major flood events.

The 66-ft-wide bridge deck accommodates four lanes of traffic and a walkway/trail. As an interim measure, however, it is striped in a "super two" configuration—a two-lane roadway with center turn lanes.

Completed on schedule and within budget, the new 955-ft-long and 66-ft-wide Wall Street Bridge is comprised of 1,763,201 lb of structural steel; 22,375 ft of steel H-piling; 873,270 lb of reinforcement; and 62,928 sq. ft of bridge deck. MSC

Owner

Clay County Highway Department, Moorhead, Minn.

Cass County Highway Department, West Fargo, N.D.

Designer

Widseth Smith Nolting & Assoc., Inc., Alexandria, Minn.

Fabricator

Roscoe Steel & Culvert, Billings, Mont. (AISC Member)

General Contractor

Industrial Builders, Inc., Fargo, N.D.

MERIT AWARDS

Lincoln Square Sky Bridge

Bellevue, Wash.

The lightweight and open, steel-framed and cable-stayed Lincoln Square Bellevue Way Skybridge in Bellevue, Wash. provides access between Lincoln Square, a new mixed-use facility, and the existing 35-acre shopping center at Bellevue Square. The 11-ft-wide bridge has a trapezoidal shape to provide protection from strong southerly winds and is skewed across the 107-ft span.

The technical challenge for the skybridge structural design was to achieve a thin bridge deck profile that was comfortable for pedestrians. This was accomplished with the following engineering innovations:

➜ To utilize structural steel throughout, the architect selected wide-flange shapes for the built-up "tree trunk" columns as well as the bridge girders and built-up Y-columns. These members are fabricated from steel plates and are tapered and curved to emulate a natural tree shape.

➜ Supporting foundations for the skybridge structure are provided by four deep-founded, 18-in.-diameter augercast piles connected to a concrete pile cap located directly below each trunk column. The pile cap and piles also react to lateral seismic forces by pile bending.

➜ The cantilevered trunk columns taper linearly from the 26-in. by 16-in. base to 6 in. by 6 in. at the mast tops using 1½-in. flange plates and double 1¼-in.-thick web plates. Connection to the concrete pile cap is provided by eight 3-in.-diameter A 588 GR 50 anchor rods.

➜ Since the bridge was designed with the Lincoln Square retail level, all longitudinal seismic forces are delivered through the floor diaphragm and steel chords directly to a single floor coupling connection at the east bridge-building interface. The engineering design employed a pin connection, using a single high-strength 2-in.-diameter bolt, to transmit the 52-kip longitudinal seismic bridge force directly to an existing building drag strut.

➜ Using upturned W21×122 floor girders and a 6-in. deep by 16-gauge steel deck with a 3-in. concrete topping slab furnished the necessary bridge mass and stiffness to control foot traffic vibration and movement with help from 16 stainless steel mast cables attached to the bottom of the W21 girders.

➜ Bridge cables consist of twelve 28-mm forestays and four 36-mm backstays, and are ASTM A316 stainless steel cables with custom Ronstan adjustable turnbuckles.

➜ STAAD Pro 3-D dimensional structural modeling was utilized for the entire bridge and support columns above the pile caps.

➜ The cable stays were designed without a pretensioning requirement and were tightened to support partial bridge dead loads plus full live loads, to suit human comfort and for the bridge dynamic response tuning.

➜ Resistance to transverse seismic and wind forces is provided by the Y-column and bridge diagonal roof pipe framing to deliver transverse forces to the horizontal bridge deck diaphragm, with final distribution to the single tree trunk cantilevered columns located near each end of the bridge. MSC

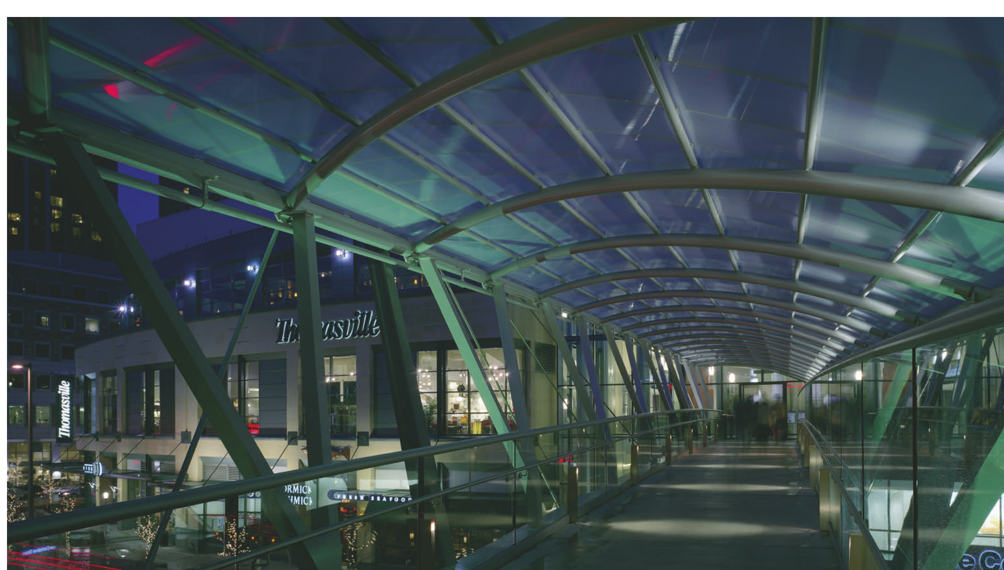
Owner
Kemper Development, Bellevue, Wash.

Designer
Andersen Bjornstad Kane Jacobs, Seattle

Fabricator
Jesse Engineering Company, Tacoma, Wash. (AISC Member)

Detailer
Pacific Northwest Detailing Ltd., Burnaby, B.C., Canada (AISC Member)

General Contractor
Skanska USA Building, Inc., Seattle



Springwater Trail (McLoughlin Blvd.) Pedestrian Bridge

Portland, Ore.

When it came to designing the Springwater Trail Pedestrian Bridge in Portland, Ore., the engineer was tasked with closing the gap in a regional mixed-use trail system located in a major metropolitan area. The key was to develop a unique cost-effective bridge crossing, taking into account the numerous project constraints. The project was highly complex and involved input from a variety of sources, including local neighborhood groups, numerous public agency partners, and other key stakeholders. A principal goal of the project from the outset was to design an attractive and visually appealing bridge that was also sensitive to the context of the local environment.

The final scheme resulted in an innovative tied through arch bridge on the boundary of two adjacent cities, clear-spanning a major six-lane highway with 63,000 cars a day passing beneath.

Slender 18-in.-diameter pipe arch segments across the highway work together with the innovative deck system including steel edge pipes and post tensioning. The span/depth ratio of the arches is L/160, well above the normal range for arch bridges. The arches were fabricated in halves and were set in place on two consecutive nights. Using edge pipes with internal post-tensioning rods allowed use of radial steel bar suspenders. The radial stays allowed the use of a circular function arch, which is not typical. The arches are connected with only two arch braces at one-third points (approximately 70-ft spacing), giving the arches an extremely clean and efficient look.

Post-tensioning (bearing) cables act as a tie for the arches during construction. The bearing cables also act as a tie for live load and serve as an alternative method of erecting the segmental deck panels by sliding them into positions. This method is also applicable to more challenging crossings.

Conventional full-length post-tensioning is placed in the cast-in-place topping slab to stiffen the entire bridge and to provide deck bending resistance to asymmetrical loading on the structure. The cast-in-place portion of the deck is poured using the segmental deck panels as the form.

Steel edge pipes and rod suspenders comprise the simple and elegant hanger system. The suspenders connect to "flying" steel floor beams cantilevered from the deck panels to provide the required path clearance. Connections to both the arch and floor beams are standard AISC clevises, opposite threads top and bottom to allow for adjustment of the deck gradeline during erection.

Finally, steel grating is used to span the gap between the edge pipe and the segmental deck. The protective fencing is placed in the plane of the suspenders to open up the deck area, and the steel rail is cantilevered from the steel bar suspenders to create an enhanced and inviting look to the user. MSC

Owner
City of Portland Parks and Recreation, Portland, Ore.

Designer
OBEC Consulting Engineers, Eugene, Ore.

Fabricator/Detailer
Fought & Company, Inc., Tigard, Ore. (AISC Member)

General Contractor
Mowat Construction, Clackamas, Ore.

Calibration: Meeting Customer Requirements

BY LARRY MARTOF

The dimensional and finish quality of your work is directly related to the calibration of your tools, equipment, and measuring instruments.

CALIBRATION IS ONLY REQUIRED FOR THOSE FABRICATORS, ERECTORS, BRIDGE BUILDERS, AND COMPONENT MANUFACTURERS who desire to meet customer requirements and who desire to meet the highest standards for quality and excellence. Calibration is one of your most customer-facing processes and is one of those wonderful unwritten customer requirements. They expect you to know what an inch is. The dimensional and finish quality of your product is directly related to the accuracy and confidence level of the tools, equipment, and measuring instruments used to produce them.

Let's roll back the clock to a time before calibration standards—a time at which we find that a very powerful customer has commissioned someone to build a boat for him. The customer provided the following dimensions:

300 cubits by 50 cubits by 30 cubits

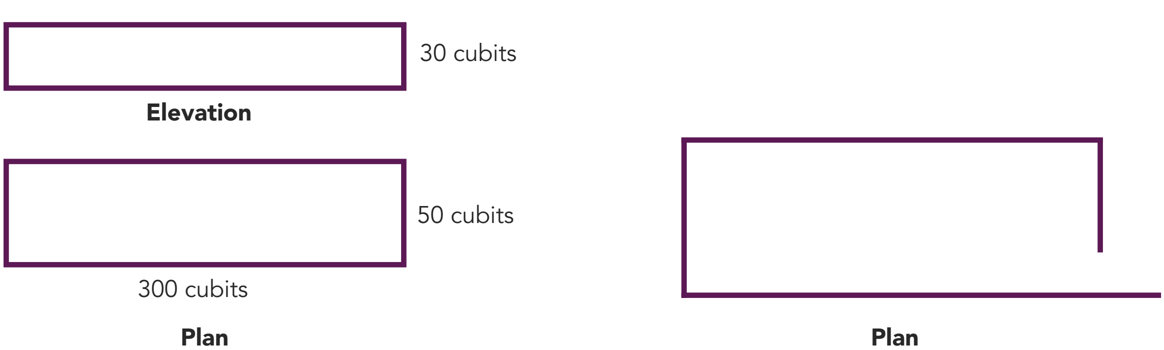
With these directions the fabricator started to plan his build. Let's say he decided that in order to meet the customer's timeline and deliver the product before bad weather set in, he would hire an assistant. He decided that each of them would start in one corner, then work down the side and meet at the other end. He supplied a second set of prints to allow them to work independently. A few days later they met at the other end with a small problem, as illustrated by the figure below.

The immediate reaction, of course, was to begin blaming each other for making the mistake and not being able to measure and count right, etc, etc. The root cause of the problem was that they didn't have a standard to build by. The customer specified dimensions in cubits, which was a normal means of measuring at that time. So if an inch is an inch, isn't a cubit a cubit? Not really. A cubit is equal to the distance from the tip of your middle finger to your elbow. For the average man this is approximately 18 in., but it can range anywhere from 17 to 21 in. Translate this to the dimensions of the boat, then translate the measurements to feet and we get the following range:

475 ± 50 ft. by 78 ± 8 ft. by 48 ± 5 ft.

If you fabricated a bridge, building, or other steel product with this amount of variance, how long would you be in business? Fortunately, the fellow in our story did construct the boat on his own, so using only his arm for measurements everything came out just fine.

Back to this topic of calibration. The National Institute for Standards and Technology (NIST) houses and controls the standards we use for measurement today. They use very controlled environments and very stable materials for these standards. Then, test laboratories create traceable items to the NIST standards and eventually, through the chain of traceability, we get accurate tape measures, squares, levels, lasers, and other measuring tools of the trade. And in the modern world of steel fabrication and construction, the dimensional tolerances continue to become tighter and tighter—hence the need for well-implemented and maintained calibration programs. These requirements are described in the AISC *Standard for Steel Building Structures* in element 14 and in ISO9001 in clause 7.6.



Customer Drawing

As-built Drawing

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**.

Best practices to keep your customers satisfied and to keep your confidence level high in regards to calibration:

- ➜ Calibrate new tape measures against a certified master at full length to ensure there are no printing or manufacturing defects, and then put a process in place to periodically check for damage to the sliding end and general condition.
- ➜ Using your master tape, calibrate your squares using the 3-4-5 triangle rule.
- ➜ Create a design drawing for a test piece, such as a beam line or drill line, that can be fabricated on your computer control equipment. Create a spreadsheet of the dimensions on the test piece drawing. Run the test piece, measure it with your master tape, and record the results on the spreadsheet. Perform this test piece process quarterly and compare the readings in the spreadsheet to watch for indications of drift or wear. Make the appropriate adjustments or use the information to guide the factory technicians in making adjustments and repairs.
- ➜ Have electronic test equipment—such as amp/volt meters for testing welding equipment, ultrasonic tester, vibration analyzer, etc.—calibrated by a certified calibration lab annually and require them to provide a report of the test results for the as-received and as-returned data. This information will assist in determining any drift that may require a shorter calibration frequency.
- ➜ Be sure to include dry film thickness gauges, weld gauges, welding equipment, and other equipment that is used to provide evidence of product conformity in your calibration program.
- ➜ Expand your calibration program beyond inspectors.

Two common myths surrounding calibration deserve a closer look:

Myth #1

We don't do calibration, we verify. Well, by definition verification is the process used to examine and prove the accuracy or correctness, and calibration is the act of verifying and adjusting the accuracy of a measuring instrument. So calibration begins with verification, which may lead to adjustment and verification of the adjustment. One could say that calibration begins and ends with verification. One caveat to this is that under automotive and aerospace standards (TS16949 and AS9100, respectively) calibration can only be performed by a certified lab. For those of you that are looking into these industries, be sure you inquire whether or not your work will come under either of these very stringent standards. For the rest of us, we can perform our own calibration with traceable NIST standards. But we do need to ensure the accuracy of our standards, sometimes referred to as "masters," by having them periodically certified by a qualified test lab.

Let's look at pre-installation verification (PIV) for the bolting process. The purpose of this is to verify that the fastener assemblies and also the pretensioned procedures perform as required prior to installation through lot testing. Typically we use a lab-certified tension calibrator (Skidmore is one brand name, e.g.) to perform the acceptance testing of the lot of bolts per our written procedure. The tension calibrator is our standard or "master," and we verify that it has a current calibration certificate. Likewise, we may use our calibrated "master" volt/amp meter to verify the output of welding meters.

Myth #2

Software calibration is stupid. Well, it isn't really, when done properly. Calibration of software is performed during the software development life cycle (SDLC) in the verification and validation phases. Software calibration is done by following very strict test scripts using validation tools and programs approved through a predefined testing protocol. When you purchase commercial software programs (often referred to as COTS—commercial off the shelf) you are paying indirectly for all of this testing, and the software can be considered calibrated with no need for any further calibration. If you decide to begin writing software code and developing your own programs, then you will need to do a lot of research into SDLC.

"But what if I made a really slick program in Excel and it does all sorts of very critical calculations?" First and foremost, all you have done is manipulated functionality already present in the software and created a spreadsheet or workbook. The software is calibrated and will remain intact. As for the equations you have created, one could say "garbage in, garbage out!" You need to verify that you are getting the desired result, but know that this is not software calibration. So your CAD, Excel, Access, Fabtrol, Steel 2000, or other purchased software does not require calibration. If you are using tools such as Visual Basic to enhance your software solution capabilities, then you should also create some basic test scripts to verify that your manipulations are providing the desired result as a part of your design process. Using clause 7.3 of ISO 9001:2000 "design and development" as a reference may assist in this process. If you use and document a controlled design process, you can avoid any non-conformances with the AISC *Building Standard* section 7.1.3.1 because your design will have covered all of the bases.

Let's return to the customer-facing side of calibration. Maintaining a well-documented and defined process for measuring equipment will ensure that you are meeting customer requirements for dimensional and finish tolerances. It also gives you the ability to proactively resolve defects that may occur from out-of-tolerance measuring equipment by knowing what product was measured and what was used to measure it. Keeping control of all measuring devices in the shop will ensure a high confidence level and allow for more advanced quality methods, such as in-process inspection and quality assurance, and will help you move away from 100% quality control inspection—thereby reducing costs, increasing confidence, and driving accountability and ownership in the product and process. These are the key building blocks to advanced techniques of "Lean Six Sigma" (a business improvement philosophy that results in faster output with better quality), but we will save that for a later article. MSC

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

Low Floor Heights: The Low-Down

BY ERIKA WINTERS-DOWNEY, S.E.

There are several practical options for reducing floor-to-floor heights.

A COMMON INQUIRY TO THE AISC STEEL SOLUTIONS CENTER IS: "How can we reduce the floor-to-floor heights of our structures without sacrificing open, flexible floor designs?"

Minimizing the structural depth at each level translates into an overall savings in building height. If you can save 6 in. per floor on a 20-story building, this turns into 10 ft of savings on building cladding, plumbing risers, and vertical mechanical chases. Ten feet of savings is equivalent to knocking a whole story out of a building. If an owner can fit 11 stories of rentable space into the height traditionally reserved for 10 stories, their profit has just risen by 10%.

In addition to providing low structural depths, the systems described below also bring the traditional advantages that structural steel adds to a project: speed, sustainability, and quality control of shop fabrication.

Staggered Truss

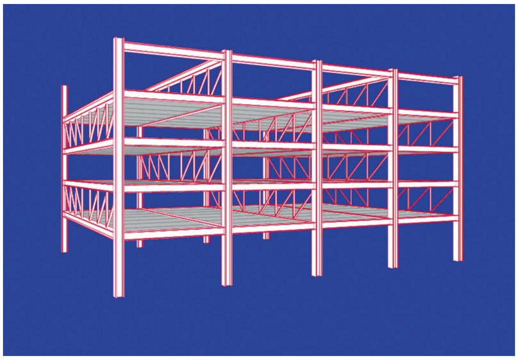
A staggered truss system uses story-high trusses spaced in alternate bays to carry gravity and, in most cases, lateral loads. The truss spans the entire width of the building, often 60 to 75 ft. As a gravity system it works similar to the beam-in-wall system (discussed later), with trusses running in demising walls between residential units. Plank spans between trusses and is supported at one end by the top chord of a truss and at the other end by the bottom chord of a truss. In this pattern, 60-ft-wide column-free spaces are achieved.

Vierendeel panels, traditionally in the center of the truss, allow openings for a central hallway corridor. This system is applicable in buildings that have a uniform room layout, such as hotels, dormitories, apartments, and condos. It has been applied in rectangular, L-shaped, and square buildings with a central atrium. It has also been applied in buildings that arc in plan. The cost-effectiveness of this system improves based on the level of repetition that can be achieved. A good rule of thumb is that there should be about 20 uniform trusses to consider using the system for a project.

A huge competitive advantage of this system is that it provides a base level with no interior columns. This means that areas like ballrooms and meeting spaces can be accommodated with no transfer beams. The fact that there are no interior columns means that there is a significant reduction in the number of foundations required and the cost associated with them. Erection is speedy because the trusses are set, then the plank is set, and so on. The staggered truss system is a completely dry system and can be erected in any type of weather.

Beam-in-wall: Economical, Speedy, Flexible

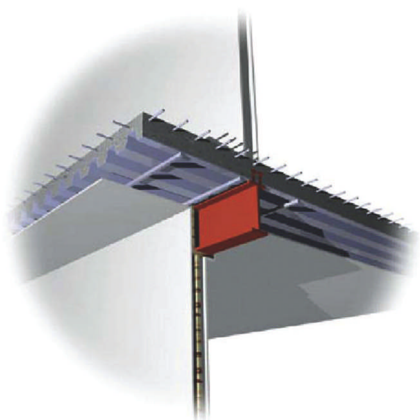
The system we refer to as "beam-in-wall" refers to running beams in demising walls between rooms, with precast plank or metal deck slabs spanning between beams. The demising wall may need to soffit around the beam. This system is a straightforward way to achieve a minimal structural depth; because beams are buried in the demising walls, the



Schematic view of the staggered truss framing system.

Column-free lower level.

Erika Winters-Downey is an advisor in AISC's Steel Solutions Center.



Beam-in-wall system.

depth of the floor slab is the only structural depth that needs to be accommodated.

This system is flexible if your room layout isn't exactly uniform or symmetric across a hallway. It can be applied in situations where the building layout isn't regular enough to use the Girder-Slab or staggered truss systems.

Room layout and spacing often dictates which type of floor slab to use. A main consideration is whether to have the slab span from demising wall to demising wall or from perimeter to corridor. Spanning from perimeter to corridor creates a very flexible, open space if your room layouts are irregular. In addition, the corridor can usually be spanned only with deck. This provides plenty of plenum space to run utilities down the corridor, which usually has a lower ceiling height than the rooms. If the plank will span from demising wall to demising wall, perimeter beams may only be necessary for erection and can often be removed afterward. This helps avoid spandrel beams and the soffits they create.

If your project will use plank flooring, it is helpful to speak with your plank provider. Do they feel that they can provide you with carpet-ready plank or do they usually recommend a skim coat? How will you attach the façade of your building to the plank? September's SteelWise article "Let's Be Plank..." (**www.modernsteel.com**) is very helpful in identifying things to consider when designing with plank.

Long-span Deck

The availability of long-span deck has increased greatly over the past few years. Manufacturers like CSI, Epic, United, and Corus all produce a deep, long-span deck available within a 4- to 5-week lead time. It usually comes in depths of 4.5 in. or 6 in. and sometimes can go up to 7.5 in. deep. CSI produces "Deep-Dek". It is available in gauges from 20 to 14. Based on continuous slab design, the 6-in. deck in 14 gauge material with 5 in. of normal weight cover can span about 19 ft unshored and about 35 ft with one row of shoring. United Steel Deck produces type "LS". Type LS is available in depths up to 7.5 in. and gages from 16 to 10. Type LS 7.5 in 10 gauge material can span about 25 ft unshored based on single-span conditions with normal-weight concrete and a 10.5 in. total slab thickness.

Many of these products have been vibration tested according to the guidelines of AISC's Design Guide 11, *Floor Vibrations due to Human Activity*. There are also UL fire ratings for assemblies using these decks. Speak with your deck provider to plan the specific details of your project.

Girder-Slab

Girder-Slab is a patented system, available through all structural steel fabricators, that uses dissymmetric beams (D-Beams) that carry precast plank on their bottom flanges. The D-Beams come in 8-in. or 9-in. depths. The sections are produced from "parent" sections (W10s or W12s) that are sliced in half through the web in a hexagonal pattern to form two equal T-sections. A 3-in.-wide bar is used to form the top flange. Traditionally, 9-in.-deep D-beams are for plank systems that require a structural topping. Eight-inch D-beams are usually sufficient for plank systems that only require a nominal skim coat topping or no topping. By resting the plank on the beams' bottom flanges, the whole structural depth is incorporated into D-Beam depth.

The beams are designed to develop composite action between the planks and grouted cells. Once the planks are erected on the beams, they are grouted into place. Grout flows through the openings in the web of the beam and into the hollow cores of the plank before it solidifies.

The precast plank slab can span either parallel or perpendicular to the perimeter of the building, and each has its own advantages. When plank spans parallel to the perimeter, D-Beams run in demising walls between residential units. Spandrel beams can often be removed after they are used for erection purposes. Because of this, true floor-to-ceiling windows can be achieved if this is a priority for your project. When plank spans perpendicular to the perimeter (spandrel beam carries plank load), beams will run along the perimeter and corridor walls. This provides truly open space between units and is helpful if the units in your building are not laid out regularly. The system is UL certified (Design K912) for fire with spray-on or board assemblies. A typical D-Beam spans 16 ft to 20 ft and can be increased to 24 ft with the use of tree columns. With precast plank spanning an average of 28 ft to 30 ft, bay sizes of about 20 ft by 30 ft are usually efficient.

This system reduces and sometimes eliminates soffits. It is optimum in regularly laid-out condo, hotel, or dormitory structures. Any steel contractor can become authorized to distribute the Girder-Slab system. MSC

Girder-Slab system.

Vendor Contact Information

Girder-Slab
www.girder-slab.com

CSI
www.metaldek.com

United Steel Deck
www.njb-united.com

Epic
www.epicmetals.com

Corus
www.corusconstruction.com

Unobstructed ceilings with Girder-Slab system.

products

BRIDGE PRODUCTS

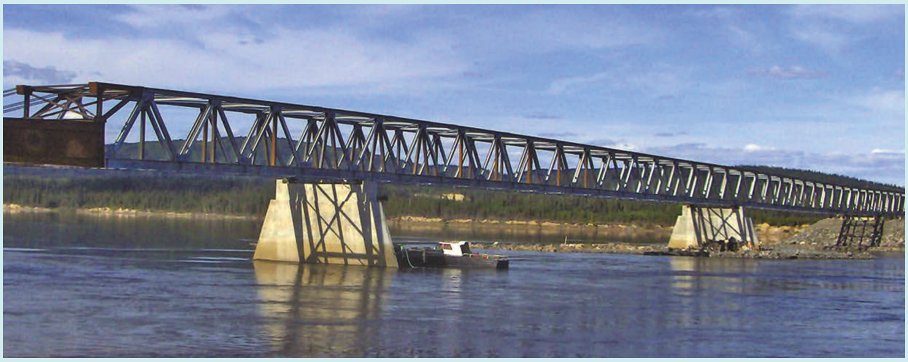
	Company	Products Offered	Product Description
	American Galvanizers Assn. www.galvanizeit.org 800.HOT.SPEC	Industry association	Get free downloads of technical publications from AGA's web site, including a specifiers' guide to galvanized rebar, bridge project application reports, hot-dip galvanized steel design guides, and more. Get toll-free technical support for all of your specifying needs. Get information on all types of hot-dip galvanized bridge products, such as fasteners and reinforcing steel.
	Applied Bolting Technology www.appliedbolting.com 800.552.1999	ASTM F959 direct tension indicators	Made for use with A325(M), A490(M), and non-structural applications. DTIs are designed to indicate minimum required bolt tensions regardless of torque. Bolt tension is checked with a feeler gage.
		Squirter DTIs	Made in accordance with ASTM F959. Resolve bolting issues once and for all. All by eye, know the bolts are tight without match-marking, torque wrenches, or feeler gages. Ironworkers know the bolts are tight by squirt alone.
		Field bolting technical services	Start your next job off right with a proactive approach to field bolting. Job-site training covers storage, pre-installation verification, installation means, and inspection. Keep bolting off the critical path.
WSBS	Atema www.atemainc.com 312.861.3000	Quality assurance programs	Atema provides detailed, custom supply chain management assessment programs for bridge owners to ensure quality of fabricated structural steel products.
WSBS	BendTec www.bendtec.com 218.722.0205	Various products and services	Services: engineering, hot and cold bending, welding, machining, blasting and painting, and non-destructive examination. Products: roof trusses, parabolic arches, Vierendell trusses, long-radius bends, light/power poles, signs, bridge arches, and window mullions.
	Bridge Diagnostics, Inc. www.bridgetest.com 303.494.3230	Testing and analysis	In addition to testing and analysis services, we supply bridge testing hardware such as the new STS WiFi Wireless Structural Testing System, the BDI Long-Term Monitoring System, the BDI Bridge Fatigue Monitoring System, and the BDI ClearanceMaster—which is designed for automatically measuring overhead clearances.
WSBS	Bridge Grid Flooring Manufacturers Association www.bgfma.org 877.257.5499	Industry association	The Bridge Grid Flooring Manufacturers Association (BGFMA) is an industry group comprised of companies who fabricate steel grid deck systems for bridges and other companies with an interest in this market. The role of the BGFMA is to promote the use of steel grid decks through data collection, research/development, and education to bridge design engineers and owners as a time-tested, prefabricated deck solution that accelerates construction.
WSBS	Bocad Service International S.A. www.bocad.be +32.86.34.91.91	Software	Bocad is a 3D CAD/CAM solution dedicated to the structural steel and other material industries. It is able to answer all demands within designing, detailing, and manufacturing of steel structures.
WSBS	Clodfelter Bridge www.cbsiusa.com 713.675.1180	Castings, sockets, cable clamps	Alloy steel bridge castings, structural strand sockets, main cable clamps, tower saddles, special designed castings, bridge forgings, etc.
	CMC Joist and Deck www.cmcjd.com 908.277.1617	Bridge form deck	2-in.- and 3-in.-deep steel deck with various pitches and yield strengths, 16 ga maximum thickness. Some profiles are available with factory-closed ends. Galvanized finishes are G165 and G235.
		Long-span bridge deck	Deep bridge steel deck profiles in 4.5-in., 6-in. and, 7.5-in. depths. Finishes include G165 and G235 galvanizing, 10 ga maximum metal thickness, and 40 ksi yield strength.
WSBS	Computers & Structures, Inc. www.csiberkeley.com 510.649.2200	SAP2000 Bridge Modeler	The SAP2000 Bridge Modeler offers sophisticated 3D parametric bridge modeling tools seamlessly integrated with SAP2000's comprehensive analysis and design software, allowing for the rapid generation of large and complex bridge models.
	CONTECH Bridge Solutions, Inc. www.contechbridge.com 800.526.3999	CONTECH Bridge Plank	For deck rehab and new construction, CONTECH Bridge Plank is available in 6-in. x 2-in., 9-in. x 3-in., and 12-in. x 4-¼-in. corrugations. CONTECH Bridge Plank serves as the structural members supporting the asphalt concrete paving. Positive welded connections provide a rigid panel construction that helps stiffen the entire structure. The deck becomes an integral part of the bridge. Rattling of loose members under traffic is eliminated.
WSBS	The D.S. Brown Company www.dsbrown.com 800.848.1730	Steelflex, Versiflex, Cableguard, Fiberbond	D.S. Brown's extensive product line includes: Steelflex Modular Expansion Joint Systems, Versiflex Bearing Assemblies, Cableguard Elastomeric Wrap, Exodermic Bridge Deck, Fiberbond FRP (Fiber Reinforced Polymer) System, and other specialty products.
WSBS	IMPACT www.impact-net.org 202.393.1147	Industry association	The Ironworker Management Progressive Action Cooperative Trust is a Labor-Management Taft Hartley Trust whose primary mission is to expand opportunites for union ironworkers and their signatory contractors through progressive and innovative labor management cooperative programs.
	LeJeune Bolt Company www.lejeunebolt.com 800.872.2658	Structural fasteners	The largest inventory of structural fasteners including A325/A490 tension control bolts (plain, MG, Type 3), A325/A490 heavy hex bolts (plain, MG, Type 3), A307 hex bolts, DTI washers, and nuts.
		Tools and equipment	New and rental tools for steel fabrication and erection including electric and pneumatic shear wrenches, Torqon wrenches, Pro-Weld stud welding equipment, Mag drills, parts, accessories, and repair services.
		Stud welding products and equipment	Headed weld studs, deformed bar anchors, threaded studs, electric arc and capacitor discharge stud welding equipment, rental equipment, parts, and accessories.
		Anchoring products	Redhead and Powers anchoring systems in stock. Mechanical anchors include wedge and sleeve anchors, HD screw anchors, and bent anchor bolts. Chemical anchors include acrylic and epoxy adhesives, capsules, dispensing tools and accessories, and threaded rod cut to length.
	Lincoln Structural Solutions www.lincolnstructural.com 800.571.6884	Commercial grade structural fasteners	ISO 9001:2000 certified distributor of structural bolts, nuts, washers, load indicating washers, tension control bolts, expansion anchors, and all-thread rod. Available plain, Type 3, mechanically and hot-dip galvanized, and zinc plated.
		Nuclear certified structural steel and fasteners	Steel pipe, bar, tubing, sheet, plate, rod, shapes and fasteners compliant to NQA-1, ASME Section 3 NCA-3800, ANSI N45.2, 10 CFR Appendix B, and 10 CRF 21.
WSBS	LUSAS www.lusas.com 800.97.LUSAS	LUSAS Bridge	Fnite element software for the analysis, design, and load rating of all types of bridges. Used on major structures worldwide, LUSAS Bridge solves all types of linear and nonlinear stress, dynamics, composite, fatigue, buckling, thermal, or soil structure interaction analysis problems.

	Company	Products Offered	Product Description
WSBS	**MDX Software** www.mdxsoftware.com 573.446.3221	Bridge software	The MDX Software Curved & Straight Steel Bridge Design & Rating package for steel bridge girder design and rating according to AASHTO ASD, LFD, and LRFD specifications.
WSBS	**Nucor Fastener Division** www.nucor-fastener.com 260.337.1600	Structural bolts	Nucor Fastener manufactures high quality ASTM A325, A325M, A490, and A490M structural bolts from 100% domestically melted and rolled material with certifications provided from our A2LA accredited laboratory.
		Structural nuts	Nucor makes ASTM A563 Heavy Hex structural nuts from ½-in. to 1-in. sizes in Grades C, C3, DH, and DH3 from 100% made in the USA materials.
		Tru-Tension structural assemblies	Tru-Tension assemblies are made to meet dimensional requirements per ASME B18.2.6 and mechanical requirements per ASTM F1852 (A325) or F2280 (A490) specifications in 5/8-in. to 1 1/8-in. diameters.
		Type III structural fasteners	Nucor offers structural fasteners made from alloy steel containing copper, chromium, and nickel to provide the desired weathering properties—all 100% made in the USA.
WSBS	**R.J. Watson** www.rjwatson.com 716.691.3301	Bearings, expansion joints, bridge deck, etc.	R. J. Watson designs, manufactures, and markets bridge bearings, seismic isolation devices, expansion joints, waterproofing membranes, FRP bridge decks, FRP bridge girders, and externally bonded FRP systems.
WSBS	**Robert W. Hunt Company, a Bureau Veritas Company** www.us.bureauveritas.com 888.CWI.WELD	Inspection services	Robert W. Hunt Company provides quality assurance and inspection services associated with the procurement of engineered equipment and materials for the water Industry.
WSBS	**Stinger Welding** www.deckjoint.com 520.723.5383 480.987.1630	Bridge components	Expansion members : strip-seal joints, compression-seal joints, modular joints, and finger joints. Bearings: rockers, slides, and pads. Railing: barrier, decorative structural, pedestrian, industrial, and commercial. Platforms, grates, frames, drains, etc.
		Bridges	Fracture-critical, vehicular, rail, light-rail, highway, community, utility, pedestrian, decorative, and specialty bridges.
		Bridge services	Design, fabrication, repairs, and upgrades.
WSBS	**Structal-Bridges, a division of Canam Group, Inc.** www.structalbridges.ws 877.304.2561	Bridges, bearings, expansion joints	Structal-Bridges is a leading manufacturer of steel bridges, structural bearings and expansion joints for the highway, railway, and forestry industries.
	Taylor Devices, Inc. www.taylordevices.com 716.694.0800	Fluid viscous dampers	Supplemental devices used in structures to dampen the vibrations caused by earthquake shaking, wind vibration, or other structural excitation. Forces and deflections are simultaneously reduced by out-of-phase response of device.
		Shock transmission units (STU/LUD)	These devices are used in structures to transmit dynamic forces from one portion to another, by providing large resistance to dynamic input. They provide little resistance to slow inputs (thermal expansion). Units function like a seatbelt.
		Cable dampers	These devices are used to dampen cables on cable-stayed bridges from rain/wind induced vibrations. Dampers can be designed to provide hurricane protection for the cables supporting the deck.
		Tuned mass dampers (TMD)	Devices comprised of mass, springs, and dampers. These devices can counteract motion and provide damping in large span structures where there is no alternative to attach direct acting fluid viscous dampers to a fixed reaction frame.
WSBS	**ThyssenKrupp Safway, Inc.** www.safway.com 262.523.6500	Scaffolding	With more than 80 branch locations throughout North America, ThyssenKrupp Safway, Inc. has been an industry leader in scaffold services since 1936. As a one-stop supplier, we offer scaffold rental, sales, delivery, labor services, engineering, training, inventory, and project management assistance. Our QuikDeck Suspended Access System is a revolutionary product used on hundreds of bridges nationwide to provide access to unconventional locations. ThyssenKrupp Safway is a subsidiary of ThyssenKrupp AG, an international technology group with more than 184,000 employees in 70 countries.
	Voigt & Schweitzer www.hotdipgalvanizing.com 614.449.8281	Galvanizing services	Six galvanizing plants, all ISO 9002 certified. Specializing in corrosion protection of steel with zinc by hot-dip galvanizing. The DUROZINQ program of packaging, tagging, and galvanizing is popular with fabricators in the Midwest and Northeast.
		DUROZINQ	A hot-dip galvanizing system that encompasses the toughest abrasive-resistant surface to fight corrosion and includes the added benefits of on-time delivery, guaranteed service, packaging, and shipping.
		COLORZINQ	A system that adds brilliant color to a base of corrosion protection. Preferred by architects and fabricators for over 30 years.
	Voss Engineering, Inc. www.vossengineering.com 800.323.3935	Expansion and fixed bearing products	Expansion and fixed bearing products. Specializing in SORBTEX-based (CDP/preformed fabric pad/ MIL-C-882E) structural bearing solutions.
WSBS	**Westfall Co., Inc.** www.westfallcompany.com 636.938.3113	Deck drains	Fiber-glass deck drains for bridges and elevated roadways.
WSBS	**Wheeling Corrugating Co.** www.wheelingcorrugating.com 304.234.2326	Metal deck	A leading fabricator of roll-formed products for residential, agricultural, construction, highway, and bridge building markets. Wheeling Corrugating offers bridge form, a heavy duty steel system for forming concrete bridge deck slabs quickly, safely, and economically. Permanent metal bridge forms from 2 to 4.5 in., accommodating girder spacings up to 14 ft, are fabricated to individual project specifications from high-strength, galvanized steel.
WSBS	**Wire Rope Corp. of America** www.wrca.com 816.233.0287	Wire rope structural assemblies	WRCA supplies the wire rope structural assemblies for bridges around the world. Suspension cables, hand ropes, and tie-down assemblies are but a few of the components available from WRCA to make today's bridges safer, longer lasting, and more economical.

WSBS denotes that the company is an exhibitor at the 2007 NSBA World Steel Bridge Symposium in New Orleans, December 4-7. Visit **www.steelbridges.org** for more information.

project case study

American Galvanizers Assn.—Churchill River Bridge, Goose Bay, Newfoundland, Canada



LONGEVITY IN THE SUB-ARCTIC ENVIRONMENT. No maintenance requirement for 50 or more years. A severely limited construction season. And the ability to withstand an abrasive installation technique. These are just four of the many reasons the Trans Labrador Highway chose hot-dip galvanizing to protect the Churchill River Bridge in Goose Bay Labrador, Newfoundland, from corrosion. Linking the giant hydroelectric projects in the interior of Labrador with the coast at the Strait of Belle Isle and the ferry connection to Newfoundland, the Bailey-style, cantilever bridge was assembled on land and then pulled over the river with special-purpose machinery. Only a hot-dip galvanized coating with intermetallic layers harder than the substrate steel is suitable to meet the demands of such assembly methods.

Over 2,000 tons of steel were galvanized in just over a month to meet the tight delivery and erection schedule. This includes the deck steel, railings, and structural steel. The bridge is comprised of three spans in excess of 400 ft each, as well as about one-half mile of approach causeways.

Significant in specifying hot-dip galvanizing was the desire for the bridge's appearance to complement the natural environment without compromising it. The naturally dulling and varied pattern of a galvanized coating blends much better into the wild, natural environment than monotone paints, and since it requires no maintenance, there is no blasting medium and harmful paint chips to contaminate the waters of the pristine river below.

Hot-dip galvanizing is uniquely suited to protect the Churchill River Bridge and ensure this important facet of the Trans Labrador Highway will be functional and maintenance-free for many years.

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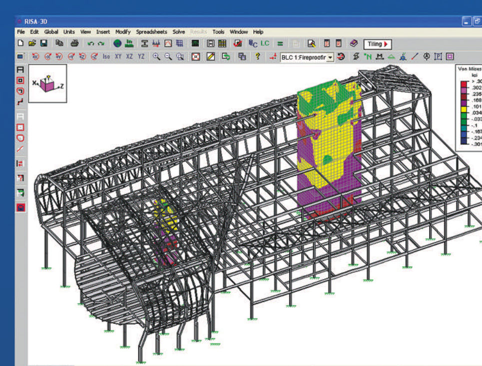

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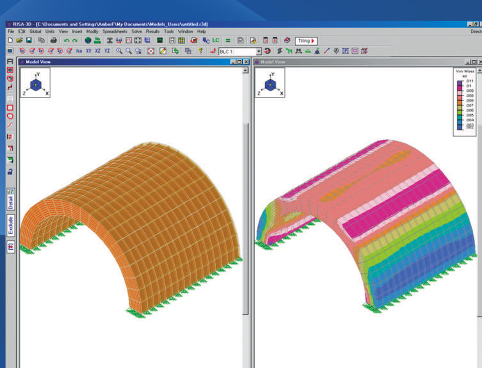

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