news & events

INDUSTRY RESOURCES

A New HSS Resource

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

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

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

DESIGN COMPETITION

2007 Blind Analysis Contest

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

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

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

letters

Not in the Spec?

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

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

Andreas Paraschos, P.E.

The author responds:

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

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

Matt Johnson, P.E.
Senior Project Engineer
TranSystems

SPECIFICATIONS

Revised ASTM Spec Opens the Door for Hot-formed HSS

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

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

A "New" Spec

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

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

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

Hot-forming

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

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

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

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

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

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

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

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

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

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

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

High-profile and Hot-formed

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

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

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

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

ENGINEERING JOURNAL

Second Quarter 2007 Article Abstracts

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

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

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

This paper presents the development and recent applications of 31.8-mm (1¼-in.) studs to steel girder bridges. The new studs have double the cross-sectional area of 22.2-mm (7/8-in.) studs, resulting in a reduction of the number of studs needed to achieve full composite action with the concrete deck by 50%. Use of the 31.8-mm (1¼-in.) studs has many advantages: (1) increase of fabrication and construction speed, (2) ease of deck construction, (3) ease of deck removal, and reduction of damage to studs and girder top flange during that removal, and (4) enhancement of the safety during construction because more space on the top flange is available for walking. Experimental investigation of the 31.8-mm stud showed that the stud fatigue and ultimate capacities can be conservatively determined using current AASHTO bridge specifications to achieve full-composite action.

Topics: Beams and Flexural Members, Bridges, Composite Construction

Seismic Performance of a 62-story Steel Frame Hotel Tower

ERIC M. HINES AND RICHARD A. HENIGE

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

Topics: Seismic Design, Structural and Buildings Systems

Improving the Seismic Stability of Concentrically Braced Steel Frames

ROBERT TREMBLAY AND LAURE PONCET

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

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

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

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

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

Topics: Connections-Simple Shear, Research, Analysis

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

MUSTAFA MAHAMID, ADEEB RAHMAN, AND AL GHORBANPOOR

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

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

Topics: Connections-Simple Shear, Research, Analysis

Graphical Design Aid for Beam-Columns (LRFD)

VINOD HOSUR AND BINSON AUGUSTINE

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

Topics: Beams and Flexural Members, Columns and Compression Members, Combined Loading

Current Steel Structures Research

REIDAR BJORHOVDE

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

Topics: Research