HSS Design with the Latest Codes and Material Specifications

Kimberley Olson, PE
Technical Consultant to the Steel Tube Institute
Topics

Uses
Materials
Availability
Connections
Structural members have been around for centuries. They’ve been used as flexural load carrying members...as columns and beams in huts and housing...and for scaffolding.

Galileo studied structural members in the 15th century. He called them “hollow solids” and analyzed specific examples from nature — the stems of flowers...the bones of animals...bamboo...structural members which are lightweight and flexible, yet strong.
Compression

No weak axis - great for columns
Torsion

Torsional constant of an HSS is $\approx 200$ times that of an open section

HSS

Wide Flange
Torsion
Torsion

Example:
Beam length 30’
torsional load 1.2 ft-k/ft

W18x35 $\theta = 2.41$ rad

HSS12x6x5/16 $\theta = 0.0063$ rad
Blast Loading

HSS are good blast resistant members

- direction of loading
- higher torsional rigidity
- composite HSS members
Manufacturing Process

Two processes:

- Electric Resistance Welding (ERW)
  - Weld - Round, Form - Square Process (continuous forming)
  - Form - Square, Weld - Square Process (direct forming)
- Submerged Arc Welding (SAW)
Manufacturing Process

All starts when steel coils are split into proper widths
Weld - Round, Form - Square
Form - Square, Weld - Square
Submerged Arc Welding
HSS Materials

A500
A1085
A1065
A847
A53
A252
ASTM A500

...has been around since the late 70’s
11.2 Wall Thickness—The minimum wall thickness at any point of measurement on the tubing shall be not more than 10% less than the specified wall thickness. The maximum wall thickness, excluding the weld seam of welded tubing, shall be not more than 10% greater than the specified wall thickness. For square and rectangular tubing, the wall thickness requirements shall apply only to the centers of the flats.
# The 0.93 Reduction

<table>
<thead>
<tr>
<th>Spec</th>
<th>Design wall thickness</th>
<th>Supporting Manual</th>
<th>Designation</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989 ASD (1)</td>
<td>( t_{nom} )</td>
<td>9th Ed. ASD</td>
<td>TS</td>
<td></td>
</tr>
<tr>
<td>1986 LRFD</td>
<td>( t_{nom} )</td>
<td>1st Ed. LRFD</td>
<td>TS</td>
<td></td>
</tr>
<tr>
<td>1993 LRFD (2)</td>
<td>( t_{nom} )</td>
<td>2nd Ed. LRFD</td>
<td>TS</td>
<td></td>
</tr>
<tr>
<td>1997 HSS (LRFD)</td>
<td>( 0.93 \times t_{nom} )</td>
<td>NA (4)</td>
<td>HSS</td>
<td>Supplement to the 1993 LRFD Spec.</td>
</tr>
<tr>
<td>1999 LRFD (2)</td>
<td>( 0.93 \times t_{nom} )</td>
<td>3rd Ed. LRFD</td>
<td>HSS</td>
<td>Supplement to the 1999 LRFD Spec.</td>
</tr>
<tr>
<td>2000 HSS (LRFD)</td>
<td>( 0.93 \times t_{nom} )</td>
<td>3rd Ed. LRFD</td>
<td>HSS</td>
<td></td>
</tr>
<tr>
<td>2005 (AISC 360-05)</td>
<td>ERW: ( 0.93 \times t_{nom} )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SAW: ( t_{nom} )</td>
<td>13th Ed.</td>
<td>HSS</td>
<td></td>
</tr>
<tr>
<td>2010 (AISC 360-10)</td>
<td>ERW: ( 0.93 \times t_{nom} )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SAW: ( t_{nom} )</td>
<td>14th Ed.</td>
<td>HSS</td>
<td></td>
</tr>
<tr>
<td>2016 (AISC 360-16)</td>
<td>A500: ( 0.93 \times t_{nom} )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A1085*: ( t_{nom} )</td>
<td>15th Ed.</td>
<td>HSS</td>
<td>* also includes A1065</td>
</tr>
</tbody>
</table>

Notes:
1. Includes previous ASD specifications and Manuals. HSS was not specifically covered in all of these specifications or manuals
2. The reduction is included by using the appropriate separate HSS Specification
3. Applies when the actual thickness of the wall is not known
<table>
<thead>
<tr>
<th></th>
<th>Yield Strength</th>
<th>Wall Thickness tolerance &amp; Mass tolerance</th>
<th>Corner Radius</th>
</tr>
</thead>
<tbody>
<tr>
<td>A500</td>
<td>hold on, i have to look it up... ranges from 33-50 ksi</td>
<td>± 10% no mass tolerance</td>
<td>&lt; 3t</td>
</tr>
<tr>
<td>A1085</td>
<td>50 ksi min, 70 ksi max</td>
<td>-5%, +10% -3.5%, +10%</td>
<td>t≤0.4” 1.6t - 3t t&gt;0.4” 1.8t - 3t</td>
</tr>
</tbody>
</table>
The 0.93 Reduction

ASTM A1085

- 0.93 factor not required!!
- Not in AISC 360 yet but has been published in *Modern Steel*
- AISC 360-16 draft includes A1085 and does not require thickness reduction
Strength Comparison

Compressive strength: HSS6x6x3/8, kL = 14’

A500 GrB

F<sub>y</sub> = 46 ksi
\( \phi P_n = 153k \)

0.93 \( \times t_{\text{nom}} \)

A1085

F<sub>y</sub> = 50 ksi
\( \phi P_n = 172k \)

12% increase

\( t_{\text{nom}} \)
ASTM A1085

$R_y$ values will go down

$$R_y = \frac{\text{actual yield}}{\text{spec’d min yield}}$$

<table>
<thead>
<tr>
<th>Application</th>
<th>$R_y$</th>
<th>$R_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot-rolled structural shapes and bars:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• ASTM A36/A36M</td>
<td>1.5</td>
<td>1.2</td>
</tr>
<tr>
<td>• ASTM A1043/A1043M Gr. 36 (250)</td>
<td>1.3</td>
<td>1.1</td>
</tr>
<tr>
<td>• ASTM A572/A572M Gr. 50 (345) or 65 (380),</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>• ASTM A913/A913M Gr. 50 (345), 80 (415), or</td>
<td></td>
<td></td>
</tr>
<tr>
<td>65 (450), ASTM A588/A588M, ASTM A992/A992M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• ASTM A1043/A1043M Gr. 50 (345)</td>
<td>1.2</td>
<td>1.1</td>
</tr>
<tr>
<td>• ASTM A529 Gr. 50 (345)</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>• ASTM A529 Gr. 55 (380)</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>Hollow structural sections (HSS):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• ASTM A500/A500M (Gr. B or C), ASTM A501</td>
<td>1.4</td>
<td>1.3</td>
</tr>
<tr>
<td>Pipe:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• ASTM A53/A53M</td>
<td>1.6</td>
<td>1.2</td>
</tr>
<tr>
<td>Plates, Strips and Sheets:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• ASTM A36/A36M</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>• ASTM A1043/A1043M Gr. 36 (250)</td>
<td>1.3</td>
<td>1.1</td>
</tr>
<tr>
<td>• A1011/A1011M HSLAS Gr. 55 (380)</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>• ASTM A572/A572M Gr. 42 (290)</td>
<td>1.3</td>
<td>1.0</td>
</tr>
<tr>
<td>• ASTM A572/A572M Gr. 50 (345), Gr. 55 (380),</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>• ASTM A588/A588M, ASTM A992/A992M</td>
<td>1.2</td>
<td>1.1</td>
</tr>
<tr>
<td>• ASTM 1043/1043M Gr. 50 (345)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel Reinforcement:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• ASTM A615, ASTM A708</td>
<td>1.25</td>
<td>1.25</td>
</tr>
</tbody>
</table>
ASTM A1085

Steels for use in primary bridge members are required to have sufficient fracture toughness to reduce the probability of brittle failure in the presence of a fatigue crack or other notch-like defect.

CVN test requirement

- Ability of a material to resist fracture under impact loading
- Measures absorbed energy during fracture
- Cut V in steel and hit with a pendulum, measure how far the pendulum swings up
- Amount of energy absorbed will increase as temperature increases
ASTM A1085

AASHTO divides US into three temperature zones for specifying fracture toughness. Delineated by lowest anticipated service temperature.

<table>
<thead>
<tr>
<th>GRADE (Y.P./Y.S.)</th>
<th>THICKNESS (in)</th>
<th>MIN. TEST VALUE ENERGY (ft-lb)</th>
<th>ZONE 1 (ft-lb @ °F)</th>
<th>ZONE 2 (ft-lb @ °F)</th>
<th>ZONE 3 (ft-lb @ °F)</th>
<th>ZONE 1 (ft-lb @ °F)</th>
<th>ZONE 2 (ft-lb @ °F)</th>
<th>ZONE 3 (ft-lb @ °F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>t ≤ 4</td>
<td>20</td>
<td>25 @ 70</td>
<td>25 @ 40</td>
<td>25 @ 10</td>
<td>15 @ 70</td>
<td>15 @ 40</td>
<td>15 @ 10</td>
</tr>
<tr>
<td></td>
<td>t ≤ 2</td>
<td>20</td>
<td>25 @ 70</td>
<td>25 @ 40</td>
<td>25 @ 10</td>
<td>15 @ 70</td>
<td>15 @ 40</td>
<td>15 @ 10</td>
</tr>
<tr>
<td>50/50S/50W</td>
<td>2 ≤ t ≤ 4</td>
<td>24</td>
<td>30 @ 70</td>
<td>30 @ 40</td>
<td>30 @ 10</td>
<td>20 @ 70</td>
<td>20 @ 40</td>
<td>20 @ 10</td>
</tr>
<tr>
<td>HPS 50W</td>
<td>t ≤ 4</td>
<td>24</td>
<td>30 @ 10</td>
<td>30 @ 10</td>
<td>30 @ 10</td>
<td>20 @ 10</td>
<td>20 @ 10</td>
<td>20 @ 10</td>
</tr>
<tr>
<td>HPS 70W</td>
<td>t ≤ 4</td>
<td>28</td>
<td>35 @ -10</td>
<td>35 @ -10</td>
<td>35 @ -10</td>
<td>25 @ -10</td>
<td>25 @ -10</td>
<td>25 @ -10</td>
</tr>
<tr>
<td>HPS 100W</td>
<td>2 ≤ t ≤ 2-1/2</td>
<td>28</td>
<td>35 @ -30</td>
<td>35 @ -30</td>
<td>35 @ -30</td>
<td>25 @ -30</td>
<td>25 @ -30</td>
<td>25 @ -30</td>
</tr>
<tr>
<td></td>
<td>2-1/2 ≤ t ≤ 4</td>
<td>36</td>
<td>Not permitted</td>
<td>Not permitted</td>
<td>Not permitted</td>
<td>35 @ -30</td>
<td>35 @ -30</td>
<td>35 @ -30</td>
</tr>
</tbody>
</table>

Lowest Anticipated Service Temperature

<table>
<thead>
<tr>
<th>Temperature Zone</th>
<th>0°F and above</th>
<th>-1°F to -30°F</th>
<th>-31°F to -60°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Zone 2</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Zone 3</td>
<td></td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>
A1065

SAW manufacturing process

only rectangular / square sections

tapered sections

larger sections (perimeter greater than 64” and up to 1” thick)

no reduction in design thickness
A500 Gr B vs Gr C Smackdown

DUAL CERT!!!
Always specify Grade C!

---

**Material Test Report**

<table>
<thead>
<tr>
<th>Heat No</th>
<th>C</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Si</th>
<th>Al</th>
<th>Cu</th>
<th>Cb</th>
<th>Mo</th>
<th>Ni</th>
<th>Cr</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>S55194</td>
<td>0.160</td>
<td>0.790</td>
<td>0.006</td>
<td>0.010</td>
<td>0.012</td>
<td>0.048</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>Yield</th>
<th>Tensile</th>
<th>Elr.2in</th>
<th>Certification</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 X 2 X 0.188</td>
<td>55129 Psi</td>
<td>67817 Psi</td>
<td>35.0 %</td>
<td>ASTM A500-10A GRADE B&amp;C</td>
</tr>
</tbody>
</table>
The Seam Weld

Per A500, “The longitudinal butt joint of welded tubing shall be welded across its thickness in such a manner that the structural design strength of the tubing section is assured”

A500-13 adds that the weld seam shall not be placed within the radius
A true pipe specification, intended for mechanical and pressure applications (steam, water, air, gas).
Not recommended by STI.
Availability Tool

The mission of the Steel Tube Institute (STI) is to promote the growth and competitiveness of North America’s steel tubular products industry, to enhance tubular manufacturing techniques, and to inform consumers about the utility and versatility of steel tube and pipe.

Choose shape:
- Square
- Rectangular
- Round

Choose grade:
- 500B/C
- 1085
- 1065

Size:
- Min
- TO
- Max
- Specific:

Additional sizes above and below range provided are available. Please adjust search criteria to see availability above and below range provided but that display of data limits number of fields viewable on a single screen.

Wall Thickness:

Seismic:
- Highly ductile
- Moderately ductile

OR DOWNLOAD A PDF OF:
- HIGHLY AVAILABLE SIZES & GRADES
- MODERATELY AVAILABLE SIZES & GRADES

Submit
<table>
<thead>
<tr>
<th>Program</th>
<th>WF bm to HSS col</th>
<th>HSS Col splices</th>
<th>HSS Col base plate</th>
<th>HSS vert bracing</th>
<th>HSS to HSS (truss)</th>
<th>Mitered Knee / End pl</th>
<th>Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enercalc</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>DESCON</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>Fastrak Connection</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td>Fastrak</td>
</tr>
<tr>
<td>LIMCON</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>None</td>
</tr>
<tr>
<td>RAM Connection</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>RSS, RE, STAAD</td>
</tr>
<tr>
<td>RISA Connection</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td>RISAFloor &amp; RISA-3D</td>
</tr>
<tr>
<td>SDS/2 Connect</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>REVIT 2014 add-in</td>
</tr>
<tr>
<td>STI's HSS Connex Online</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>TEDDS</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td>STI development</td>
</tr>
</tbody>
</table>
Connections - TEDDS

Select the design method: LRFD

Design Loads:
Factored loads from LRFD load combinations
Beam shear load: 24 kips

HSS Column:
HSS 8x8x0.375
Column Steel Grade: ASTM A500 Gr C

WF Beam:
W 18x40
Beam Steel Grade: ASTM A992

Output: Detailed
Connections - TEDDS

8. HSS columns checks

HSS Column: Wall slenderness per AISC 360-10 Section B4.1
Evaluate the HSS column wall using the requirements in section "Design Considerations for Simple Shear Connections to HSS Columns" in Part 10 of the AISC Steel Construction Manual. The section on single-plate connections to HSS states: "As long as the walls are not classified as slender, the local distortion caused by the single-plate connection will be insignificant in reducing the column strength of the HSS."

Wall slenderness per Table B4.1a of AISC 360-10 for members subject to axial compression
Case 6 for walls of rectangular HSS
\[ \lambda_t = 1.40 \times \sqrt{\frac{F_{\text{steel}}}{\text{column_Fy}}} = 33.7 \]
Width-to-thickness ratio
\[ b_t = 19.9 \]

OK: The column wall is not slender

HSS Column: Wall thickness to support fillet welds
Evaluate the HSS wall thickness to support the fillet welds using the requirements in section "Connecting Element Rupture Strength at Welds" in Part 9 of the AISC Steel Construction Manual, 14th Ed. using Eq. 9-2.

Weld metal strength
\[ F_{\text{weld}} = 70 \text{ ksi} \]
Minimum column wall thickness
\[ t_{\text{min,9.2}} = 0.6 \times F_{\text{weld}} \times (\sqrt{2}) \times t_{\text{weld}} / (0.6 \times \text{column_Fu}) = 0.2 \text{ in} \]

OK: The column wall is thick enough to support the weld on the shear plate

HSS Column: Wall thickness per AISC 360-10 Section K1.3
Equation K1-3 from Table K1.1 for round HSS or Table K1.2 for rectangular HSS limits the plate thickness based on the HSS wall thickness and the material properties of the HSS and the plate. This limit is applied as a minimum HSS column wall thickness to support the shear plate.

Minimum wall thickness
\[ t_{\text{min,K1.3}} = (\text{plate_Fy}/\text{column_Fu}) \times \text{plate_t} = 0.218 \text{ in} \]

OK: The column wall is thick enough to support the selected plate
Connections - Excel

Single Plate Shear Connection of WF Beam to HSS Column

Moment Connection of WF Beam to HSS Column
  • Continuous Beam over Column
  • Through Plate
  • Directly Welded

Truss Connection
  • K Connection
  • T/Y Connection
Connections - Excel

Hollow Structural Sections

Design Aids

Coming soon: HSS Connex Online, connection design tools and typical details, and column load tables for ASTM A1085.

Moment Connection of Wide Flange Beam to HSS Column

Truss Connections

Shear Connection of a Wide Flange Beam to HSS Column

Column Design Aid

Column strength check for axial, bending and shear loads for HSS and concrete filled HSS.

Download document.
Connections - HSS Connex Online

Software Usage Agreement
By using this software, you agree to the terms within the STI-Connex Agreement.

Getting Started
Provide Feedback on This Software Here
Getting Started Guide

Selection of Planar Connection Type
- Plate-to-HSS Connection
- HSS-to-HSS Connection
- Round HSS
- Rectangular HSS
- Transverse Surface
- Longitudinal Surface
- Longitudinal Through
- Cap Plate

Input Parameters
- Chord
- Plate
- Branch A
- Branch B
- Branch C
- Branch D
- Gap/Overlap

Material: A500 Gr. B HSS
- Yield Stress $F_y$ (ksi) = 42
- Tensile Strength $F_u$ (ksi) = 58

www.ncsea.com
2014 NCSEA Annual Conference - New Orleans
Proprietary Connections

Sideplate

ConXtech
Proprietary Connections

Cast Connex

Hollo Bolt* by Lindapter, Blind Bolt, Box Bolt by LNA*
Resources

- AISC Manual & Design Guide 24
- CIDECT Design Guides
- Hollow Structural Section Connection and Trusses by J.A. Packer & J.E. Henderson
- STI’s Contact page
- Coming Q1/2015 STI Product Manual
Thank you!!

Kim Olson, PE
303.720.4076
kim@forseconsulting.com