

Design of HSS Structures

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Physical properties of HSS

Physical properties	Value
Density, ρ	$7.85 \times 10^3 \text{ kg/m}^3$
Poisson's ratio in elastic range, ν	0.3
Modulus of elasticity, E	210000 MPa (at 20 °C)
Shear modulus, G	$\frac{E}{2(1 + \nu)} \approx 81000 \text{ MPa}$
Coefficient of linear thermal expansion, α	$12 \times 10^{-6} \text{ per K (for } T \leq 100 \text{ °C)}$
Thermal conductivity, λ_a	53.3 W/mK (at 20 °C)
	47.3 W/mK (at 200 °C)
	40.7 W/mK (at 400 °C)

Construction standards for HSS

Materials and Products

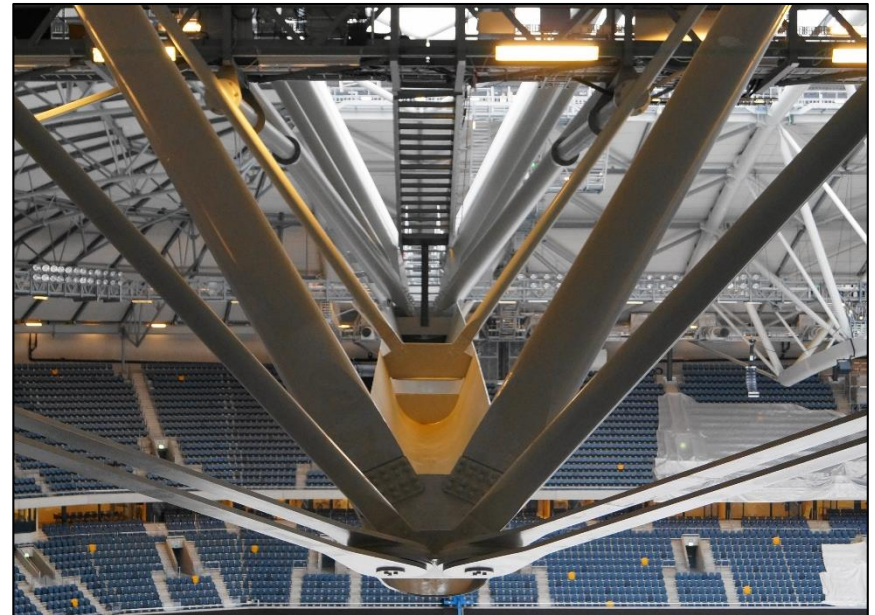
EN 10025, EN 10210, EN 10219

Design

EN 1993, EN 1994

Execution

EN 1090-2 (Execution class?)




How to design HSS: EN 1993

Now:

EN 1993-1-1: S235 to S460

EN 1993-1-12: S500 to S700

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- Stricter ductility requirements
 - Same buckling curve as S460
 - Restrictions on plastic analysis
 - Restrictions on connection design methods utilising large plastic deformations

Second Generation Eurocodes:

EN 1993-1-1 S235 to S700

EN 1993-1-12 S700 to S960

Impact of ↑ strength on resistance

Cross-section classification (↓)

$$\varepsilon = \sqrt{235/f_y}$$

- ε reduces as f_y increases: more stringent limits

f_y	$f_y/235$	ε
235	1.00	1.00
355	1.51	0.81
460	1.96	0.71
690	2.94	0.58

Slenderness (↓)

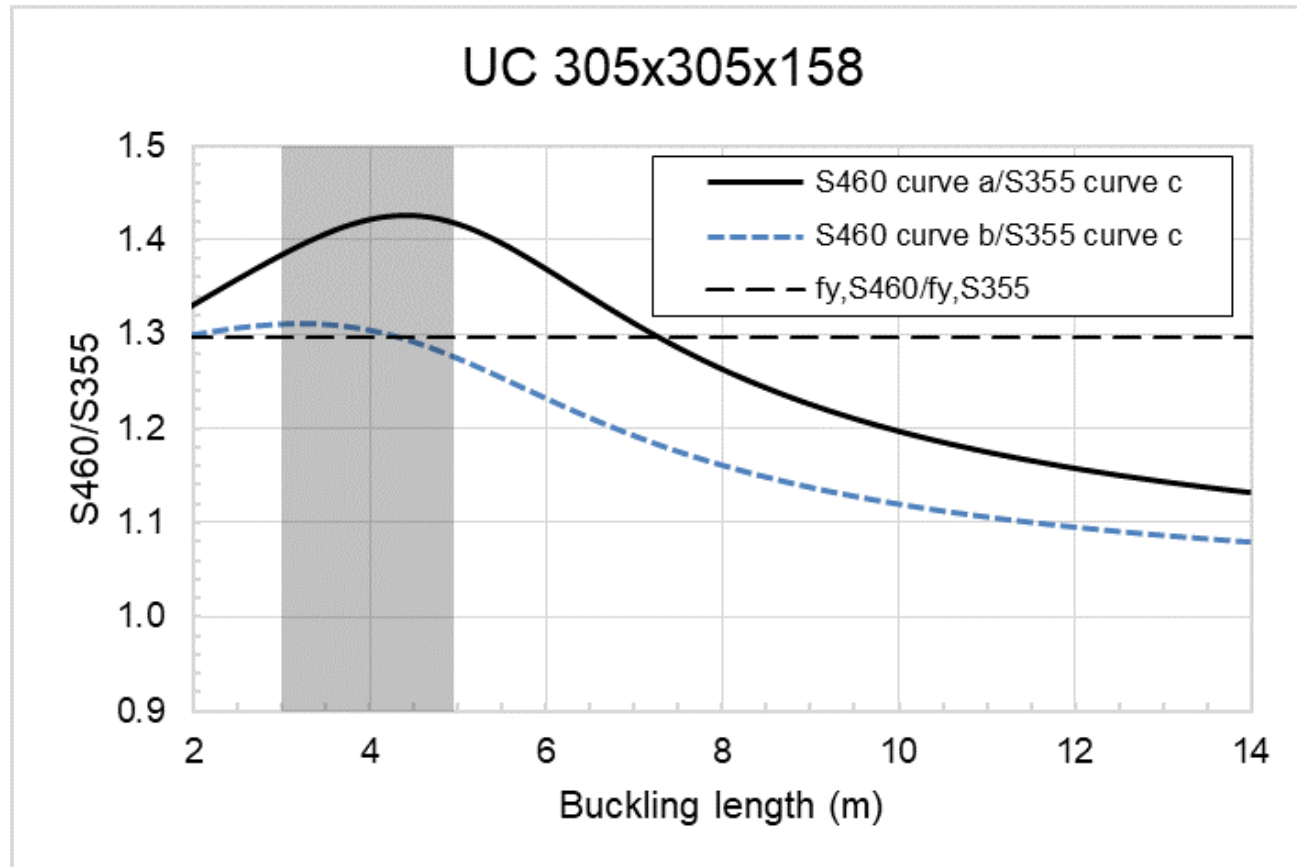
- Slenderness increases slightly with f_y $\bar{\lambda} = \frac{L_{cr}}{i} \frac{1}{\lambda_1}$ $\lambda_1 = \pi \sqrt{\frac{E}{f_y}} = 93,9\varepsilon$

Buckling curve (↑)

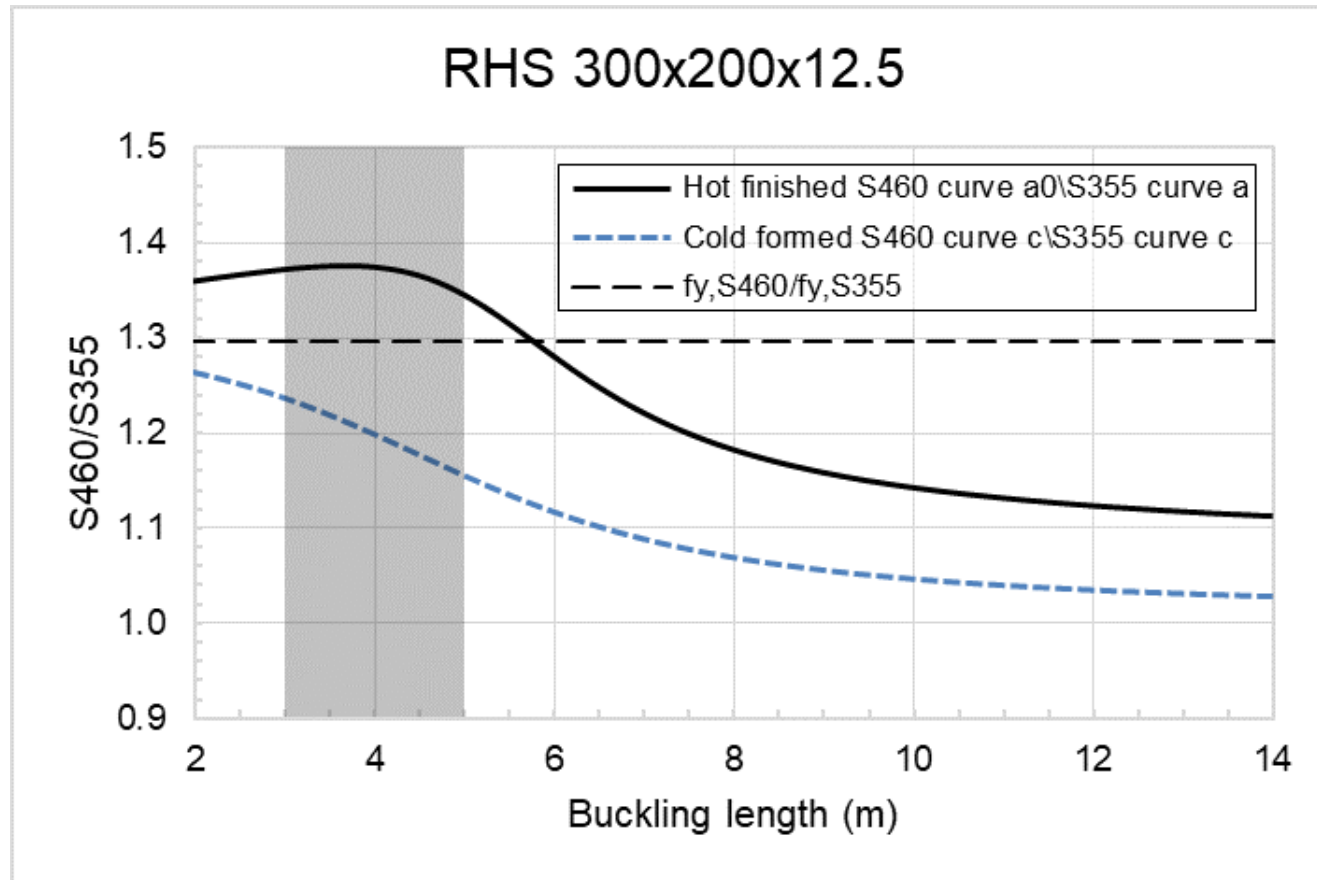
- S460 and above - higher flexural buckling curve
- Most significant at mid-range slendernesses

Strength (↑)

S460:S355 flexural resistance UC



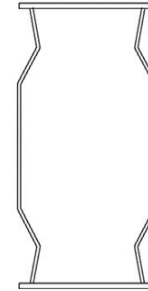
S460:S355 flexural resistance RHS



Methods to inhibit buckling at ULS

Local buckling

- Welded or cold formed stiffeners
- Concrete filled hollow sections (EN 1994)



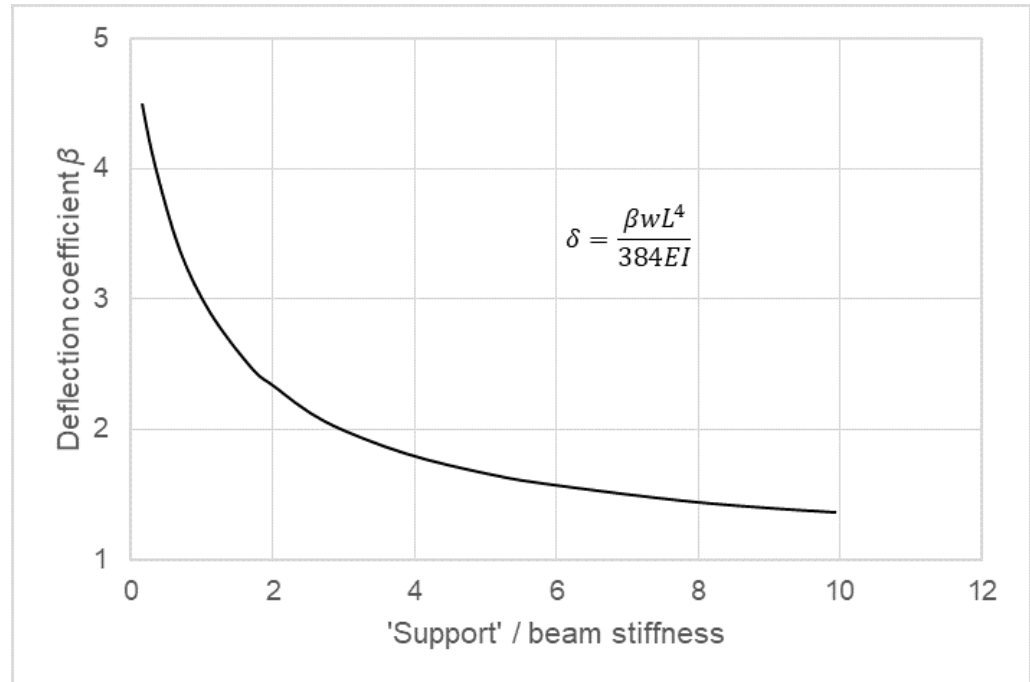
Global buckling

- Avoid using cross-sections with high h/b ratios as columns due to relatively low moment of inertia
- Take advantage of end fixity and nominal base stiffness (to reduce column buckling length)

Replicating an S355 design will not always lead to optimum design in HSS

Methods to reduce deflection at SLS

- Increase cross-section depth
- Pre-camber
- Take advantage of end fixity
- Composite action



Fire resistance of HSS

BS EN 1993-1-2:2005 EN 1993-1-2:2005 (E)

(6) The methods given are applicable to structural steel grades S235, S275, S355, S420 and S460 of EN 10025 and all grades of EN 10210 and EN 10219.

EN 1993-1-12:

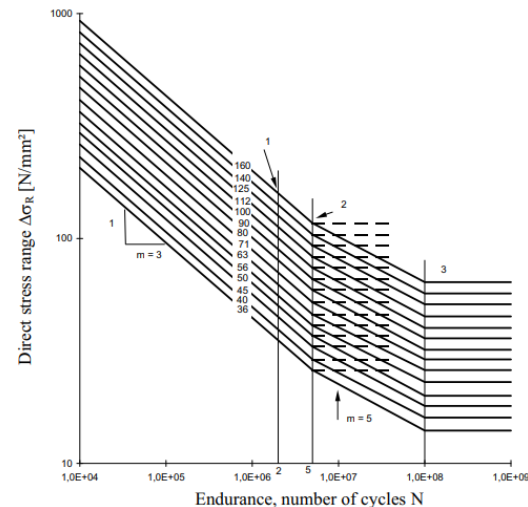
2.2 Additional rules to EN 1993-1-2

The standard is applicable to steels with grades greater than S460 up to S700 without further additional rules.

HSS members are likely to have thinner plate thicknesses, and so the rise in temperature may be quicker than for lower strength steels.

Fatigue

- Section sizes ↓, stress levels ↑, ratio of variable to permanent loads ↑, so stress range ↑
 - Fatigue conditions more critical
 - Rules in EN 1993-1-9 apply for steels up to S700
- (HSS still beneficial where permanent loading >> variable loading, or where number of load cycles low)



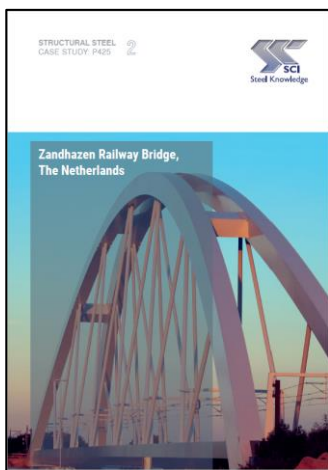
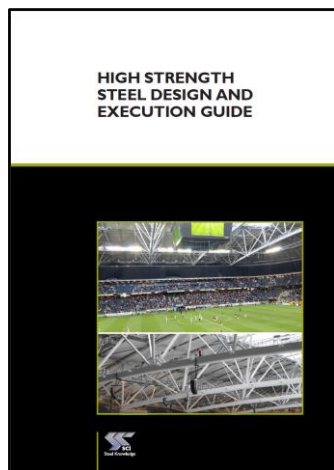
STROBE

- New **ductility and toughness** requirements
- Rules for **plastic design** of HSS beams & frames
- Rules for **stability** of HSS members
- Floor vibration analysis tool to assess **dynamic performance** of HSS floors
- Comparative designs (weight, carbon & cost savings)



- S460 to S700
- Hot rolled I shapes
- Fabricated I shapes
- Homogeneous & hybrid

- Recordings and pdfs of each webinar
- SCI Pub: High strength steel design & execution guide
- Web tool for designing HSS plate girders
- Case studies
- STROBE deliverables (end of March)



Project Details

Design company:	Company name	L [m]	10
Client:	Company name	Stipe [m]	10
Project Name:	Project name	S _{1,28} [m]	10
Element:	Description / ID	a [m]	2.5
Designed by:	Name & surname	L _{tot} [m]	10
Checked by:	Name & surname	L _{tot,28} [m]	10

Geometry Inputs

L [m]	10
Stipe [m]	10
S _{1,28} [m]	10
a [m]	2.5
L _{tot} [m]	10
L _{tot,28} [m]	10

Steel Profile Definition

Element Type	Fabricated
r _{total} [mm]	1450
r _{top flange} [mm]	700
r _{bottom flange} [mm]	645
r _{web} [mm]	12
r _{top flange} [mm]	25
r _{bottom flange} [mm]	18

Steel Properties

Top Flange	S460
Bottom Flange	S460
Web	S355
E [MPa]	210000

Design Inputs

National Annex	EN
Buckling checks	Yes
Load applied on EN 1993-1-1 (6.58)	S.C.
C ₁ calculation	Calculated
C ₁ - LTB	1.12
k _c - LTB	0.86
M _{Ed} - Override	Override

Load Inputs

All inputs are characteristic loads. Design combination - EN 1990 (6.10)	
q _d [kN/m ²]	10
q _k [kN/m ²]	10
M _{Ed, permanent} [kN]	450
M _{Ed, imposed} [kN]	995
G ₁ [kN]	100
G ₂ [kN]	100
Q ₁ [kN]	200
Q ₂ [kN]	200
Position - G ₁ [m]	4
Position - G ₂ [m]	6
Position - Q ₁ [m]	4
Position - Q ₂ [m]	6

Inputs for SLS checks

W _{dynamic} - Vibrations	0.10
f _{dynamic} [Hz]	3
Min. Total Load - L/L	250
Min. Imp. Load - L/L	380

Further guidance on welding

BCSA's new guide for
fabrication and welding HSS:

Typical welding procedure
specifications for S460 steels

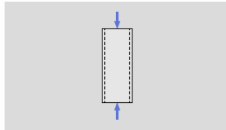
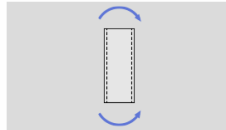
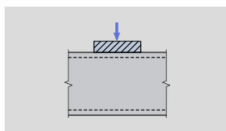
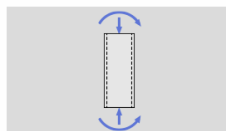


Available from BCSA shop:
www.steelconstruction.org/shop

Resistance tables for S420 and S460 products





Tata steel tubes S420 & S460:

<https://www.tatasteelbluebook.com>

 <p>Axial compression resistance</p> <p>Celsius® 355 Celsius® 420 Celsius® 460</p>	 <p>Bending resistance</p> <p>Celsius® 355 Celsius® 420 Celsius® 460</p>
 <p>Web bearing and buckling resistance</p> <p>Celsius® 355 Celsius® 420 Celsius® 460</p>	 <p>Axial force and bending</p> <p>Celsius® 355 Celsius® 420 Celsius® 460</p>

ArcelorMittal Orange Book: Hot rolled and Welded I sections in S460 (homogeneous and hybrid)

<https://orangebook.arcelormittal.com>

 <p>Axial compression resistance</p> <p>S355/HISTAR®355 S460/HISTAR®460</p>	 <p>Buckling resistance moment</p> <p>S355/HISTAR®355 S460/HISTAR®460</p>
 <p>Web bearing and buckling resistance</p> <p>S355/HISTAR®355 S460/HISTAR®460</p>	 <p>Axial force and bending - cross-section resistance and member buckling checks</p> <p>S355/HISTAR®355 S460/HISTAR®460</p>