Online Design Tool for High Strength Steel (HSS) Beams

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A. Online Design Tool

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STROBE

Stronger Steels in the Built Environment

Research Programme of the Research Fund for Coal and Steel

The web tool

This software has been engineered and developed by **SCI - The Steel Construction Institute** and **HOCHTIEF Engineering** for the Research Programme of the Research Fund for Coal and Steel "STROBE". The software performs the design of bare steel beam-column elements and offers an optimization tool. The design tool covers standard hot-rolled profiles and fabricated steel sections with normal and high strength steels up to S690. For fabricated sections, different steel grades may be specified for flanges and web plates (hybrid profiles). The optimization can be carried out for hot rolled sections (UK and Euro-standard profiles) and welded sections based on user inputs. The tool covers the design of class 1, 2, 3 and 4 cross sections. Core Eurocode, UK, German and Portuguese national annexes to Eurocode 3 are available. A quick user guide can be found **here**.

Disclaimer

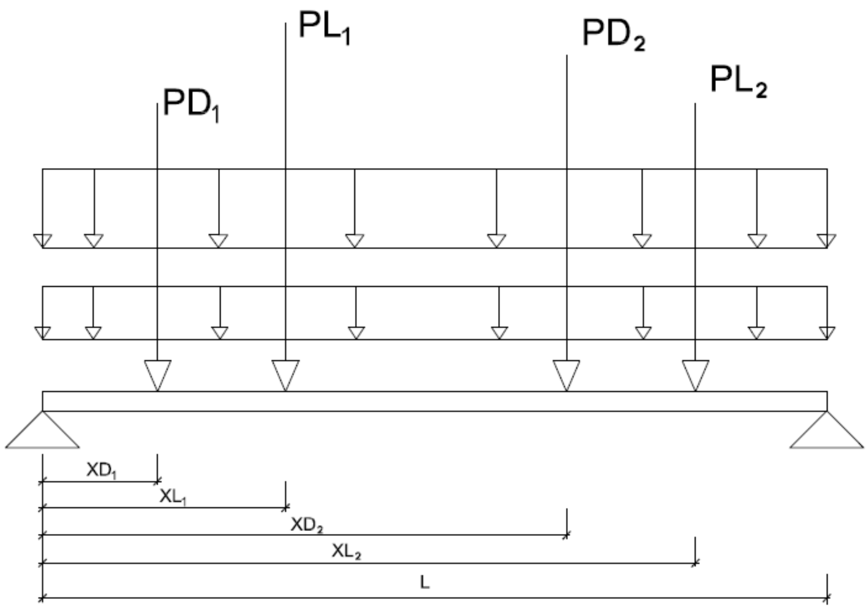
Although care has been taken to ensure that the calculated values are correct, users should verify the output. The Steel Construction Institute, HOCHTIEF Engineering and other parties associated with this software and website assume no responsibilities for errors or misuse of this software, or damage arising from the use of this software.

European Commission | SCI | RWTH AACHEN UNIVERSITY | Imperial College London | UNIVERSIDADE D COIMBRA | DILLINGER | HOCHTIEF

http://strobe.steel-sci.org

A. Online Design Tool

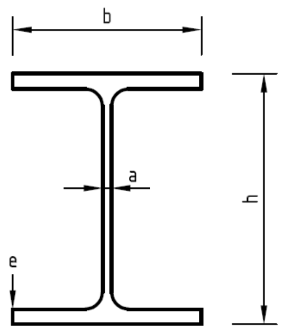
Scope of the design and optimization tool

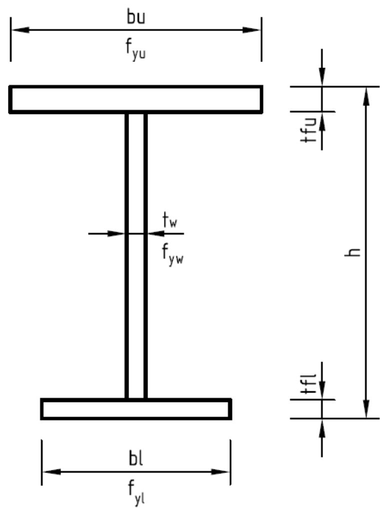


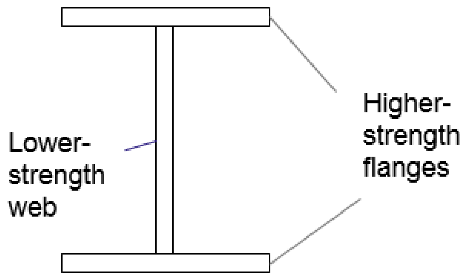
1. **Structural system**
   - simple beams
   - point loads and line loads
   - axial force
2. **Steel grades**
   - standard steels S235, S275, S355
   - HSS S420, S460, S690

A. Online Design Tool

Scope of the design and optimization tool







3. Cross-sections
- cross-sections classes 1-4
- standard hot-rolled sections
- welded plate girders
- welded hybrid girders

4. Optimization
- determination of dimensions with the lightest weight
- optimization considerations: deflection limit, lateral-torsional buckling, section height etc.

B. General Parametric Study

Investigated parameters

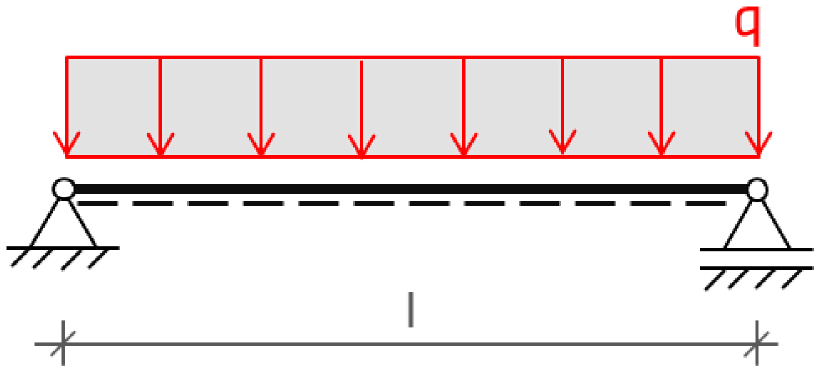
System:
- simple beams

Loading:
- uniform distributed load
- p_k = 2.5/5/10/15/20/30/40/50 kN/m

Span:
- l = 2.5 / 5 / 10 / 20 m

Deflection limit:
- Yes / No

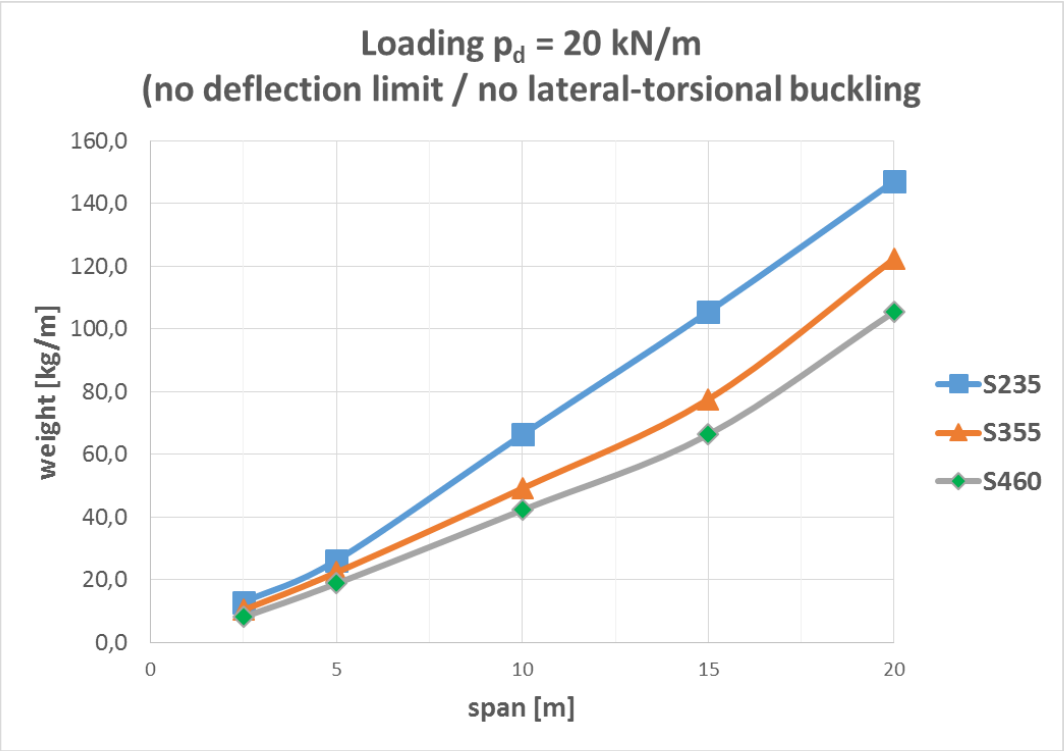
Lateral-torsional buckling:
- Yes / No

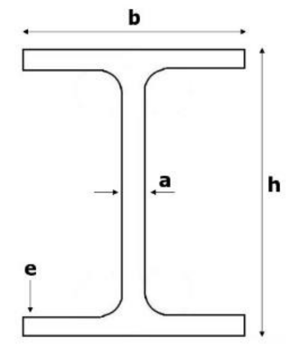


Sections and steel grades:
- hot-rolled sections in S235/S355/S460
- welded plate/hybrid girders in S235/S355/S460/S690

B. General Parametric Study

Results for the hot-rolled sections





When no deflection limit &

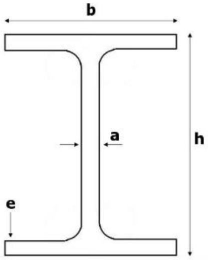
no lateral-torsional buckling

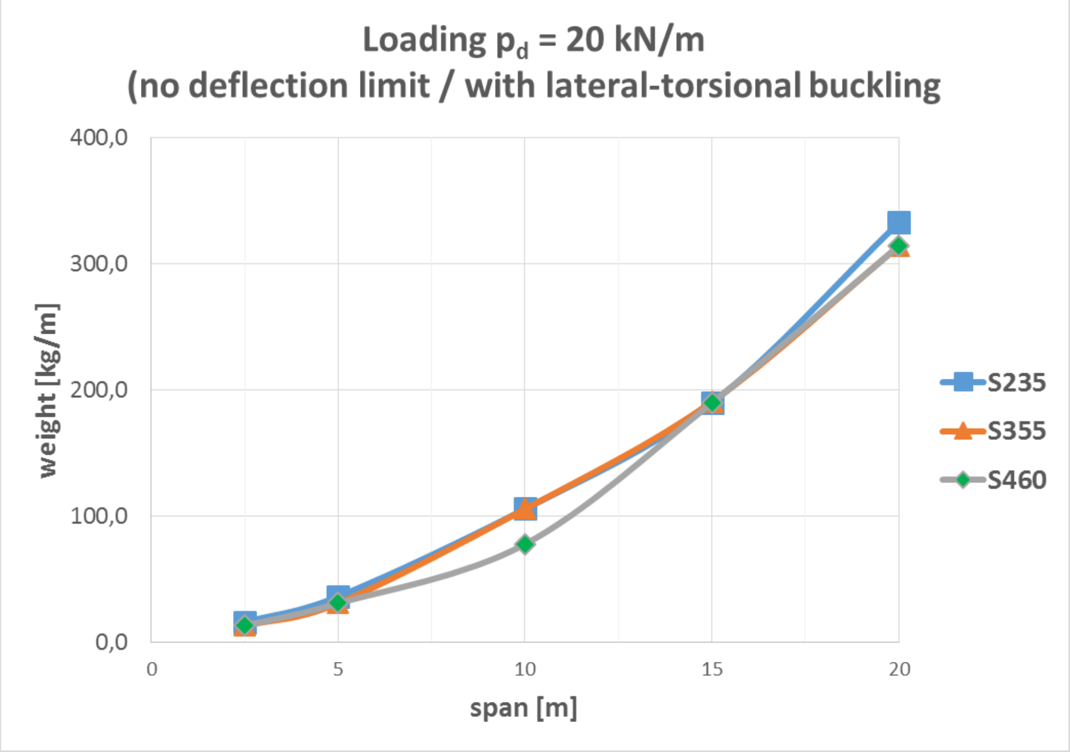
→ weight reduction up to **40%**

for **S460** compared to **S235**

B. General Parametric Study

Results for the hot-rolled sections





When no deflection limit &

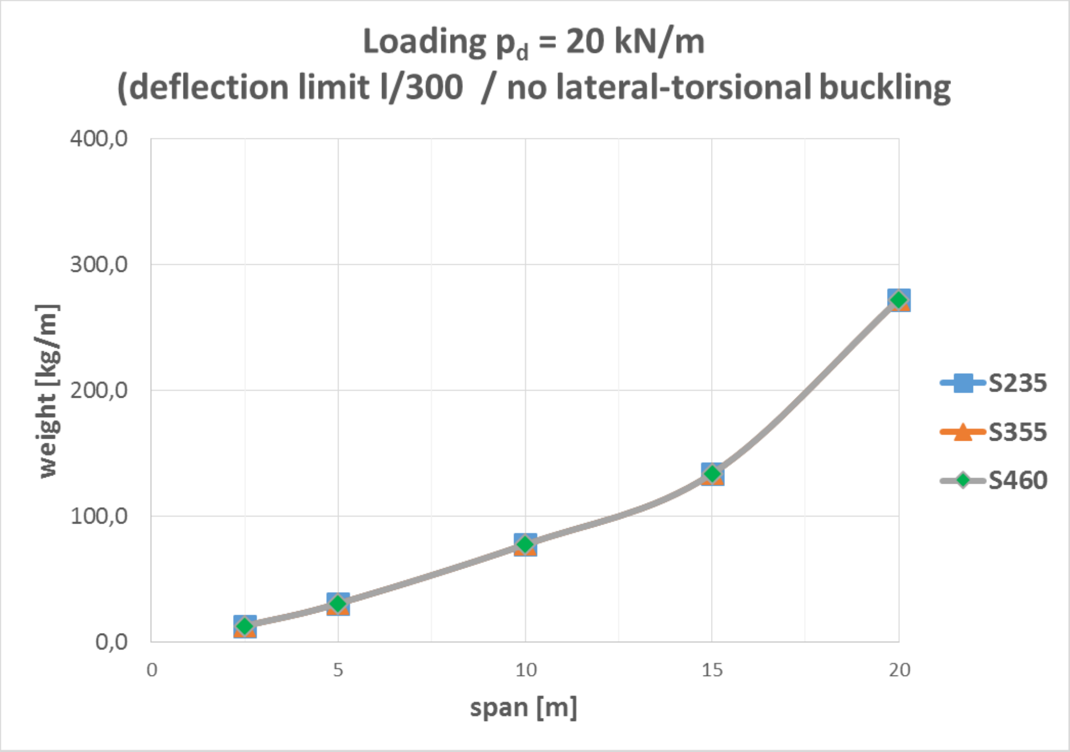
with lateral-torsional buckling

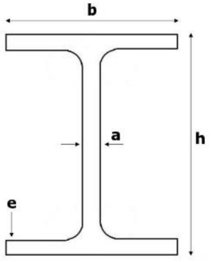
→ weight reduction for **S460** compared to **S235** is reduced to 0-20%

→ no benefit for **S460** compared to **S355**

B. General Parametric Study

Results for the hot-rolled sections



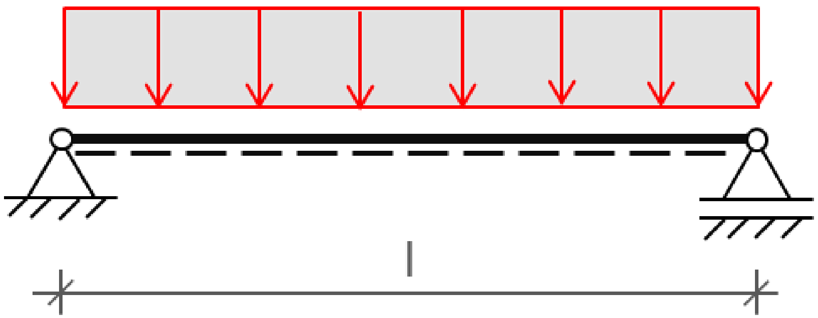


When deflection limit is l/300 for dead and imposed load & no lateral-torsional buckling → no benefit for **S460** compared to **S235** and **S355**

B. General Parametric Study

Example: Beam with large span (L=20m)

Total load: $p_d = g+q = 40$ kN/m



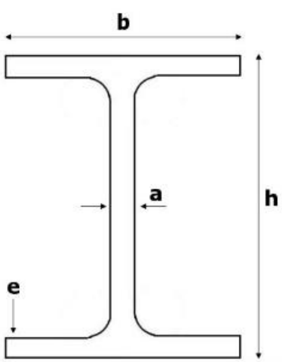
Load ratio: g /q =1

Deflection limit: l/300 for imposed load

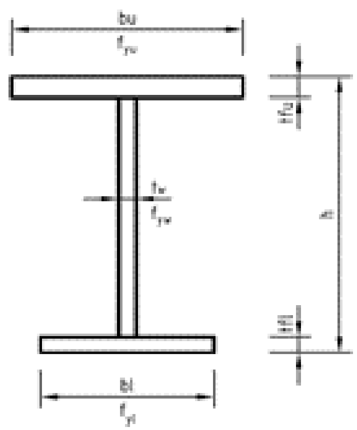
+ precamber the beam for dead load

No lateral-torsional buckling

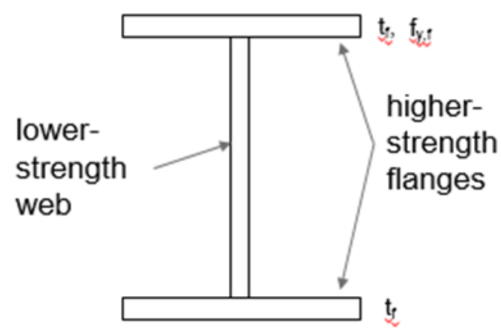
Hot-rolled section



Welded plate girder

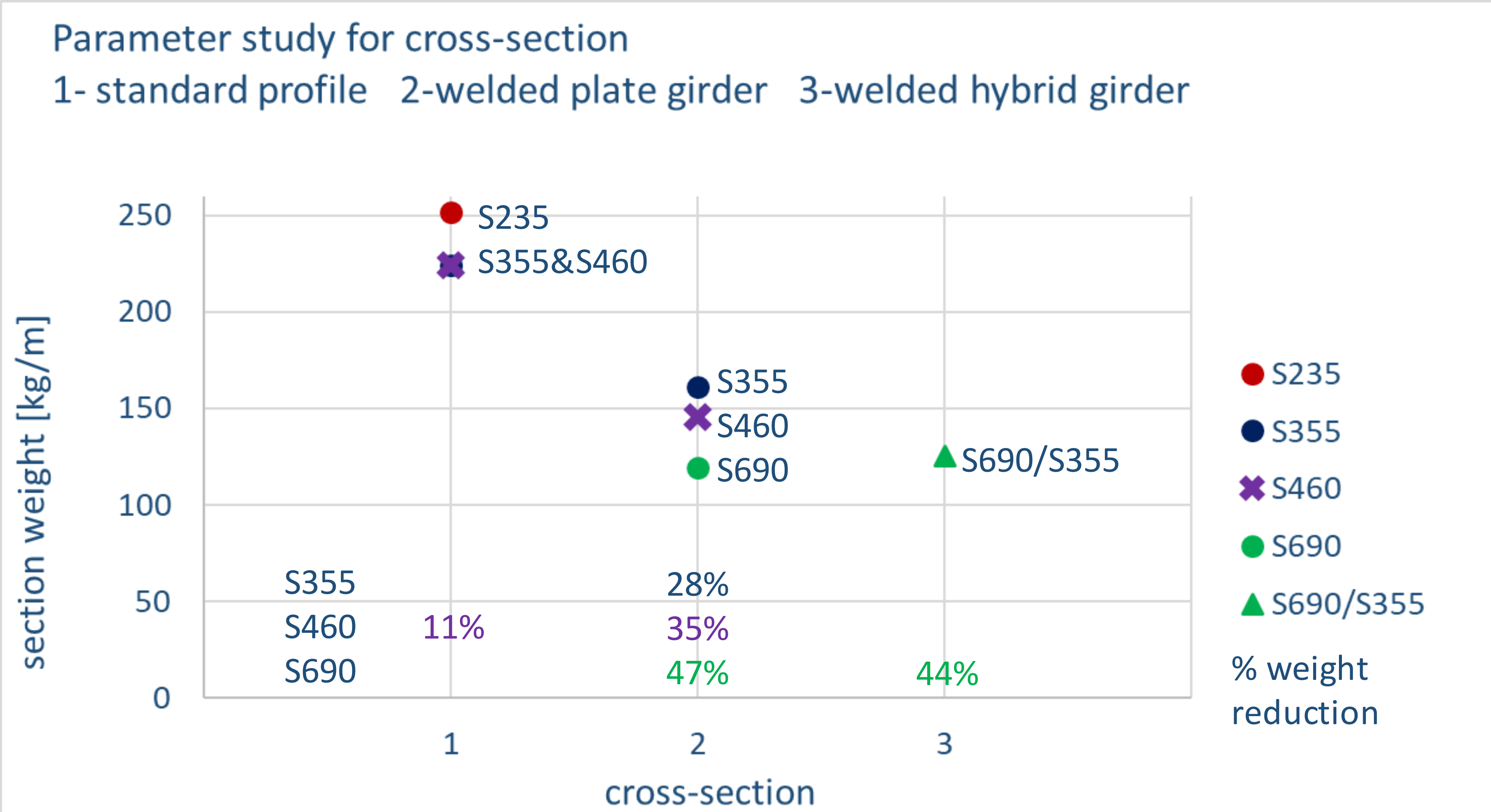


Welded hybrid girder



B. General Parametric Study

Example: Beam with large span (L=20m)



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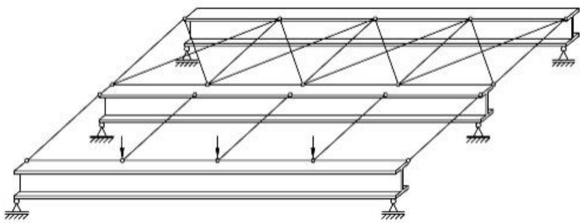
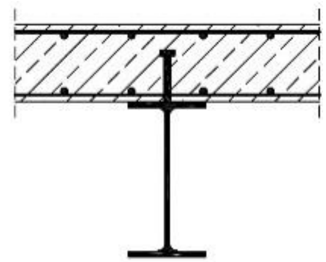
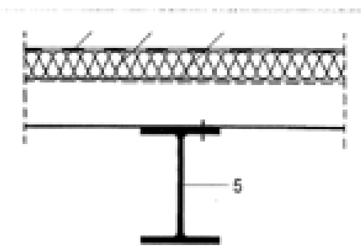
Constructive measures for using HSS

Lateral-torsional buckling:

- Lateral constraints on the upper flange are recommended

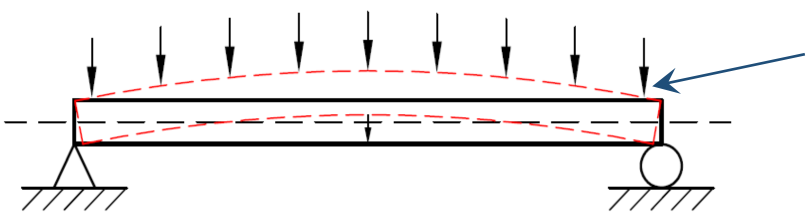






Deflection limit:

Deflection limit has to be reduced - for example precamber the beam to balance the dead loads - deflection limit only for the imposed loads



precamber of the beam

For more information see SCI P432

C. Case Studies

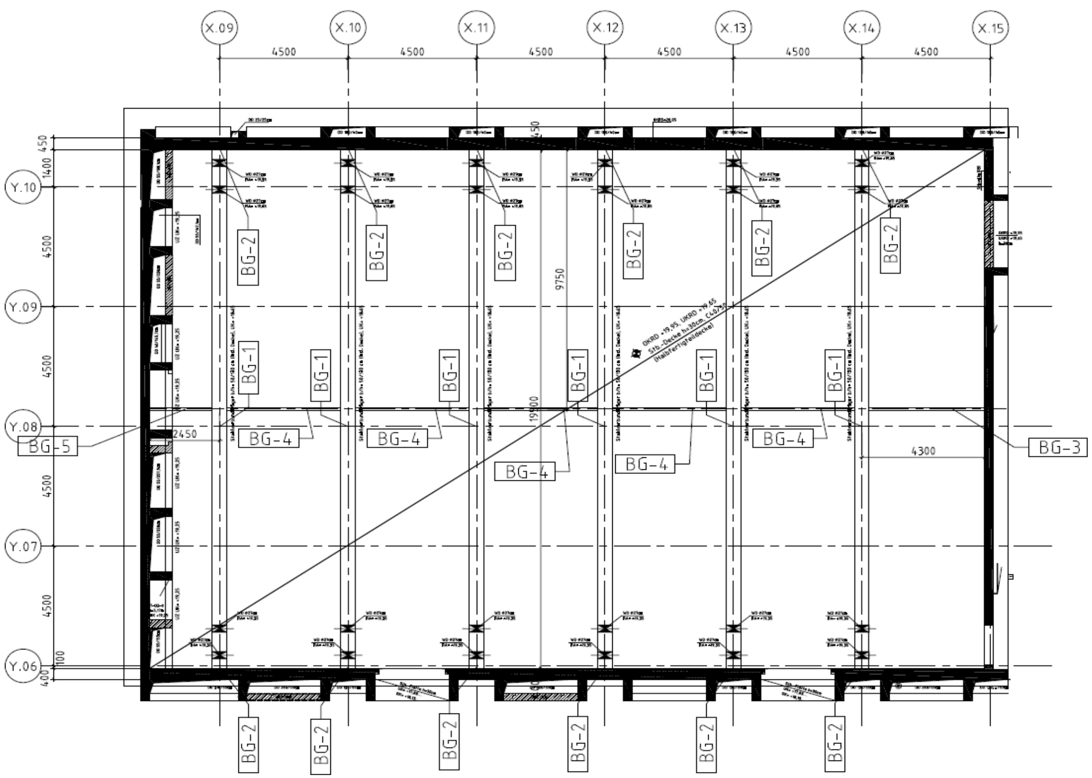
Summary of case studies

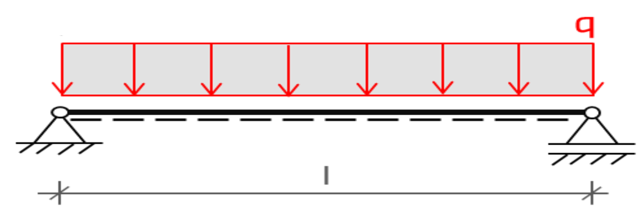
Four real projects are re-designed with HSS using the optimization online design tool

No.	Name	type	span L [m]	load ratio g_K/q_K	lateral-torsional buckling	critical failure mode
1	B015	industrial building	6	0.07	yes	deflection
2	VAC	industrial hall	16.73	~1.0	yes	deflection
3	Hafenbogen Frankfurt a.M.	office building	7.5	0.82	no	ULS
4	Museum Berlin	public building	20	2	no	deflection

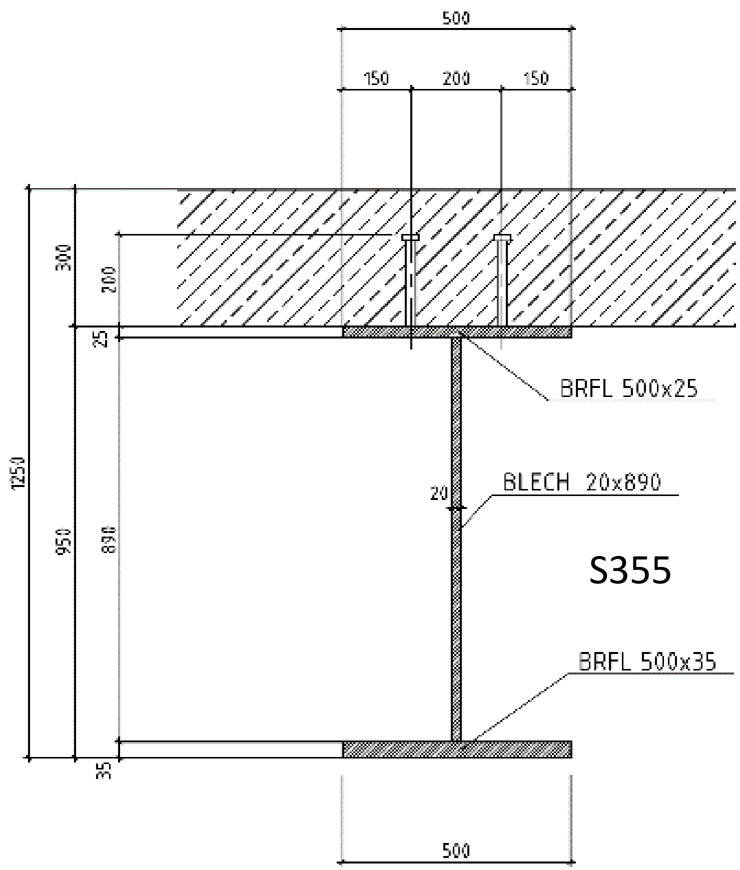
C. Case Studies

Case 4: a floor system in a public building





Case 4: a floor system in a public building



Deflection limits:

for total Load: L/150 or

L/50 (with precamber) +

L/300 for imposed Load

Load ratio:

$g_K / q_K = 10 / 5 \text{ kN/m}^2 = 2$

Without lateral-torsional buckling

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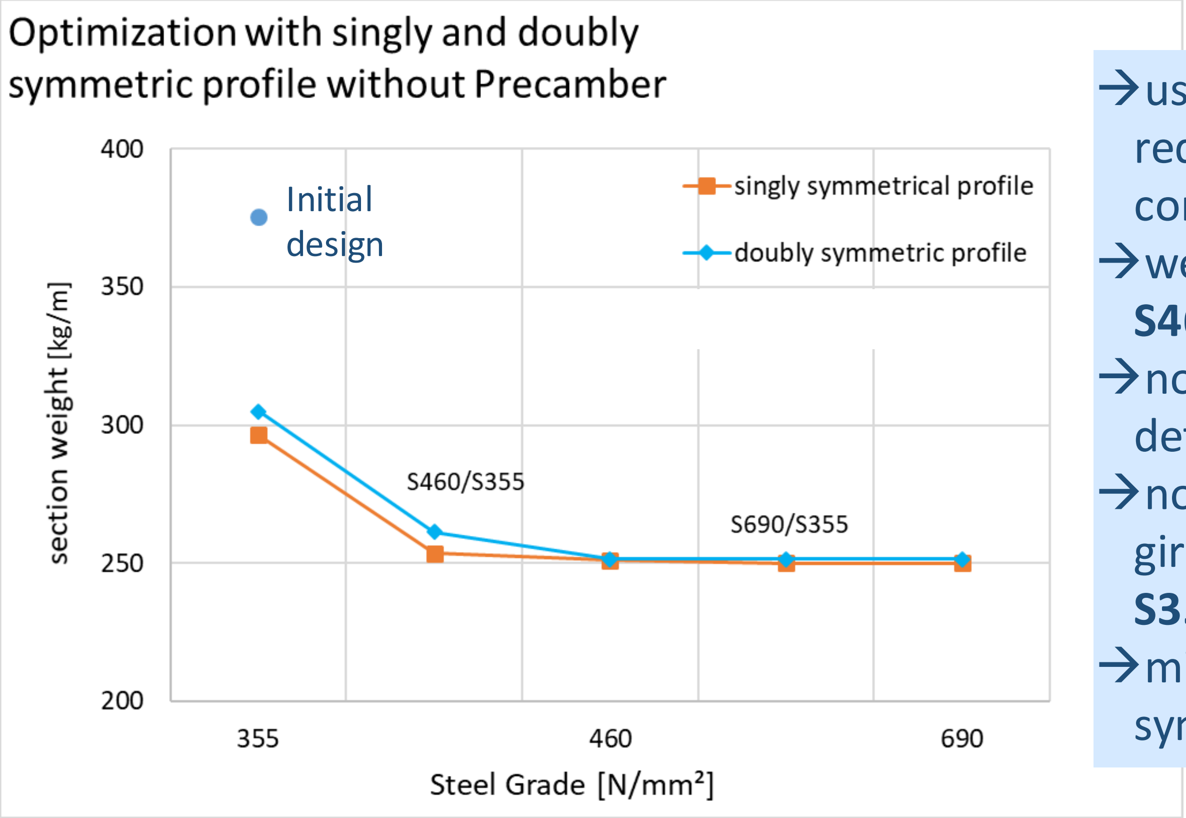
Case 4: optimization – singly and doubly symmetrical profile (without precamber)



- → using online tool weight reduction up to **19% -21%** compared to initial design **S355**
- → weight reduction up to **33%** for **S460** compared to initial design
- → no benefit for **S690** considering deflection limits
- → no difference between plate girder and hybrid section with **S355** in the Web
- → minor benefit for singly symmetrical profile (~2%)

C. Case Studies

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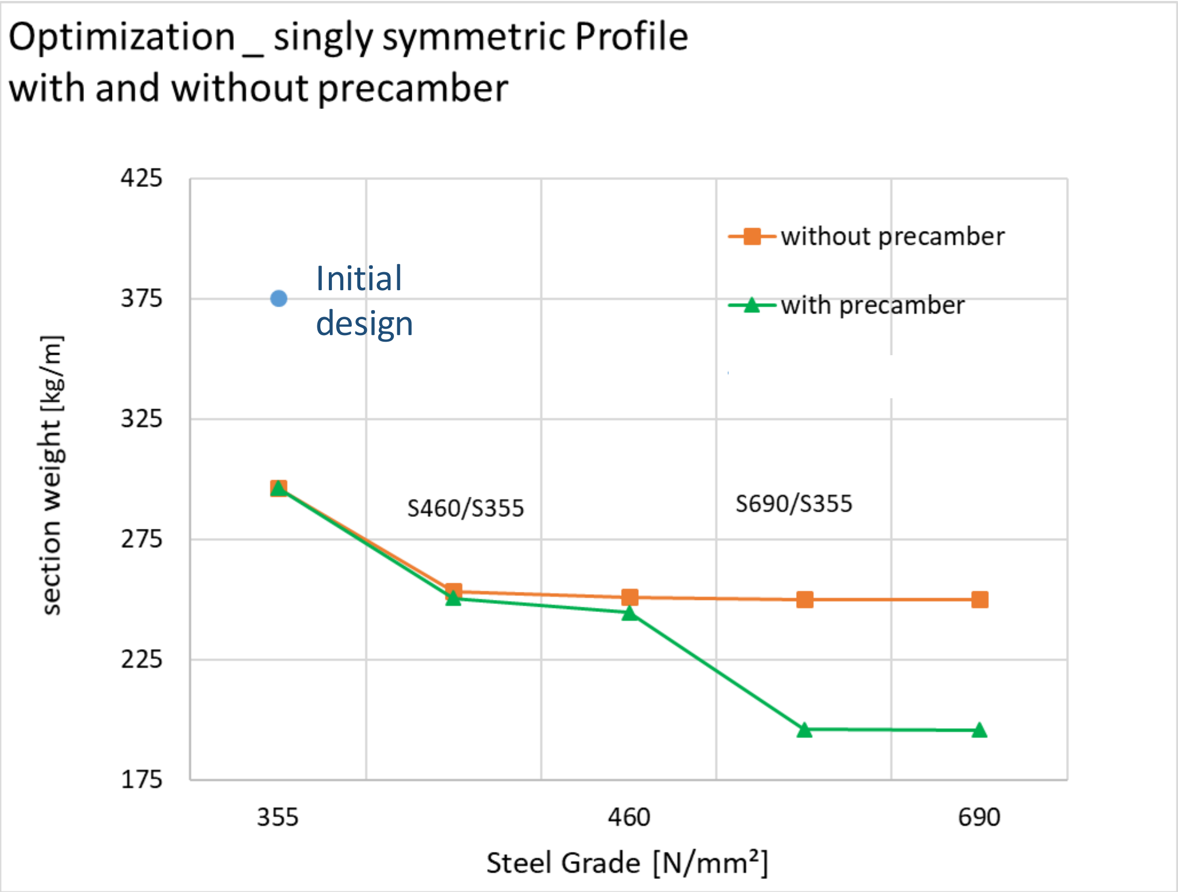
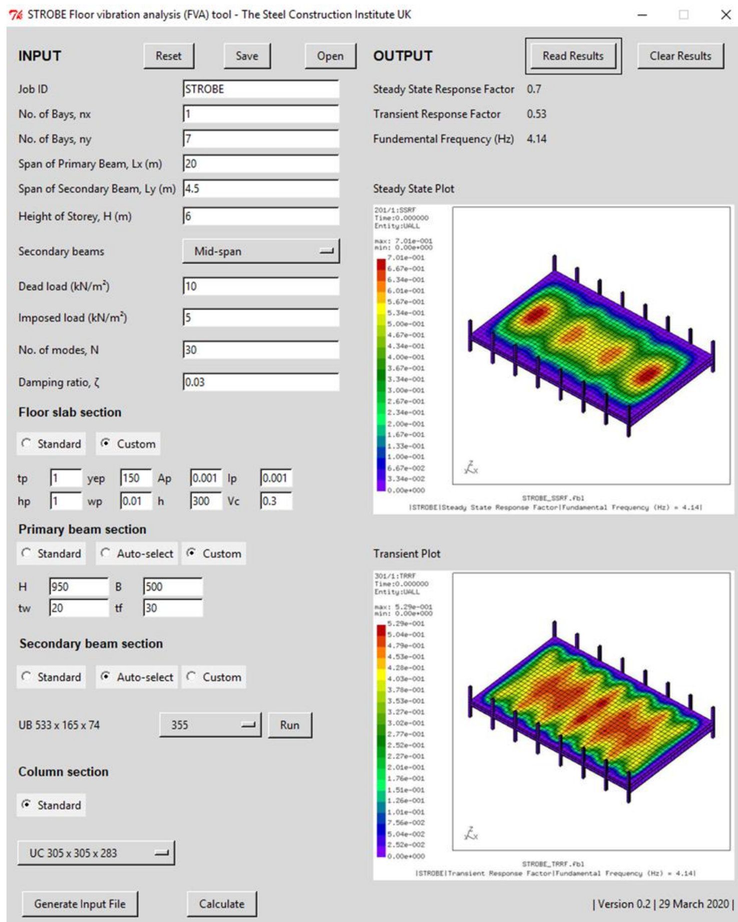
Case 4: optimization – welded singly symmetrical profile (with precamber)



- → more benefits for **S690** with **precamber**
- → weight reduction up to **~22%** compared to the case without precamber

C. Case Studies

Case 4: vibration analysis with FVA tool



SLS Outputs	
Total Deflection: L/	210
Imposed Load: L/	665
$\delta_{Total\ load}$ [mm]	95
$\delta_{Imposed\ Load}$ [mm]	30
f[Hz]	2.16

C. Case Studies

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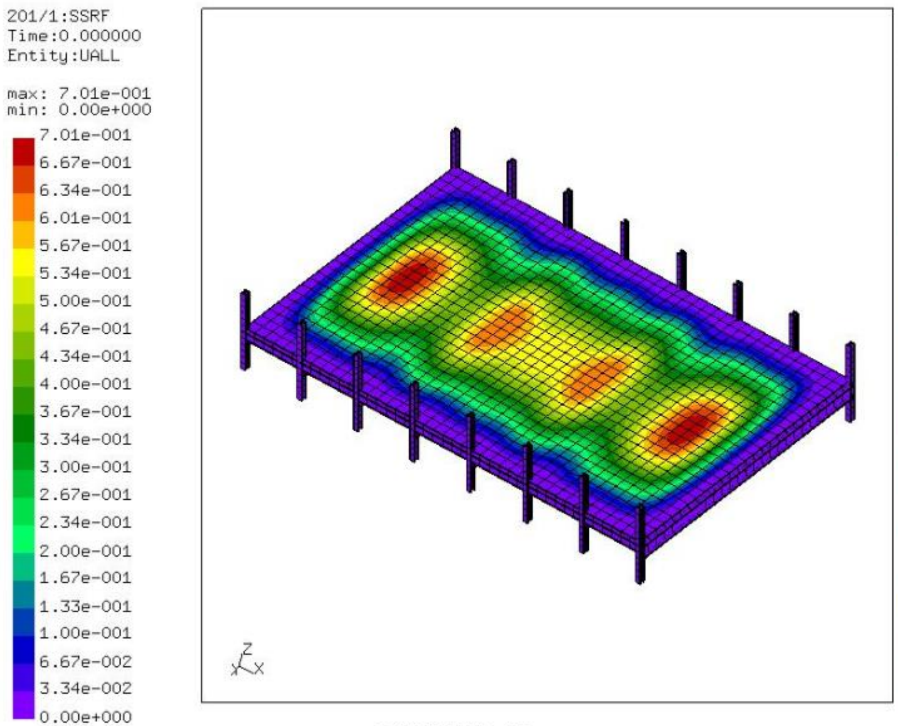
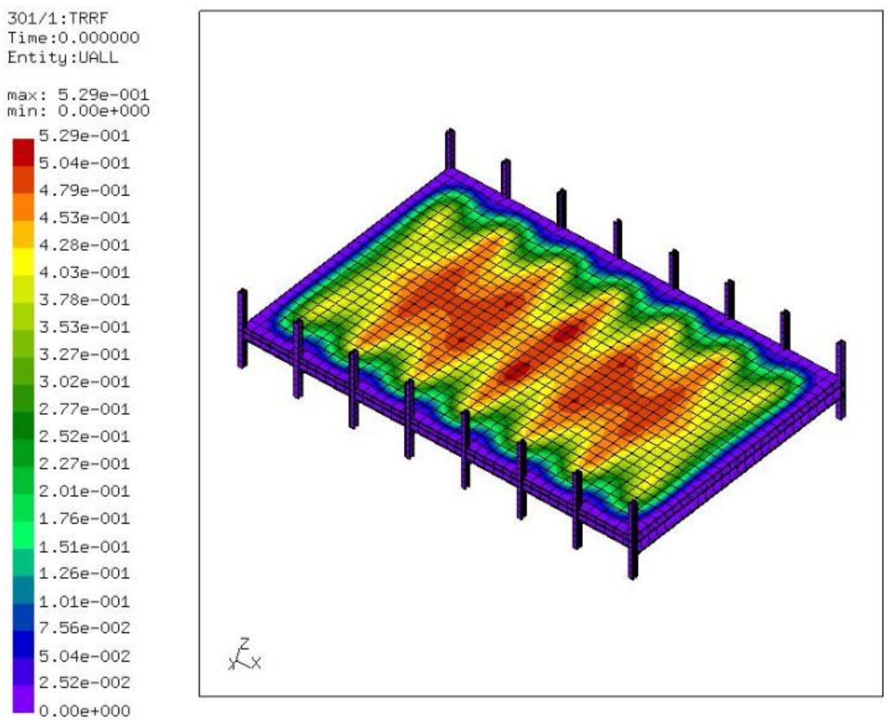
Case 4: vibration analysis of floor system with S355_initial design



STROBE_SSRF.fbl
|STROBE|Steady State Response Factor|Fundamental Frequency (Hz) = 4.14|



STROBE_TRRF.fbl
|STROBE|Transient Response Factor|Fundamental Frequency (Hz) = 4.14|

Fundamental Frequency = 4.14 Hz > 3 Hz

C. Case Studies

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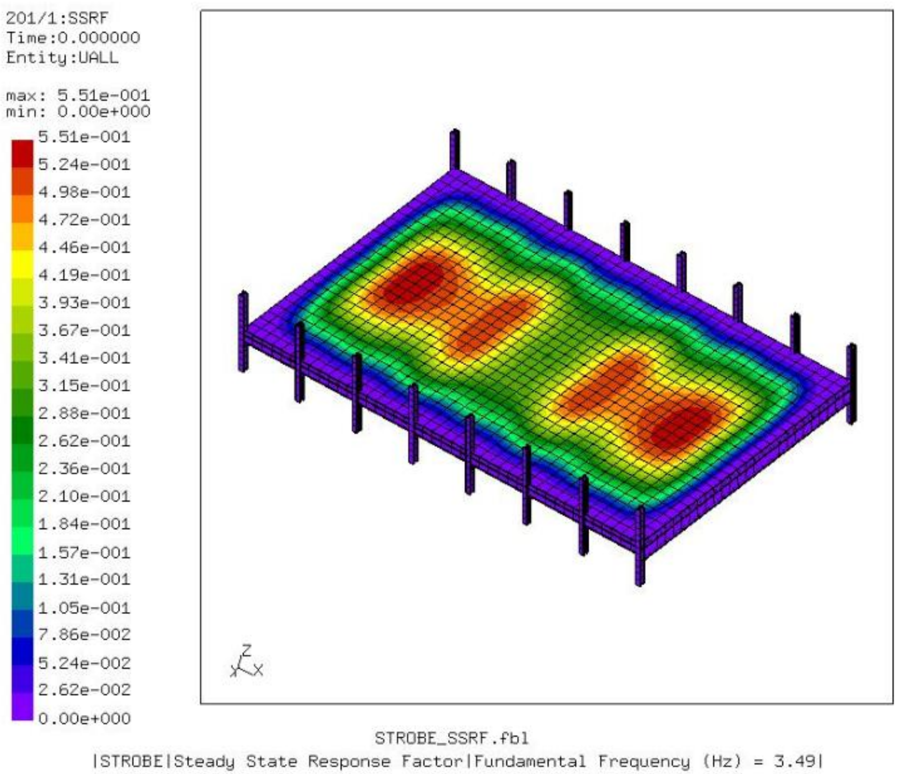
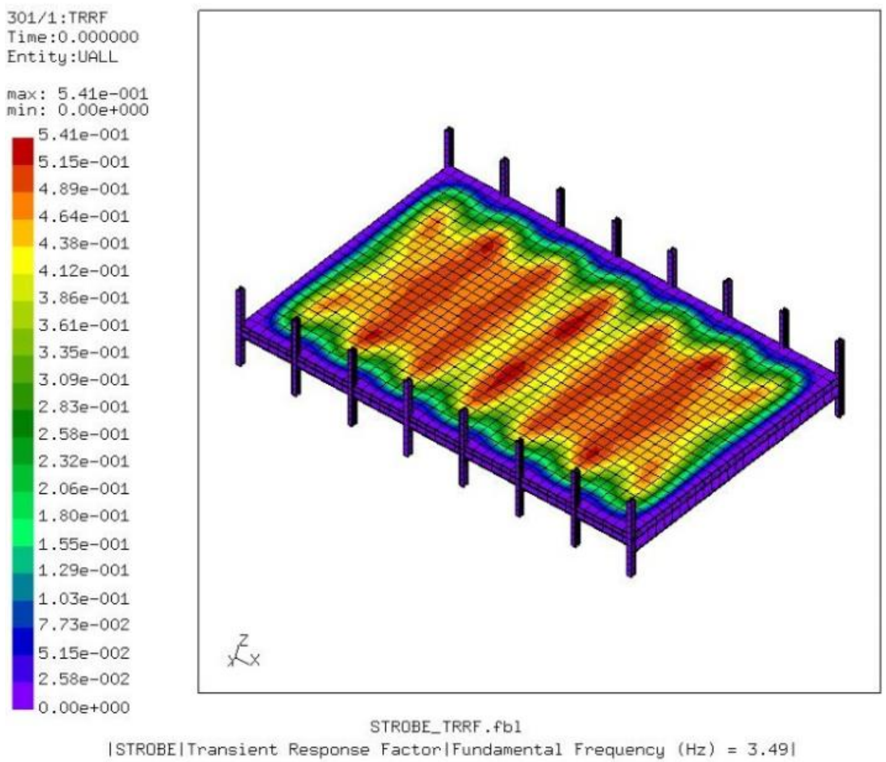
Case 4: vibration analysis of floor system with HSS steel girder

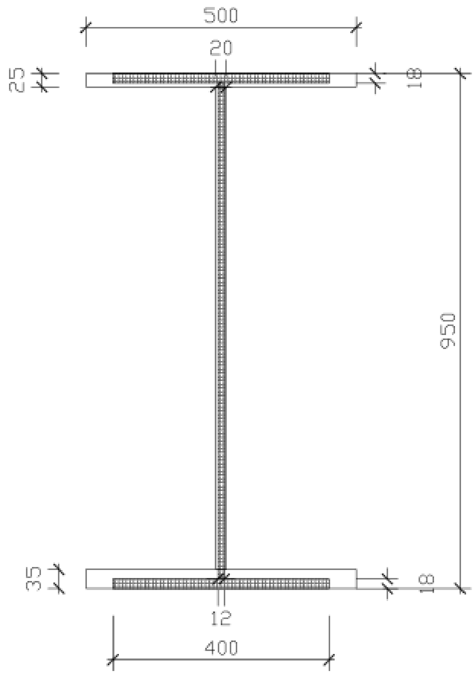




Fundamental Frequency = 3.49 Hz > 3 Hz

C. Case Studies

Case 4: summary of the optimization results



→ weight reduction up to **47%** for **S690** compared to initial design

→ the fundamental frequency by HSS is smaller

→ but it still satisfied the criterion (> 3 Hz)

Steel Grade	Section Height	Top flange Width	Bottom flange Width	Web Thickness	Top flange Thickness	Bottom flange Thickness	Section Weight	Comparison Steel Weight	Fundemental Frequency
	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[kg/m]	---	[Hz]
S355	950	500	500	20	25	35	375.23	100%	4.14
S690	950	400	400	12	18	18	199.14	53%	3.49

D. Recommendations for HSS

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Conclusions

Large Span:

- Especially for large spans and high loadings welded plate sections with HSS are highly effective
- The span to depth ratio of a girder should be chosen within a range of 20 to 25

Section geometry:

- Larger girder heights + smaller plate thicknesses are effective geometries
- Hybrid sections with lower strength of the web are very effective

D. Recommendations for HSS

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Conclusions

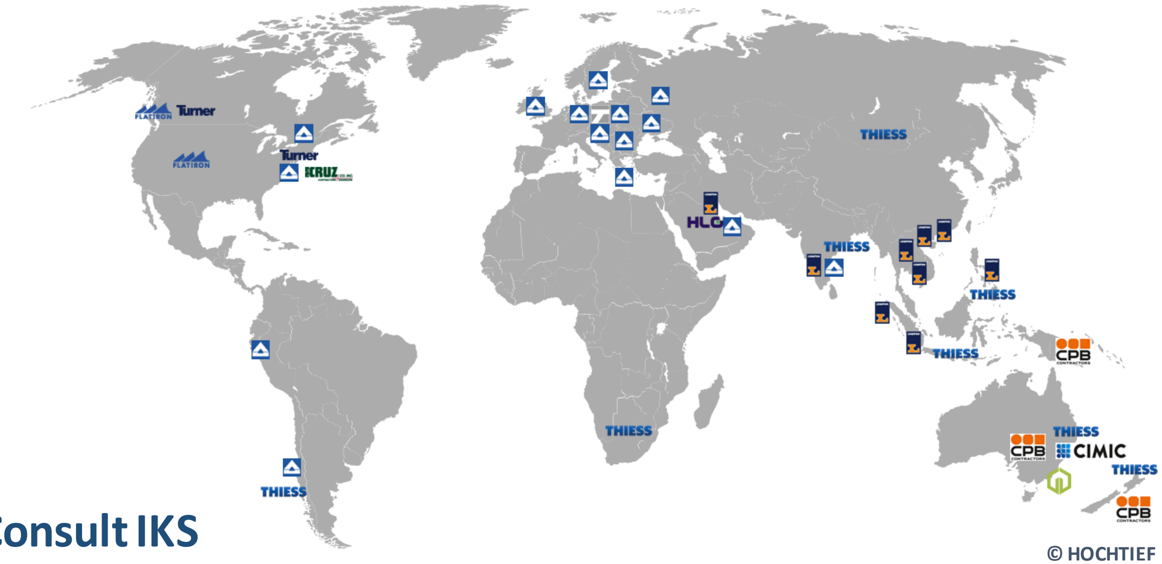
Lateral-torsional buckling:

- Generally lateral constraints on the upper flange are recommended
- More benefits for welded profiles than standard profiles with HSS
- Singly symmetric welded profile with larger upper flange is efficient for the optimization

Deflection and vibration response:

- Deflection limit has to be reduced
  i.e., considering precamber of the beam for dead loads
- The SCI FVA Tool could be applied for a more accurate vibration analysis of a floor system

Further Support



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