Online Design Tool for High Strength Steel (HSS) Beams

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A. Online Design Tool

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.

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: $p_d = g + q = 40 \text{kN/m}$
- 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)

Parameter study for cross-section
1- standard profile  2-welded plate girder  3-welded hybrid girder

<table>
<thead>
<tr>
<th>Cross-section</th>
<th>S355</th>
<th>S460</th>
<th>S690</th>
<th>S690/S355</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11%</td>
<td>11%</td>
<td>11%</td>
<td>11%</td>
</tr>
<tr>
<td>2</td>
<td>28%</td>
<td>35%</td>
<td>47%</td>
<td>44%</td>
</tr>
<tr>
<td>3</td>
<td>44%</td>
<td>44%</td>
<td>44%</td>
<td>44%</td>
</tr>
</tbody>
</table>

% weight reduction
B. General Parametric Study

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

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

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>type</th>
<th>span L [m]</th>
<th>load ratio $g_K/q_K$</th>
<th>lateral-torsional buckling</th>
<th>critical failure mode</th>
<th>Failure mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B015</td>
<td>industrial building</td>
<td>6</td>
<td>0.07</td>
<td>yes</td>
<td></td>
<td>deflection</td>
</tr>
<tr>
<td>2</td>
<td>VAC</td>
<td>industrial hall</td>
<td>16.73</td>
<td>~1.0</td>
<td>yes</td>
<td></td>
<td>deflection</td>
</tr>
<tr>
<td>3</td>
<td>Hafenbogen Frankfurt a.M.</td>
<td>office building</td>
<td>7.5</td>
<td>0.82</td>
<td>no</td>
<td></td>
<td>ULS</td>
</tr>
<tr>
<td>4</td>
<td>Museum Berlin</td>
<td>public building</td>
<td>20</td>
<td>2</td>
<td>no</td>
<td></td>
<td>deflection</td>
</tr>
</tbody>
</table>
C. Case Studies

Case 4: a floor system in a public building

Webinar Series: Structural Design of High Strength Steels
STROBE: Stronger Steels in the Built Environment EU RFCS Research Project 743504
C. Case Studies

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:
\[ \frac{g_K}{q_K} = \frac{10}{5} \text{ kN/m}^2 = 2 \]
Without lateral-torsional buckling
C. Case Studies

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

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

Optimization _ singly symmetric Profile with and without precamber

section weight [kg/m]

Initial design

Steel Grade [N/mm²]

S460/S355
S690/S355
C. Case Studies

Case 4: vibration analysis with FVA tool
C. Case Studies

Case 4: vibration analysis of floor system with S355_initial design

Fundamental Frequency = $4.14 \text{ Hz} > 3 \text{ Hz}$
C. Case Studies

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

Fundamental Frequency = 3.49 Hz > 3 Hz
### Case 4: summary of the optimization results

<table>
<thead>
<tr>
<th>Steel Grade</th>
<th>Section Height</th>
<th>Top flange Width</th>
<th>Bottom flange Width</th>
<th>Web Thickness</th>
<th>Top flange Thickness</th>
<th>Bottom flange Thickness</th>
<th>Section Weight</th>
<th>Comparison Steel Weight</th>
<th>Fundamental Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>S355</td>
<td>950</td>
<td>500</td>
<td>500</td>
<td>20</td>
<td>25</td>
<td>35</td>
<td>375.23</td>
<td>100%</td>
<td>4.14</td>
</tr>
<tr>
<td>S690</td>
<td>950</td>
<td>400</td>
<td>400</td>
<td>12</td>
<td>18</td>
<td>18</td>
<td>199.14</td>
<td>53%</td>
<td>3.49</td>
</tr>
</tbody>
</table>

- **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)**
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

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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