HIGH STRENGTH STEEL IN LONG SPAN STRUCTURES

RECENT AND CURRENT EXPERIENCES WITH LONG-SPAN STRUCTURES, WITH A VIEW TO HIGH STRENGTH STEELS

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BuroHappold Engineering is an independent, international engineering practice that over the last 40 years has become synonymous with the delivery of creative, value led building and city solutions for an ever changing world.
Aviva Stadium
Client: LRSDC
Architect: Populous, ScottTallonWalker Architects
Structural Design: BuroHappold Engineering
Engineering Contractor: Sisk
Steel Roof Contractor: Cimolai
Use of HSS

- Limited to primary truss main tension splice connection plates
2012 Olympic Stadium
Client: LRSDC
Architect: Populous
Structural Design: BuroHappold Engineering
Engineering Contractor: Sir Robert MacAlpine
Steelwork Fabricator: Severfield Watson
Use of HSS in Existing Stadium

- Original design adopted S355 for all steelwork
- Watson proposed HSS tube due to stock availability - various API pipeline grades X52–X65
- Large diameter thin wall sections for compression buckling resistance and lightweight slender aesthetic
- Of course – much high strength steel in the cables – very high strength, but with detailing and handling costs
Olympic Stadium Transformation
Client: LLDC
Architect: Populous
Structural Design: BuroHappold Engineering
Engineering Contractor: Balfour Beatty
Steelwork Fabricator: William Hare
Design development with HSS

- Limited suppliers to market
- Very limited availability in thicker sizes
- Tata were still in development of ‘standard’ sections in HSS, other suppliers also had a limited range of rolled sections
- Longer lead-in times, typically a minimum of 1 month depending on size, quantity and grade
- Quantity of S420 difficult to procure given programme
- S420 and S460 grade steel could be sourced for both fabricated girders and some standard CHS bracing elements
- Key issue was lead-in time, critical on a rapid delivery programme
- Of course – still much high strength steel in the cables – very high strength, but with detailing and handling costs
Atlanta Falcons Stadium
Client: Atlanta Falcons
Architect: HOK 360
Structural Design: BuroHappold Engineering
Fabricator: Canan
Design development with HSS

- A significant amount of $f_y = 65,000$ psi steel used, generally for the four primary trusses and the four main secondary trusses.
ANOTHER STADIUM ROOF (IN DEVELOPMENT)

Design development with HSS

- Grade 460 material around the compression ring
Design development with HSS

- Grade 460 steel in the main deck girders
Louvre Abu Dhabi
Client: TDIC
Architect: Ateliers Jean Nouvel
Structural Design: BuroHappold Engineering
Contractor: Arabtec/San Jose/Oger JV
Steelwork Fabricator: Waagner Biro
THE FINAL STRUCTURAL TOP SURFACE
STRUCTURAL BEHAVIOUR

Hogging over supports + bending between supports + perimeter belt truss + central arching
CLADDING TUNED TO LIGHTING REQUIREMENT
Design development with HSS

- None considered at the time of design, but the orange and red elements in the following slide would be considered if the design were to be repeated in the present day.
HSS? NEXT TIME...........
Olaya Metro Station, Riyadh, KSA
Designers: GerberHappoldJointVenture
Architect: Gerber Architekten
Structural Design: BuroHappold Engineering
Design development with HSS

- The structural steel truss of open sections is being computationally optimised for strength considering S355 and S460

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Weight S355</th>
<th>Weight S460</th>
<th>Total weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>1.00</td>
<td>-</td>
<td>1.00</td>
</tr>
<tr>
<td>HSS flange &gt; 50mm</td>
<td>0.21</td>
<td>0.73</td>
<td>0.94</td>
</tr>
<tr>
<td>All HSS</td>
<td>-</td>
<td>0.78</td>
<td>0.78</td>
</tr>
</tbody>
</table>

3-D truss arrangement of open sections
Welded nodal junctions
Relative steel weights
Xiqu Centre
Client: Architect:
Structural Design: BuroHappold Engineering
Design development with HSS

- Theatre hung from 7m deep roof trusses made from fabricated plated sections. The most highly stressed trusses use S460 grade plates for these fabricated sections.

- S460 was used as the major trusses are strength governed and using S460 enabled reduction of member sizes, plate thicknesses and a considerable reduction in weld volume for full penetration welds. S460 was offered to the client as a cost saving option during a value engineering study at scheme design stage.

- Approximately 1000t of S460 grade plates are being used on the project in thicknesses from 30mm to 100mm.

- More lightly loaded trusses have low enough forces to be made from standard rolled (UC) sections which are not widely available in S460 steel in China.
City of Dreams Hotel Tower
Client: Macau
Architect: Zaha Hadid
Structural Design: BuroHappold Engineering

**Design development with HSS**

- S460 grade fabricated box sections as part of both the complex geometry exoskeleton and internal columns in the lower floors of the building.

- S460 is used to reduce member sizes for highly stressed members
Makkah Umbrellas
Structural Design: SL Rasch + Liebherr
Structural Consultant: BuroHappold Engineering

Design development with HSS

- Struts supporting the arms - S770
- Arms - S690.
- Main column - S355
FABRICATOR FEEDBACK

- Typically all respondents had similar opinions on the use of HSS
- All had at least some experience using up to S460, beyond this experience was very limited
- All suggested limited supply and lead-in times were the biggest issues associated with its adoption (not technical)
CONCLUSIONS

- A developing trend of use of HSS in our designs
- Continuing architectural challenges
- Some procurement difficulties
- But we will continue to be specifying it more and more, such as for the arena on the following slide