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Market leader in structural steelwork
Severfield plc

The largest specialist structural steelwork group in the UK, with a reputation for performance and value
Market Sectors

- Power & Energy
- Stadia & Leisure
- Hospitals
- Education
- Bridges
- City Centre & Retail
- Commercial Offices
- Industrial & Warehousing
- Transport & Car Parks
- Residential & Hotels
Commercial Offices

5 Broadgate, London

The Shard at London Bridge

70 Mark Lane, London

Co-op Headquarters, Manchester

London Bridge Place
Group overview

- **Severfield (UK) Ltd**
  (Previously Severfield-Watson Structures Ltd)
  Dalton, N Yorks & Lostock, Lancashire

- **Severfield (Design & Build) Ltd**
  (Previously Atlas Ward Structures Ltd)
  Sherburn, N Yorks

- **Severfield (NI) Ltd**
  (Previously Fisher Engineering Ltd)
  Enniskillen, Co Fermanagh

- **JSW Severfield Structures**
  (Indian-based joint-venture business)
  Mumbai, India
Table 3.1: Nominal values of yield strength $f_y$ and ultimate tensile strength $f_u$ for hot rolled structural steel

<table>
<thead>
<tr>
<th>Standard and steel grade</th>
<th>$f_y$ [N/mm$^2$]</th>
<th>$f_u$ [N/mm$^2$]</th>
<th>$f_y$ [N/mm$^2$]</th>
<th>$f_u$ [N/mm$^2$]</th>
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<tbody>
<tr>
<td><strong>EN 10025-2</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>S 235</td>
<td>235</td>
<td>360</td>
<td>215</td>
<td>360</td>
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<tr>
<td>S 275</td>
<td>275</td>
<td>430</td>
<td>255</td>
<td>410</td>
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<td>S 355</td>
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<td>510</td>
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<td>470</td>
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<tr>
<td>S 450</td>
<td>440</td>
<td>550</td>
<td>410</td>
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<td><strong>EN 10025-3</strong></td>
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<tr>
<td>S 275 N/NL</td>
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<td>390</td>
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<td>S 355 N/NL</td>
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<td>470</td>
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<tr>
<td>S 420 N/NL</td>
<td>420</td>
<td>520</td>
<td>390</td>
<td>520</td>
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<tr>
<td>S 460 N/NL</td>
<td>460</td>
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<td>430</td>
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<td><strong>EN 10025-4</strong></td>
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<td>255</td>
<td>360</td>
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<tr>
<td>S 355 M/ML</td>
<td>355</td>
<td>470</td>
<td>335</td>
<td>450</td>
</tr>
<tr>
<td>S 420 M/ML</td>
<td>420</td>
<td>520</td>
<td>390</td>
<td>500</td>
</tr>
<tr>
<td>S 460 M/ML</td>
<td>460</td>
<td>540</td>
<td>430</td>
<td>530</td>
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<td><strong>EN 10025-5</strong></td>
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<td>S 235 W</td>
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<td>360</td>
<td>215</td>
<td>340</td>
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<tr>
<td>S 355 W</td>
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<td>510</td>
<td>335</td>
<td>490</td>
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<td><strong>EN 10025-6</strong></td>
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<td>S 460 Q/QL/QL1</td>
<td>460</td>
<td>570</td>
<td>440</td>
<td>550</td>
</tr>
</tbody>
</table>
High Strength Steels
BS EN 10025-4 and -6

Some steel companies will make thermo-mechanically rolled steels with yield strengths well in excess of 460N/mm² which conform to BS EN 10149.
Eurocode 3 — Design of steel structures —

Part 1-12: Additional rules for the extension of EN 1993 up to steel grades S 700
Tooling of mechanical cutting and machining machines for use on high strength steels is usually more expensive.

Harder tools made from ‘better’ cutting steels are generally employed to ease the cutting process and prolong the life of the tool.

Normal steel cutting blades and drill bits can be used however their performance and longevity can be compromised when used on HSS.
Thermal cutting processes such as Plasma and Oxy-fuel are ignition based – They heat the steel up to above it’s ignition temperature before shooting a narrow high pressure oxygen stream to ‘burn’ away the material and form a cut.
Plasma cutting uses an electric arc to generate the heat whereas oxy-fuel, as the name suggests, uses a mixture of oxygen and a fuel gas such as acetylene or propane.

Both cutting processes produce a Heat Affected Zone (HAZ).

Properties of material are changed affecting hardness, toughness, etc.
EN 1090-2 States that hardness of cut free edges for steels conforming to EN 10025-2 to -5 must be below 380Hv and HSS must be below 450Hv

Table 10 — Permitted maximum hardness values (HV 10)

<table>
<thead>
<tr>
<th>Product standards</th>
<th>Steel grades</th>
<th>Hardness values</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 10025-2 to -5</td>
<td>S235 to S460</td>
<td>380</td>
</tr>
<tr>
<td>EN 10210-1, EN 10219-1</td>
<td>S260 to S700</td>
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</tr>
<tr>
<td>EN 10149-2 and EN 10149-3</td>
<td>S460 to S690</td>
<td>450</td>
</tr>
</tbody>
</table>

**NOTE** These values are in accordance with EN ISO 15614-1 applied to steel grades listed in ISO/TR 20172.
Preheat and cut at a speed that will prevent rapid cooling and hence high hardness and undesired microstructures.

OR

Mechanically remove hard edge (1-2mm) after cutting by grinding, machining, etc.

This is especially important for bridges and other fatigue sensitive structures as hard, brittle edges are areas susceptible to crack initiation.
Welding High Strength Steels

Widely used Welding Processes for Structural Steels

- MIG/MAG
- Submerged Arc
- TIG
- MMA (Stick)
- GS-FCAW
- SS-FCAW
Welds must be made to a relevant Weld Procedure Specification which is backed up by appropriate Weld Procedure Qualification Records containing test results for strength, hardness, toughness, material and calibration certs, etc.
Hardenability of steel is measured and evaluated using the Carbon Equivalent Value. This value is derived by assessing the quantity of various elements contained in the steel that have an effect on hardenability. A standard formula is used to derive the value:

\[
CE = %C + \left( \frac{%Mn + %Si}{6} \right) + \left( \frac{%Cr + %Mo + %V}{5} \right) + \left( \frac{%Cu + %Ni}{15} \right)
\]

General grade steels are relatively easy to weld as their CEV’s are usually less than 0.46 and hence low hardenability.

TMCP Steels tend to also have a low CEV however the thicker, stronger variants of Q+T steels have CEV’s over 0.5 and hence are considered more difficult to weld.
High Strength Steels
Welding

**HSS Microstructure**

Q+T steels have a tempered Martensitic microstructure

![Martensite](image1)

Tempered Martensite

Heavily Tempered

TMCP steels have a fine grained ferrite+pearlite microstructure

![Conventional](image2)

TMCP
Hydrogen Cracking (Cold / Delayed Cracking)
Both types of steel gain strength from controlled cooling and heat treatment.

Welding generates high localised heat which can destroy parent metal properties if not appropriately controlled.

- Pre-heat to help prevent hydrogen cracking and decrease cooling rate may be employed.
- Inter-pass temperature and heat input kept relatively low to help prevent grain growth (lowering toughness) and over-tempering (lowering strength).
- Inter-pass temperature maintained to stop cold cracking in weld metal.

TIGHTER CONTROLS ON PARAMETERS
**Consumables (Filler Metal) for HSS**

- Usually strength of filler is ‘matched’ or ‘under-matched’
- Consumables for HSS usually more expensive
- Are highly alloyed
- Can have high CEV

Parent material has strength gained from careful control of micro-structure and grain refinement. Consumables do not have this luxury and hence gain their strength from micro-alloying.

This means that the filler metal for HSS can suffer from hydrogen cracking before the parent material. Parameters may have to be controlled based on the filler metal rather than the parent metal as is usually the case for ‘general’ grade steels.
High Strength Steels

Welding

SHEET CAPACITY: \( \frac{1}{3} \times 2.0 \times 1930 \times 690 = 15377 \text{ kN} \)

SAY 60% OF SHEAR CAPACITY = 15377 x 0.6 = 9226 kN

\[ \begin{align*}
I_{xx} &= \frac{400 \times 2000^3}{12} = 380 \times 1930^3 \quad = 3.90 \times 10^{10} \, \text{mm}^4 \\
2a_{cr} &= \frac{3.90 \times 10^9}{1000} = 3.90 \times 10^7 \, \text{mm}^3
\end{align*} \]

\[ \sigma_{w} @ 60\% P_{w} = \frac{9226 \times \frac{3.9}{2} \times 600 \times 982.5}{2 \times 3.70 \times 10^3} = 1.63 \text{ kN/mm} \]

\[ \alpha_{w} = \frac{1.63 \times 0.3 \times \sqrt{3}}{2} = 6.7 \text{ mm} \]

From EN 1993-1-8 6.3.3

LEG LENGTH REQ = 10 \text{ mm}
High Strength Steels

Welding

Distortion

HIGH YIELD + ‘LOW’ YOUNG’S MODULUS = HIGH DISTORTION

- Heat straightening limited to a temperature of 50°C lower than that given on material certs
- Tighter control required over sequencing of welds
- Pre-set geometry
- More ‘jigging’ and clamping
- Under-matching filler materials
High Strength Steels

Fatigue

![Graph showing stress range for life of $10^6$ cycles vs. ultimate tensile strength of steel, N/mm$^2$. The graph compares unwelded, drilled hole, and welded conditions.]

Courtesy of TWI
7.2 Fatigue strength modifications

7.2.1 Non-welded or stress-relieved welded details in compression

(1) In non-welded details or stress-relieved welded details, the mean stress influence on the fatigue strength may be taken into account by determining a reduced effective stress range $\Delta \sigma_{e,2}$ in the fatigue assessment when part or all of the stress cycle is compressive.

(2) The effective stress range may be calculated by adding the tensile portion of the stress range and 60% of the magnitude of the compressive portion of the stress range, see Figure 7.4.
High Strength Steels

Fatigue

![Graph of stress range vs. life cycles for different treatment methods, including As-welded, Hammer peened, Fully burr machined, Shot peened, Plasma dressed, Disc ground or locally burr machined.](Courtesy of TWI)
Table 14 — Technical knowledge of the coordination personnel
Structural carbon steels

<table>
<thead>
<tr>
<th>EXC</th>
<th>Steels (steel group)</th>
<th>Reference standards</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>EN 10025-2, EN 10025-3, EN 10025-4, EN 10025-5, EN 10149-2, EN 10149-3, EN 10210-1, EN 10219-1</td>
<td>t ≤ 25&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>EXC2</td>
<td>S235 to S355 (1.1, 1.2, 1.4)</td>
<td></td>
<td>B</td>
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<tr>
<td></td>
<td>S420 to S700 (1.3, 2, 3)</td>
<td>EN 10025-3, EN 10025-4, EN 10025-6, EN 10149-2, EN 10149-3, EN 10210-1, EN 10219-1</td>
<td>S</td>
</tr>
<tr>
<td>EXC3</td>
<td>S235 to S355 (1.1, 1.2, 1.4)</td>
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<td>S</td>
</tr>
<tr>
<td></td>
<td>S420 to S700 (1.3, 2, 3)</td>
<td>EN 10025-3, EN 10025-4, EN 10025-6, EN 10149-2, EN 10149-3, EN 10210-1, EN 10219-1</td>
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</tr>
<tr>
<td>EXC4</td>
<td>All</td>
<td>All</td>
<td>C</td>
</tr>
</tbody>
</table>

<sup>a</sup> Column base plates and endplates ≤ 50 mm.

<sup>b</sup> Column base plates and endplates ≤ 75 mm.

<sup>c</sup> For steels up to and including S275, level S is sufficient.

<sup>d</sup> For steels N, NL, M and ML, level S is sufficient.
QUESTIONS?