Specification of Structural Hollow Sections & Welded Joints In Tubular Steel

Steve Whitfield  Beng (Hons) CEng MIStructE
Customer Technical Services - Manager
Tata Group

One of the world’s fastest-growing and most reputable corporations

Tata Group is highly diversified

- Steel, Consultancy, Automotive, Power, Communications, Hotels, beverages
- Operations in more than 100 countries and 580,000 employees
- Total revenues $100 billion (67% from outside India)
- Ranked world’s 11th most reputable and 17th most innovative company
- Tata Sons 66% owned by philanthropic trusts
- £170 million invested in community projects last year
Tata Steel Group
One of the world’s most geographically-diversified steel producers

- Top 12 global steel producer
- Annual crude steel capacity of more than 29 million tonnes
- Around 80,000 employees
- Manufacturing operations in 26 countries across 4 continents
- Present in both mature and emerging markets
- Turnover in 2013-14: $ 24.8 billion (€18.0 billion)
- Fortune 500 company
Tata Steel Group

A global network serving demanding markets worldwide
Our key markets

Serving the most demanding markets worldwide

- Aerospace
- Automotive
- Construction
- Consumer products
- Defence & security
- Energy & power
- Lifting & excavating
- Packaging
- Rail
Tata Steel – Tube manufacturing

- Celsius is manufactured from Hartlepools & Corby mills.
- Hybox is manufactured from Hartlepools, Corby, Maastricht & Zwijndrecht mills.

- Hartlepools: 20° EW Mill
- Corby: EWSR No 1 Mill, EWSR No 2 Mill, 6° EW Mill, CFM 1 Mill, CFM 2 Mill
- Zwijndrecht: M93 Mill
- Maastricht: M80 Mill, M81 Mill
Tata Steel Europe, Tubes

Celsius – EN10210 Hot finished Structural Hollow Sections

Steve Whitfield  Beng (Hons) CEng MIStructE
Customer Technical Services - Manager
<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Tata Steel Europe, Tubes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Technical information</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Testing, Certification and traceability</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Technical Support &amp; Tools</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Summary</td>
</tr>
</tbody>
</table>
Manufacture of Hollow Sections

EN10219 – Cold Formed Structural Hollow Sections
Hybox

EN10210 – Hot Finished Structural Hollow Sections
Celsius
Celsius 420 – Full Body Normalised

Furnace
The right product for the rights application

Hot Finished Structural Hollow Sections
- EN10210:S355 NH, EN10210:S355J2H
- EN10210:S420 NH

Cold Formed Structural Hollow Sections
- EN10219:S355J2H
- EN10219:S355JRH

It is important to ensure you have the correct specification
Technical Information

Hot Finished Structural Hollow Section of Non-alloy and Fine Grain Steels

CELSIUS 355 - EN10210:S355 NH

- Tensile Strength: 470N/mm² – 630 N/mm²
- Minimum yield strength: <= 16mm - 355 N/mm²
- Minimum Impact -20°C @ 40 J
- Elongation - 19%
- Carbon Equivalent (CEV) - 0.43
- Silicon Content Si - 0.60
- Silicon Content (Si) Celsius 420 NH – 0.15 to 0.25

Product Specification
Hot Finished Structural Hollow Section of Non alloy and Fine Grain Steels

**CELSIUS 420 - EN10210:S420 NH**

- **Tensile Strength**: 520N/mm² – 680 N/mm²
- **Minimum yield strength**: <= 16mm : 420 N/mm²
- **Minimum Impact**: -20°C @ 40 J
- **Elongation**: - 19%

- **Carbon Equivalent (CEV)**: - 0.50
- **Silicon Content Si**: - 0.60
- **Silicon Content (Si)**: Celsius 420 NH – 0.15 to 0.25
- **Carbon Equivalent (CEV)**: Celsius 420 NH – 0.45
Technical Information

Due to the manufacture the Celsius has many advantages on a size for size basis compared to EN10219:

- Tighter corner profiles on hot. – Better area less weight.
- Weld line - Due to the full body normalising the weld line becomes the same as the tube. Better consistency for product
- Consistent hardness values around the whole perimeter. – During heating or manipulating/ bending no loss of yield, tensile, Charpy impacts. Can weld in corner of hot but issues with cold.
- No built in stress – Design standards recognise the difference and have higher compression and tension for same size same thickness.

Advantages of Celsius Compared to Cold Formed
Technical Information

EN10219 Cold Formed products

Hybox

EN10210 Hot Finished products

Celsius

Advantages of Celsius Compared to Cold Formed
### Technical Information

**Comparison Hot and Cold for design - Sectional properties**

<table>
<thead>
<tr>
<th>EN10210 Hot finished</th>
<th>Area(A) cm²</th>
<th>Moment of Inertia(I) cm⁴</th>
<th>Elastic modulus(Z) cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 10219 Cold formed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>120 x 120 x 8 RHS Hot Finished</td>
<td>35.2</td>
<td>726</td>
<td>121</td>
</tr>
<tr>
<td>120 x 120 x 8 RHS Cold Formed</td>
<td>33.6</td>
<td>677</td>
<td>113</td>
</tr>
</tbody>
</table>

**Advantages of Celsius Compared to Cold Formed**
Hot finished

- Test results follow normal load extension characteristics with clear indication of yield strength.
- Gives the recommended ratio of yield to ultimate strength - 0.84 maximum.
- High ductility - adequate warning of dangerous overload condition indicated by excessive deformation.
Mechanical properties

Cold formed

- Test results differ in samples taken from corners and flat sides.
- There is no clear yield point-0.2% proof stress is normally quoted for yield strength.
- Increase in ratio of yield to ultimate strength may be above that recommended by design standards.
- Lower ductility-less visible warning of dangerous overload condition possibility of brittle fracture.

Advantages of Celsius Compared to Cold Formed
## Comparison of strut capacity (kN) EC3

<table>
<thead>
<tr>
<th>λ bar</th>
<th>Hot finished S355J2H</th>
<th>Cold formed S355J2H</th>
<th>CF/HF Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>120x120x5</td>
<td>0.8</td>
<td>641</td>
<td>526</td>
</tr>
<tr>
<td>120x120x10</td>
<td>0.8</td>
<td>1212</td>
<td>954</td>
</tr>
<tr>
<td>300x300x12.5</td>
<td>0.8</td>
<td>4011</td>
<td>3103</td>
</tr>
<tr>
<td>406.4 x 16</td>
<td>0.8</td>
<td>5536</td>
<td>4607</td>
</tr>
</tbody>
</table>

Advantages of Celsius Compared to Cold Formed
Structure & Hardness

Hot Finished products

- Uniform grain structure and hardness values
- Mechanical properties are stable and uniform across the whole section

Cold Formed products

- Varying grain structure and hardness values, particularly in the corners and seam weld area
  - Mechanical properties vary across the section

Advantages of Celsius Compared to Cold Formed
### 4.14 Welding in cold-formed zones

(1) Welding may be carried out within a length $5t$ either side of a cold-formed zone, see Table 4.2, provided that one of the following conditions is fulfilled:
- the cold-formed zones are normalized after cold-forming but before welding;
- the $r/t$-ratio satisfy the relevant value obtained from Table 4.2.

<table>
<thead>
<tr>
<th>$r/t$</th>
<th>Strain due to cold forming (%)</th>
<th>Maximum thickness (mm)</th>
<th>Generally</th>
<th>Fully killed Aluminium-killed steel ($\text{Al} \geq 0.02%$)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Predominantly static loading</td>
<td>Where fatigue predominates</td>
</tr>
<tr>
<td>$\geq 25$</td>
<td>$\leq 2$</td>
<td>any</td>
<td>any</td>
<td>any</td>
</tr>
<tr>
<td>$\geq 10$</td>
<td>$\leq 5$</td>
<td>any</td>
<td>16</td>
<td>any</td>
</tr>
<tr>
<td>$\geq 3.0$</td>
<td>$\leq 14$</td>
<td>24</td>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>$\geq 2.0$</td>
<td>$\leq 20$</td>
<td>12</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>$\geq 1.5$</td>
<td>$\leq 25$</td>
<td>8</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>$\geq 1.0$</td>
<td>$\leq 33$</td>
<td>4</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

**NOTE**: Cold formed hollow sections according to EN 10.219 which do not satisfy the limits given in Table 4.2 can be assumed to satisfy these limits if these sections have a thickness not exceeding 12.5 mm and are Al-killed with a quality J2H, K2H, MH, MLH, NH or NLH and further satisfy $C \leq 0.18\%$, $P \leq 0.020\%$, and $S \leq 0.012\%$.

In other cases welding is only permitted within a distance of $5t$ from the corners if it can be shown by tests that welding is permitted for that particular application.

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**Eurocode**

EC3-1-8 table 4.2 (including corrigenda feb 2010)
Comparison between Hot & Cold

- Hot Finished Celsius - has no residual stresses from manufacturing.
- Hot Finished Celsius - has uniform grain structure and hardness.
- Hot Finished Celsius - has tighter corner profile (2T max – Celsius).
- Hot Finished Celsius - has higher geometric properties.
- Hot Finished Celsius - has higher load capacity.
- Hot Finished Celsius - is fully weldable at corners.
- Hot Finished Celsius - has superior ductility for seismic & shock loads.
- Hot Finished Celsius - has greater fire resistance.

Advantages of Celsius Compared to Cold Formed
The Celsius 420 is full body normalised and final shaped at a high temperature ensuring that the product is fully stress relieved. The product Standard EN10210 does allow for warm/ stress relieved which will not give the same consistent values as Celsius. The warm product is manufactured cold then shaped giving similar disadvantages for manufacture as the cold product.

Advantages of Celsius Compared to Warm/ Stress relieved products
Technical Information

The Celsius 420 is a true full body normalised hot finished structural hollow section. It should be compared more with the seamless tube than warm and cold. When we compare the Celsius 420 against the seamless product due to the consistent manufacture it has better tolerances. The product standard EN10210 recognises this and the Celsius has better tolerances.

- **Celsius 420** has better control on wall thickness (seamless can be up to -12,5% over 25% of perimeter)
- **Celsius 420** has a uniform wall thickness and thus a concentric “Bore”. Seamless sections may be more difficult in fabrication
- **Celsius 420** sections have a finish similar to original strip condition whereas seamless finish is typical of a hot rolling process
- **Celsius 420** has tighter tolerance on supplied length (0/+150mm) versus seamless (+/- 500mm)
- **Celsius 420** has full chemical composition stated on inspection certificate
Welded Joints In Tubular Steel

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Overview

1. Introduction
2. Eurocode 3 Part 1-8
3. Failure Modes
4. Examples
5. New Developments
Introduction
Emirates Stadium

Long span trusses
Gloucester Quays

Speed and simplicity of construction
M8 Footbridge Harthill

Speed and simplicity of construction
M8 Footbridge Harthill

Quality control
M8 Footbridge Harthill

Lifting
Design Guidance

Evolution
Design Guidance

Second Edition Cidect Design Guides
Typical Joints

Lattice Girders

T or Y-Joint ➔ X-Joint ➔ Gap K-Joint
Typical Joints

Miscellaneous

- Transverse Gusset Plate
- Longitudinal Gusset Plate
- I or H Bracing
Joint Symbols

Brace 1 usually compression brace
Eccentricity & Effects On Geometry

Parameters

Joint with \( e = 0 \)

- Eccentricity limit: \(-0.55 \leq e/d_0 \leq 0.25\) (shaded)
- Gap limits:
  \[ g \geq t_1 + t_2 \]
  \[ 0.5(1-\beta) \leq g/b_0 \leq 1.5(1-\beta) \]
- Overlap limit:
  \[ 25\% \leq Ov \leq 100\% \]
Eccentricity & Effects On Geometry
Positive eccentricity – gap joint

Eccentricity limit: \(-0.55 \leq \frac{e}{d_0} \leq 0.25\)
Gap limits: \(g \geq t_1 + t_2\)
\(0.5(1-\beta) \leq \frac{g}{b_0} \leq 1.5(1-\beta)\)
Overlap limit: \(25\% \leq Ov \leq 100\%\)
Joint Symbols

Negative eccentricity – overlap joint

Eccentricity limit: \(-0.55 \leq \frac{e}{d_0} \leq 0.25\)

Gap limits:
\[ g \geq t_1 + t_2 \]
\[ 0.5(1-\beta) \leq \frac{g}{b_0} \leq 1.5(1-\beta) \]

Overlap limit: \(25\% \leq Ov \leq 100\%\)
# Fabrication Costs

Bracing Handling, Cutting and Welding

<table>
<thead>
<tr>
<th>Fabrication Cost</th>
<th>Type of Joint</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RHS chord - gap joints</td>
</tr>
<tr>
<td></td>
<td>RHS chord – 100% overlap joints</td>
</tr>
<tr>
<td></td>
<td>CHS chord – gap joints</td>
</tr>
<tr>
<td></td>
<td>RHS chord – partial overlap joints</td>
</tr>
<tr>
<td></td>
<td>CHS chord – 100% overlap joints</td>
</tr>
<tr>
<td></td>
<td>CHS chord – partial overlap joints</td>
</tr>
</tbody>
</table>
Laser Cutting

- Repeatability
- High Volume Manufacturing
- Versatility - Ease of assembly

- Speed
- Reduced Weld preparation
- Can cut bent tube
## Fabrication Costs

### Bracing Handling, Cutting and Welding

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<td></td>
<td>CHS chord – partial overlap joints</td>
</tr>
</tbody>
</table>
Parameter Effects

Gap Joints

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Direction</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chord width to thickness ratio</td>
<td>Down</td>
<td>Capacity up</td>
</tr>
<tr>
<td>Bracing to chord width ratio</td>
<td>Up</td>
<td>Capacity up</td>
</tr>
<tr>
<td>Bracing angle</td>
<td>Down</td>
<td>Capacity up</td>
</tr>
<tr>
<td>Chord factored to yield stress ratio</td>
<td>Less compressive</td>
<td>Capacity up</td>
</tr>
</tbody>
</table>
Parameter Effects – Gap Joints

Chord width to thickness ratio
Parameter Effects – Gap Joints

Bracing to chord width ratio
Parameter Effects – Gap Joints

Bracing angle
Parameter Effects – Gap Joints

Chord factored to yield stress ratio
## Parameter Effects

### Overlap Joints

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Direction</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chord width to thickness ratio</td>
<td>Down</td>
<td>Capacity up</td>
</tr>
<tr>
<td><strong>Bracing width ratios</strong></td>
<td>Down</td>
<td>Capacity up</td>
</tr>
<tr>
<td>Overlap</td>
<td>Up</td>
<td>Capacity up</td>
</tr>
<tr>
<td>Chord factored to yield stress ratio</td>
<td>Less compressive</td>
<td>Capacity up (CHS only)</td>
</tr>
<tr>
<td>Bracing angle</td>
<td>Down</td>
<td>Capacity up (CHS only)</td>
</tr>
</tbody>
</table>
Parameter Effects – Overlap Joints

Bracing width ratios

Overlapped brace

Overlapping brace

Overlapping brace
Parameter Effects – Overlap Joints

Overlap percentage
Failure Modes
Failure modes

- **Chord Face Deformation**
- **Chord Punching Shear**
- **Chord Side Wall Buckling**
- **Chord or brace localised buckling**
- **Chord Shear**
- **Bracing Effective Width**
Chord Face Deformation Failure

Also known as chord face yielding. This is the chord face deflecting under the bracing load. The formula limits the chord face deflection to 3% of the chord width as the deformation can be substantial without failing but it would not be practical to allow such deformation. Common for T, Y-joints and gap K, N-joints with the bracing to chord width ratio less than 0.85.
Where the bracing punches through the chord face. This occurs on the tension brace, important to realise it applies to compression and tension bracings. Shear can occur when the brace is pulling just the same as when the brace is pushing. Not usually critical but can occur when the chord width to thickness ratio is small.

The chord has sheared not the weld.
Chord Side Wall Buckling

Typically a gap joint or single brace with beta ratio (brace width to chord width ratio) >0.85 as in this example. The chord side wall under the compression brace acts as a strut and if the chord side wall is too thin and tall it will buckle under the compressive load.
Chord or Bracing Localised Buckling

Due to a non-uniform stress distribution at the joint but does not occur providing the joint parameters are met.
Chord Shear

Not often critical unless RHS chords with width greater than depth are used. Does not occur for CHS joints if within parameters.
**Horizontal Shear**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear of overlapping bracings</td>
<td><img src="image" alt="Diagram of shear" /></td>
</tr>
</tbody>
</table>

- **Local shear of overlapping bracings**, figure 17, is due to the horizontal component from the bracing forces shearing. This failure mode becomes critical for large overlaps, over 80% or 60% depending if the hidden toe of the overlapped bracing is welded to the chord.
Failure modes

Bracing effective width RHS/SHS Chord

Axial stress distribution

Hypothetical axial stress distribution
Failure modes

Bracing effective width UB/UC Chord

Axial stress distribution

Hyperthetical axial stress distribution
Detailing and Welding
**Detailing**

**Overlaps**

- Overlap = p
- Overlap % = p/q x 100

- Overlap bracings should NEVER be made like this
- Difficult to fabricate
- Up to 20% weaker

- Use division plate as alternative
- Helps to reinforce joint
Detailing

Knee Joints

Un-reinforced Knee

Reinforced Knee
Detailing

Multiplanar joints
Multiplanar Joints

TT Joint

Member 1 may be either tension or compression.

\[ \mu = 1.0 \]

\[ 60^\circ \leq \varphi \leq 90^\circ \]
Multiplanar Joints

XX Joint

Members 1 and 2 can be either in compression or tension. $N_{2,Ed}/N_{1,Ed}$ is negative if one member is in tension and one in compression.

$$\mu = 0.9 \left(1 + 0.33 \frac{N_{2,Ed}}{N_{1,Ed}}\right)$$

taking account of the sign of $N_{1,Ed}$ and $N_{2,Ed}$

where $|N_{2,Ed}| \leq |N_{1,Ed}|$
Multiplanar Joints

KK Joint

\[ \mu = 0.9 \]

provided that, in a gap-type joint, at section 1-1 the chord satisfies:

\[ \left( \frac{N_{0,Ed}}{N_{pl,0,Rd}} \right)^2 + \left( \frac{V_{0,Ed}}{V_{pl,0,Rd}} \right)^2 \leq 1.0 \]
Multiplanar Joints

Finite element modelling
Welding

Throat thickness

<table>
<thead>
<tr>
<th>STEEL GRADE</th>
<th>Minimum throat size a (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(EN10210 S355J2H)</td>
<td>CIDECT DESIGN GUIDE 1 &amp; 3</td>
</tr>
<tr>
<td>CELSIUS 355</td>
<td>1.1 t</td>
</tr>
</tbody>
</table>
Welding

Throat thickness

<table>
<thead>
<tr>
<th>Leg length (l) mm</th>
<th>Throat thickness (a) mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>4.2</td>
</tr>
<tr>
<td>8</td>
<td>5.6</td>
</tr>
<tr>
<td>10</td>
<td>7.0</td>
</tr>
</tbody>
</table>

Elements at 90°
Welding

Cold forming

### 4.14 Welding in cold-formed zones

(1) Welding may be carried out within a length 5t either side of a cold-formed zone, see Table 4.2 provided that one of the following conditions is fulfilled:
- the cold-formed zones are normalized after cold-forming but before welding;
- the $r/t$-ratio satisfy the relevant value obtained from Table 4.2.

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</tr>
<tr>
<td>≥ 25</td>
<td>≤ 2</td>
<td>any</td>
<td>any</td>
</tr>
<tr>
<td>10</td>
<td>≤ 5</td>
<td>any</td>
<td>any</td>
</tr>
<tr>
<td>3,0</td>
<td>≤ 14</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>2,0</td>
<td>≤ 20</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>1,5</td>
<td>≤ 25</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>1,0</td>
<td>≤ 33</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

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Slide

Welded Joints In Tubular Steel

Tata Steel

Slide 73
Welding

Cold forming

200 x 200 x 10 CF RHS
Welding

Cold forming

Material Standard EN10219 has the following corner radius range:

- T<6 mm: 1.6T to 2.4T
- 6mm<T<10: 2.0T to 3.0T
- 10<T: 2.4T to 3.6T
Joint Design Considerations

- The joint strength is determined by the selected chord and bracing member sizes, grades and geometry.
- These are decided by the designer.
Summary

- From a compression member strength consideration, large thin wall sections are preferred (reduced l/r ratio).

- From a joint strength consideration, small thick wall chords are preferred to large thin wall chords.

- A large bracing width to chord width ratio generally increases the joint strength. This favours the use of a small thick wall chord to large thin bracing.
Conclusion

- Joint Capacity is dependant on:
  - Brace Angle
  - Bracing Width to Chord Width Ratio
  - Chord Width to Thickness Ratio
  - Gap or Overlap Bracings
  - Chord Compressive Stress
  - Chord Yield Strength
Joint Design Examples

Example 1 – CHS Gap K-joint

DESIGN CHECKS :-

• Parameter Limits (5.1.1)
• Chord Face Deformation (5.1.3), Chord End Load Function (5.1.2)
  Gap/Lap Function (5.1.2)
• Chord Punching Shear (5.1.3)
Joint Design Examples

Example 2 – CHS Overlap K-joint

DESIGN CHECKS :-

• Parameter Limits (5.1.1)
• Chord Face Deformation (5.1.3), Chord End Load Function (5.1.2)
  Gap/Lap Function (5.1.2)
• Localised shear check (if greater than 60 %)
• Chord Punching Shear (5.1.3)
Joint Design Examples

Example 3 – RHS Gap K-joint

DESIGN CHECKS :-

• Parameter Limits (5.2.1)
• Chord Face Deformation (5.2.3), Chord End Load Function (5.2.2)
• Chord Shear Between Bracings (5.2.3), Chord Shear Area (5.2.2)
• 4. Bracing Effective Width (5.2.3), Normal Effective Width (5.2.2)
• 5. Chord Punching Shear (5.2.3), Normal Effective Width (5.2.2)
  Punching Shear Effec. Width (5.2.2)
• 6. Chord Axial Load Resistance At Gap (5.2.3),
  Factored Applied Shear Load In Gap (7.1)
  Chord Shear Capacity (7.1)
New Developments

**Tubular Joint Design Program**
- Updated to include latest amendments to Eurocode 3 Part 1-8

**Concrete Filled Hollow Section**
- FireSoft design software available and Design Guide for Concrete Filled Structural Hollow Section which constitutes NCCI to Eurocode 4 Part 1-2

**Fine Grained Steel**
- Celsius S420 now available as EN10210 S420 NH
### Celsius 420 - Specification

#### EN10210:S420 NH

<table>
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<th>Property</th>
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<tr>
<td>Minimum yield strength</td>
<td>&lt;= 16mm: - 420 N/mm²</td>
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<tr>
<td>Tensile Strength</td>
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<td>Minimum Impact</td>
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<td>Elongation</td>
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**Carbon Equivalent (CEV)**
- Celsius 420 NH – 0.45
- Carbon Equivalent (CEV) – 0.50

**Silicon Content Si**
- 0.60
- Silicon Content (Si) Celsius 420 NH – 0.15 to 0.25
Celsius 420 starts to deform plastically (irreversible) at a higher Yield

Celsius 420 reaches a higher ultimate strength before sample fractures

- Yield / Ultimate

\[ \frac{420}{355} = 1.17 \]
Celsius 420 - Technical Information

- **Celsius S355**
  - 200x100x10

- **Celsius S420**
  - Can make thinner/lighter
  - e.g. 200x100x6.3

- **Celsius S420**
  - Or smaller
  - e.g. 200x100x6.3
Celsius 420 - Technical Information

50 m span plain roof truss
4m deep
Purlins at 4m centres, Trusses @ 15 m centres

EN10210 S355 J2H Design
Chord – 273 x 10 CHS
Brace – 219.1x6.3 CHS
Truss weight = 9.5 tonnes

Celsius EN10210 S420 NH Design
Chord – 244.5 x 10 CHS
Brace – 193.7x6.3 CHS
Truss weight = 8.4 tonnes

Weight Saving - Example
Celsius® 420 – Size range and offering

**Celsius® 420 - Circular Hollow Sections**

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**Celsius® 420 – Size range and offering**

**Celsius® 420 - Square Hollow Sections**

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Celsius® 420 – Size range and offering

### Celsius® 420 - Rectangular Hollow Sections

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r = External corner radius > 2T but < 3T

### Celsius® 420 - Elliptical Hollow Sections

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Celsius® – Additional Tools

Tube Element Design Package

To assist Engineers in the design using Celsius®.
For software download from –

Commercial enquiries –
commercialcelsius420@tatasteel.com

Technical enquiries –
technicalcelsius420@tatasteel.com
Concrete Filled Hollow Sections

Wellcome Trust - London
SHS Joint Design References

  - Corrigenda 2 was issued September 2006
  - Final CEN corrigenda added February 2010
- Similar rules to Annex K (1992) except symbols changed but the major equations remain the same.
  - Eg: End load function $f_n$ now $k_p$
  - Joint partial safety factor with UK NA
    - Annex K :- Formula $\times 1.10/\gamma_{Mj}$ where $\gamma_{Mj} = 1.10$
    - EC3-1-8 :- Formula $/\gamma_{M5}$ where $\gamma_{M5} = 1.00$