TATA STEEL

TATA

Celsius® 355: the ultimate choice

Hot structural hollow sections

Contents

CELSIUS® 355

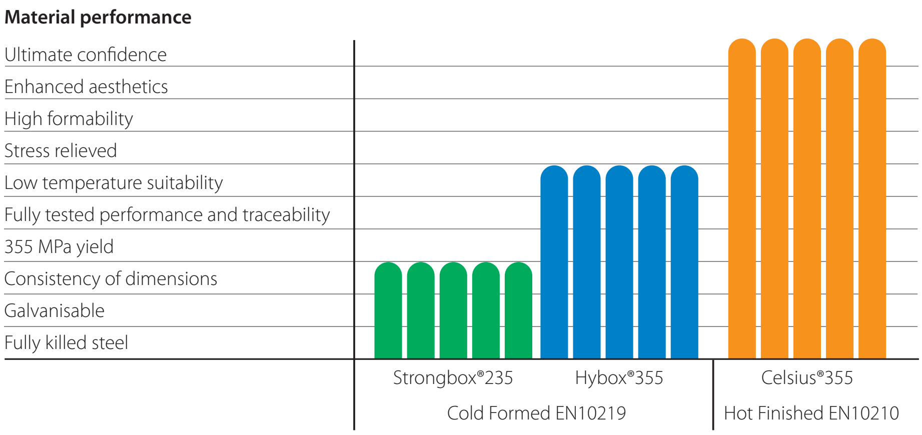
The quality of hollow sections is critical to the performance of structures. Not all hollow sections are the same. Using the wrong type of section may reduce the performance of your structure.

Celsius® 355 is the ultimate hot-finished structural hollow section. Developed to perform in the most arduous conditions, **Celsius® 355** has outstanding properties and is the only choice where failure is not an option.

Why choose Celsius® 355?
Key differences between **Celsius® 355** and cold-formed hollow sections.

- Homogeneity
- High ductility
- Resistance to fracture
- Virtual absence of residual stress
- Section properties
- Buckling strength
- Dimensional stability
- Fire resistance

Quality progression



Key

Strongbox®235 | Hybox®355 | Celsius®355

CELSIUS® 355 EXPLAINED

EN10210 – Hot-finished structural hollow sections
ASTM A501 – Hot-formed welded carbon steel structural tubing

Celsius® 355 is a hot-finished, welded structural hollow section. It is supplied in accordance with both the European Standard EN 10210 and the American Standard ASTM A501. It far exceeds the minimum specified requirements, with guaranteed minimum yield strength of 355 N/mm^2 (51.5 ksi). **Celsius® 355** complies with and exceeds the classification EN10210 S355 J2H. It can also be produced to meet EN10210 S355 NH as an optional extra.

The majority of the **Celsius® 355** range is produced using the high frequency induction (HFI) welding process (dimensions up to 400mm x 400mm square, 500mm x 300mm rectangular and 508mm circular). The submerged arc welding (SAW) process is used to manufacture larger section sizes (dimensions up to 800mm x 800mm square, 750mm x 500mm rectangular and 2134mm circular).

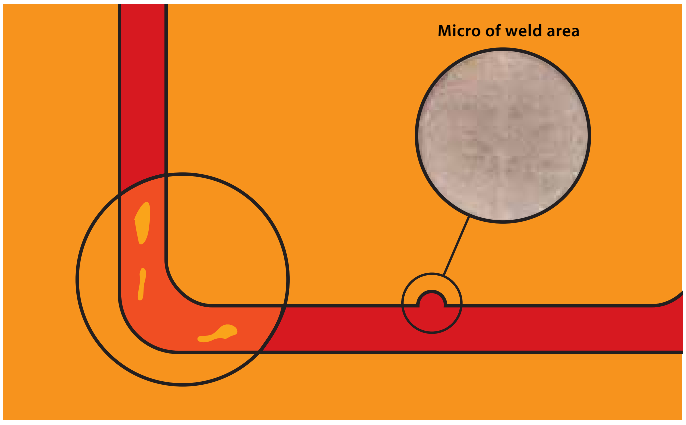
All Celsius® 355 hot-finished structural hollow sections:

- Are formed at a high, normalising temperature while fully austenitic
- Have a uniform grain structure and hardness over the whole section
- Have mechanical properties that are stable and uniform over the whole section

Celsius® 355 is not simply stress-relieved but fully formed at a high temperature, usually in excess of 840°C. As the material cools, a phase transformation takes place, producing a fine-grained, uniform ferrite structure with consistent properties. Under EN10210, stress relieving of cold-formed products at lower temperature is allowed, enabling minimum standards to be met. However, this does not produce a phase change and leaves a varying grain structure throughout the section. Therefore, areas of microstructural inhomogeneity will exist and mechanical properties will also vary around the section. These properties will vary at the same points normally found in cold-formed hollow sections.

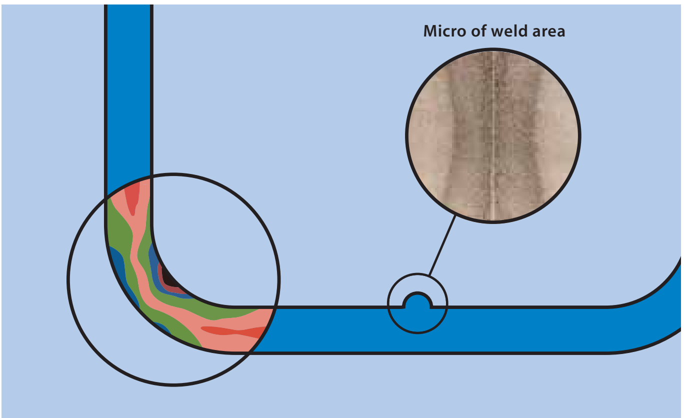
Celsius® 355 is manufactured differently to cold-formed hollow sections (European Standard EN10219 and American Standard ASTM A500). Cold-formed sections are shaped at ambient temperature without further heat treatment, meaning they have a non-uniform microstructure. The mechanical properties in the weld heat-affected zones and in the corners of square and rectangular sections are inferior to those in the body of the section. These differences are illustrated in Figures 1 and 2, which show photomicrographs of the weld areas and schematic maps of Vickers Hardness values in the corners. **Celsius® 355** has low and uniform hardness in the corners whereas a typical cold-formed section has hardness of 180 in the centre of the thickness, peaking to over 200 and 250 on the outside and inside surfaces respectively.

Figure 1:



Celsius®355 has uniform grain structure with low hardness.

Figure 2:



Cold-formed structural hollow sections have varying grain structure with hardness peaks.

For traceability and quality of the material for each specific structural application, all **Celsius®355** is certified to EN10210 and American Standard ASTM A501. In accordance with EN10204, we issue Inspection Certificate Type 3.1.

Figure 3:

TATA A04 **Tata Steel UK Limited** A01
Corby Works
PO Box 101
Corby Northants UK NN17 5UA
Telephone: +44 (0)1536 402121
Fax: +44 (0)1536 404111

INSPECTION CERTIFICATE
EN10204 Type 3.1 A02

Page No. 1 of 1

Date	01/09/10 Z02
Cert No.	120/1035/0397C A03
Del. Note	EWC /0029

Customer A06
A.N.OTHER
ANYTOWN
ANYWHERE
AB12 3CD

CE 0038 0840080 4004615

Tata Steel Ref.No. Sales GXA 300667 Works 30 3976 A08
Customer Order No. P/O: 40113677 OF 17/JUN/10 A07
Product Description B01-B04
CELSIUS HOT FINISHED WELDED STEEL RECTANGULAR HOLLOW SECTIONS TO EN 10210 : 2006 GRADE S355J2H.

EC CERTIFICATE (FPC) NUMBER 0038/CPD/20070003/A
DURABILITY: NO PERFORMANCE DETERMINED - SUBJECT TO FINAL COATING

L=Longitudinal T=Transverse B=Body W=Weld HAZ=Heat Affected Zone S=Stripped Section F=Full Section KV=Charpy - V HV= Hardness Vickers(10Kg Load) HR=Hardness Rockwell B

Item No.	B08 Number of Pieces	B09-B12 Product Dimensions (mm)	B07 Cast/Heat No.	Tensile Test C01 C02 C10	C11 Yield Stress Re (N/mm²)	C12 Tensile Strength Rm (N/mm²)	C13 Elong A 5.65 (%)	Impact/Hardness Tests C01 C02	C40 C30 Test Type	C41 Width (mm)	C03 Temp (C)	C42 C31 Values (J)	C43 C32 Ave (J)	Steel Making Process C70 / Other Tests C50-C69 D02-D99
														BASIC OXYGEN STEEL
2	12	120.00 x 120.00 x 8.00 x 12.200M = 146.40M	7T28703	B L S	376.0	515.0	32	B L	KV	5.0	-20	102 98 92	97	WELD SEAM 100% EDDY CURRENT TESTED TO EN 10246-3 FLATTENING TEST FOR SEAM WELD QUALITY CONTROL, SATISFACTORY

x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x END OF ITEM x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x

x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x END OF CERT x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x

C71-C99 Analysis % Cast No.	C	Si	Mn	P	S	Cr	Mo	Ni	Al	B	Cu	N	Nb	Sn	Ti	V	CEV
7T28703 LADLE	0.15	0.22	1.40	0.016	0.0034	0.015	0.001	0.015	0.029	0.0002	0.015	0.004	0.033	0.003	0.003	0.001	0.39

Code Numbers in accordance with EN 10168 (see overleaf).

Alterations to this document or its use for other products shall be regarded as falsification of documents and be subject to criminal jurisdiction.

The products covered by this inspection document are certified by Tata Steel UK Limited and comply with the requirements of the Product Description. Z01
Corby Works Quality System complies with Pressure Equipment Directive (PED) 97/23/EC Annex I Para. 4.3.

J.M.Dawson Z02
Test House Manager A05

This document has been prepared by a computer system and is valid without signature.

Typical inspection certificate type 3.1 produced to EN10204

AN INFORMED CHOICE

The difference between Celsius® 355, cold-formed and cold-formed stress-relieved products. Celsius® 355 shows different characteristics over a range of properties because of the manufacturing process. The key differences are as follows:

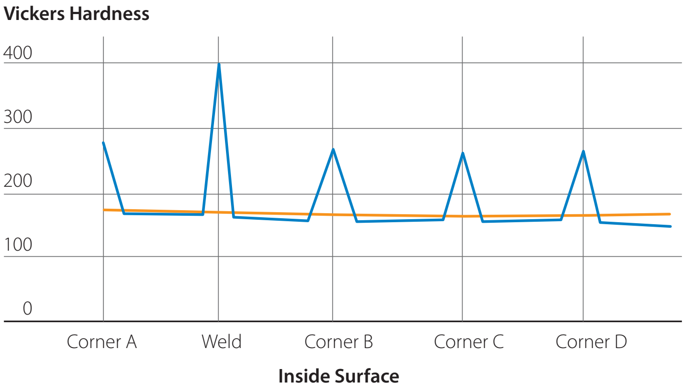
Homogeneity

Celsius® 355 has a uniform grain structure and similar properties right across the section. Vickers Hardness values are the same in the flat, corner and seam weld zones (**Figure 4**). Cold-formed sections have greater brittleness in the corner and seam weld zones compared to the body of the section. This is illustrated in **Figure 4** by peaks of hardness.

Ductility

Celsius® 355 has high ductility at all points and in all directions. So, even after yield, there is still a reserve of ductility beyond the unloading line, such as in areas local to connection points. The tensile test is used to measure ductility using specimens in a longitudinal direction, from the centre of the flat face or away from the weld in circular sections. However, in cold-formed sections, ductility is substantially reduced in these areas and the standard test will not show this. In general, bodies under load need to be able to resist a certain level of multidirectional stresses and this cannot be guaranteed in cold-formed sections.

Figure 4:

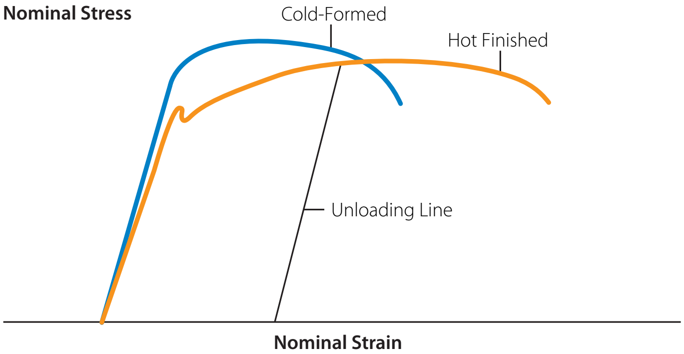


Key

Hot Cold

Typical plot of hardness values on inside surface of square structural hollow sections.

Figure 5:



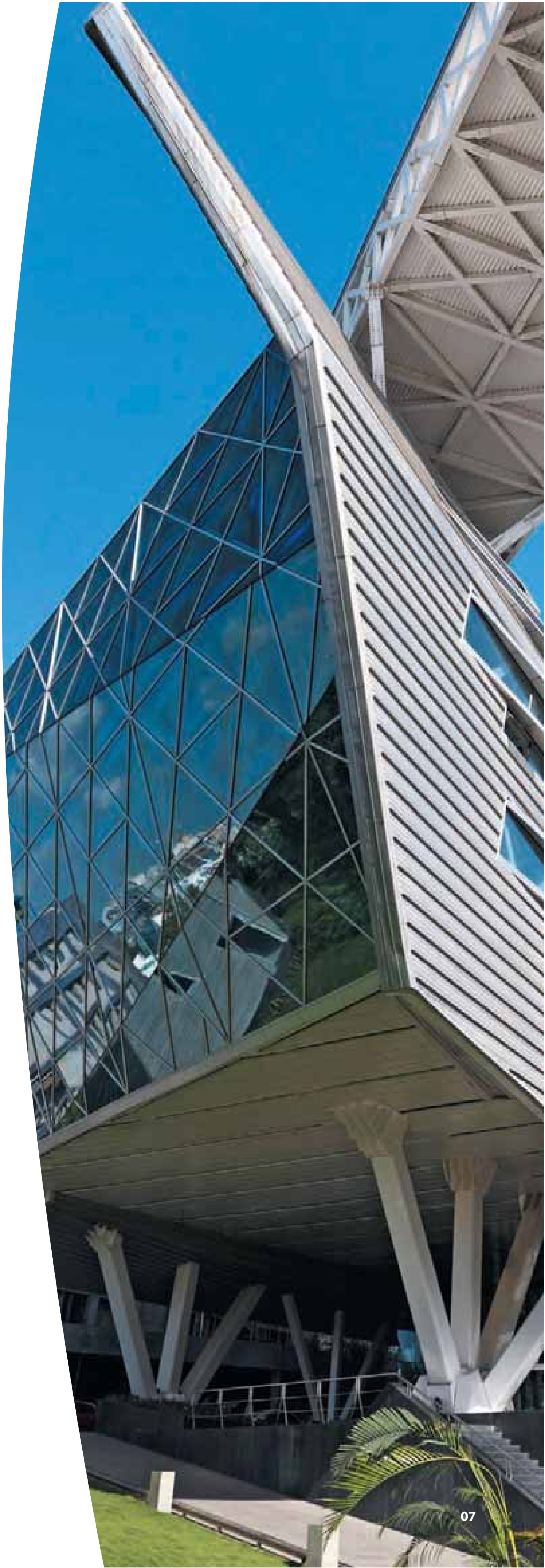
Key

Hot Cold

Schematic stress: strain plots for test specimens taken from corners of **Celsius® 355** and cold-formed structural hollow sections indicating differences in ductility.

Figure 6:

Photograph of stages of the tensile test indicating ductility achieved by test specimen taken from **Celsius®355**.



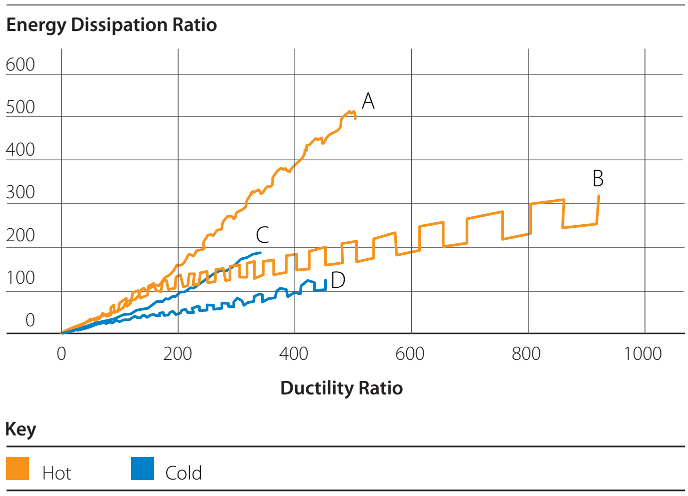
Resistance to fracture

Whilst maintaining a low yield ratio (yield/tensile), **Celsius® 355** has good energy absorption and high resistance to fracture. These properties ensure much better endurance under load, particularly cyclic or dynamic impact load. In the standard Charpy test, **Celsius® 355** achieves uniformly high absorbed energy values and low transition temperatures.

When tested, impact specimens are taken from a longitudinal direction and the centre of the flat face or away from the weld in circular sections. This means the substantially reduced fracture resistance in the corners or weld zones is not indicated in cold-formed hollow sections (**see figures 7 and 8**). So, when specifying materials, it is important to take into account the cold-formed hollow section's planes of relative weakness of resistance to fracture either side of the weld lines. Our **Celsius® 355** products substantially exceed the minimum impact values set out in EN10210 and ASTM A501. Also, the yield ratio is approximately 0.74 for the larger sizes (not specified in the standard).

Figure 7:

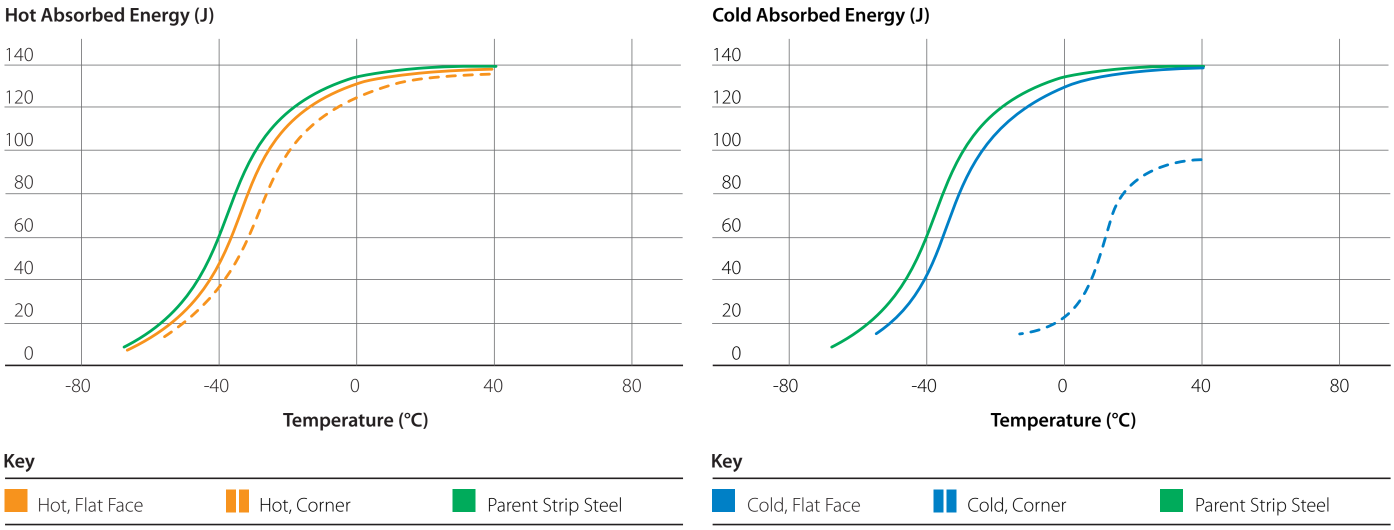
A & C = 150sq/100sq bird-beak joint
B = 150sq/120sq traditional joint
D = 150sq/120sq bird-beak joint



Energy dissipation versus ductility plots for X-joints under reverse loading. This indicates superior performance of the hot-finished sections (see Footnote 1).

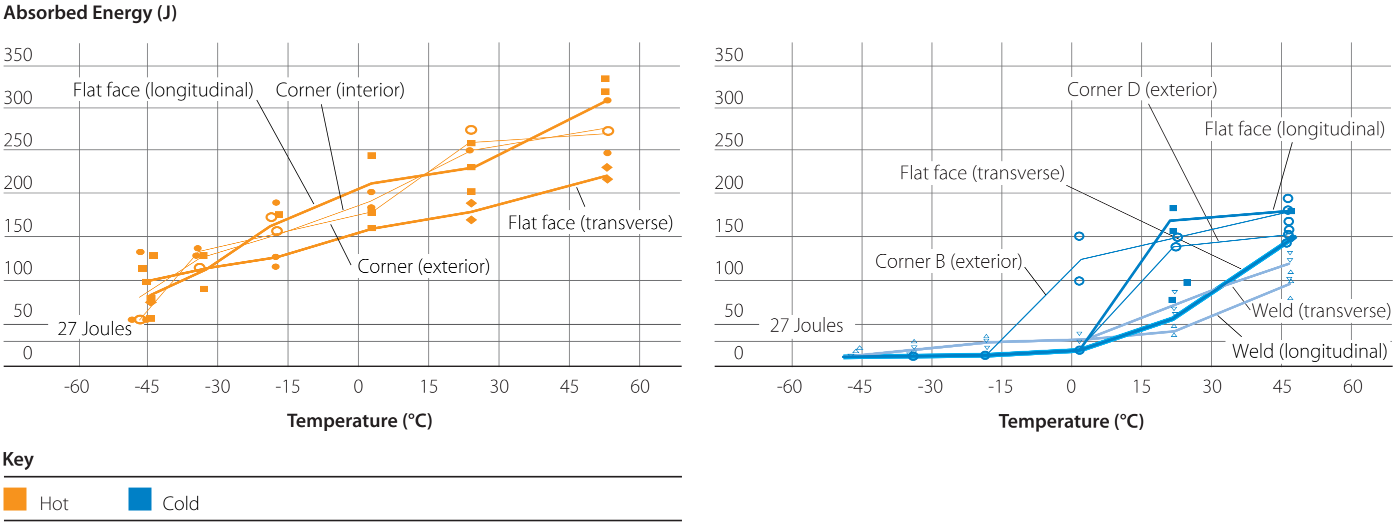
Reproduced by kind permission of the University of Nottingham

Figure 8:



Typical Charpy toughness: temperature graph for specimens taken from structural hollow sections.

Figure 9:



Charpy toughness versus temperature plots for specimens taken on flat faces, in longitudinal and transverse directions, at welds and in corners (see Footnote 2).

Footnotes:

1. Hall, S. and Owen, J. The behaviour of hollow section connections under seismic loading. The Structural Engineer vol. 82/4 February 2004.
2. Kosteski, N., Packer J.A. and Puthli R.S. 2003. Notch toughness of cold-formed hollow sections. Cidect Report 1B-2/03.

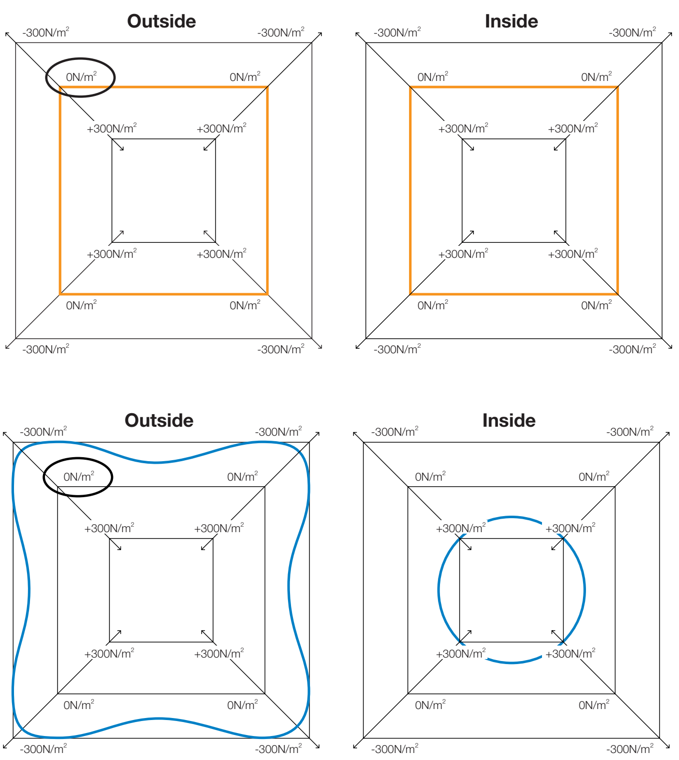
Residual stress

Celsius® 355 is produced virtually free of residual stress in all directions. These residual stresses, sometimes in combination with stresses due to weld shrinkage, may have the effect of bringing forward the point of failure and increasing the likelihood of heat-affected zone and liquid metal cracking.

Section properties

In almost all sizes, **Celsius® 355** has corner radii less than 2 x thickness (2T) which is better than the maximum allowable corner radii specified in EN 10210. Small corner radii offer superior section properties, reduced fabrication costs and an improved appearance. In addition, the material properties may be exploited. The use of plastic design is not limited by a lack of ductility which is an issue when using cold-formed sections.

Figure 10:



Key

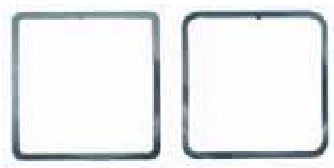
Hot Cold

Plots of typical residual stresses found on the outside and inside surfaces.

Figure 11:

Photograph comparing corner radii, from left to right, in hot-finished, cold-formed stress-relieved and cold-formed structural hollow sections.

Figure 12:



Photograph showing the difference in profile between hot-finished (left) and cold-formed (right) structural hollow sections.

Buckling strength

Celsius® 355 offers improved resistance to buckling compared to cold-formed sections. The buckling strengths are up to 35% greater than cold-formed sections of the same dimensions. When designing with cold-formed sections, a lower buckling curve must be used to calculate strength. This allows for residual stresses and the reduced plastic deformation of the material.

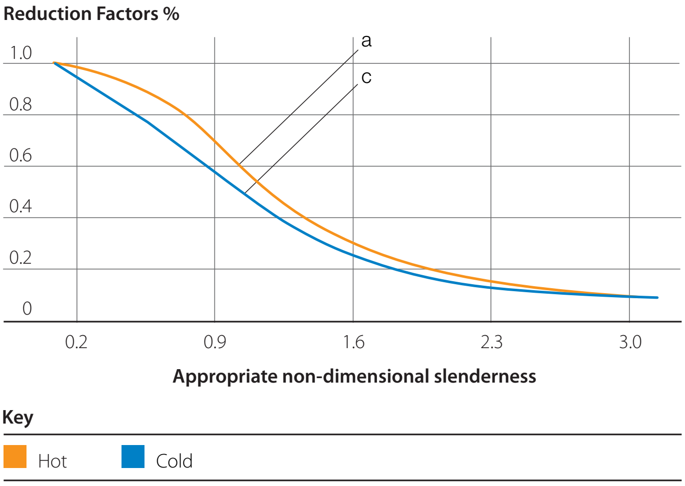
Dimensional stability

Celsius® 355 is stable and not prone to distortion during cutting, welding or other fabrication procedures. No special precautions are required for shot-blasting, galvanising or welding near corners. However, cold-formed sections have high levels of residual stresses and are more likely to distort during processing and fabrication.

Fire resistance

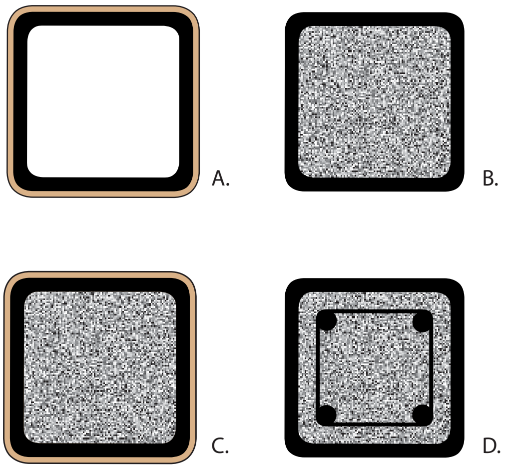
Unlike cold-formed sections, **Celsius® 355** has consistent and reliable performance in the event of a fire and will not suffer from sudden losses in yield strength on heating. By filling the section with concrete (with or without fibre or steel reinforcement) and/or applying an external protection, most periods of fire rating can be achieved.

Figure 13:



Buckling curves from EC3 Part 1.1 showing 'a' curve for hot-finished and 'c' curve for cold-formed structural hollow sections.

Figure 14:



Fire resistance may be achieved by A. Intumescent external protection, B. Concrete filling of the inside, C. Filling together with an intumescent external protection or D. Concrete filling with reinforcement.

BENEFITS OF USING CELSIUS® 355

Structural frames using Celsius® 355 can be designed to provide the following benefits:

Economy

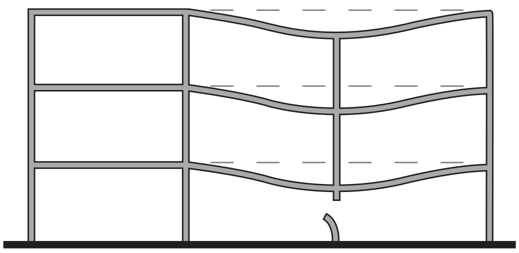
Celsius® 355 provides savings in time and money because of its built-in fire resistance, coordinated outside dimensions and efficient shape. For example:

- Heavily-loaded columns can still be small enough to fit between partitions. This saves space and reduces the amount of fire protection required.
- Larger columns can arrive on site fully finished, with fire resistance designed-in and, if required, needing only splice connections to be made on site.

Ductile behaviour

Celsius® 355 has high ductility. When correctly jointed as a frame, it exhibits ductile structural behaviour. This means there is still strength in the frame even after gross deformation has taken place. For example, in the unexpected removal of an element under extreme loading conditions or in the heating or cooling phase in a fire (**Figure 15**).

Figure 15:

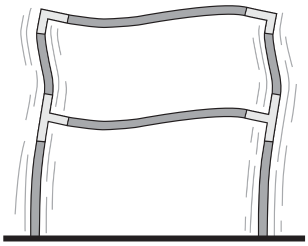


Frames can be designed to exhibit ductile behaviour, offering alternative load paths in the event of unexpected removal of columns.

Resistance to shock loads

Celsius® 355 has the ability to absorb large amounts of energy, both as bare steel sections and as composite elements filled with concrete. For example, joints in a triangulated frame structure under axial load show good ductility and energy absorption under cyclic loading (**Figure 16**). Also, in a moment frame with correctly-designed joints, the ductile elements give energy-absorbing characteristics to the whole frame. Even at low temperatures, **Celsius® 355** has high fracture toughness, together with a low yield ratio.

Figure 16:



Moment frames can be designed to have ductile and energy-absorbing characteristics under extreme loading conditions.

Resistance to temperature effects

Celsius® 355 has good performance at both ends of the temperature scale. At low temperatures, yield, elasticity and fracture toughness are maintained. At high temperatures, these properties reduce slowly and in a predictable way. Under fire conditions, increased safety is provided due to the ductile behaviour and the slower loss of properties in the heating and cooling phase.

IN SUMMARY

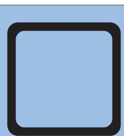
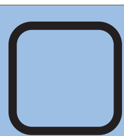
Celsius® 355 cannot be substituted for cold-formed hollow sections of the same dimensions without a full re-analysis of the design.

- At high or low temperatures, **Celsius® 355** generally has higher load-bearing capacities and better performance than cold-formed structural hollow sections of similar dimensions.

- Under extreme loading conditions, **Celsius® 355**, when correctly detailed in frames, is inherently more robust. For example: fire, collision, impacts, explosions or earthquakes.

- **Celsius® 355** presents less risk during processing and fabrication. This is because it is less prone to cracking and more predictable in use than cold-formed sections

STRUCTURAL HOLLOW SECTION COMPARISON GUIDE

	Celsius®355	**Cold-formed**
Manufacture	Shaped within the normalising range, at a temperature in excess of 840°C .	Shaped at ambient temperature without any further heat treatment.
Micro-structure	Uniform fine-grained structure over the whole section.	Non-uniform grain size and structure around the section.
Homogeneity	Hardness and tensile properties are uniform over the whole section.	Hardness and tensile properties vary around the section.
Ductility	Excellent ductility so substantial reserves of plasticity after yield point has been exceeded.	Only moderate reserves of plasticity after yield point has been exceeded.
Resistance to fracture	Impact properties are uniform over the whole section.	Non-uniform impact properties around the section and in the weld area (also in the corners of square and rectangular sections).
Residual stress	Virtually free of residual stress.	Areas of high stress throughout the section.
Section properties	Small radii corners for optimum section properties; easier welding and improved appearance.	Larger radii corners than hot-finished sections to avoid brittleness, giving inferior section properties.
Buckling strength	Design uses European buckling 'a' curve and optimum section properties, giving the highest strut capacity.	Designed to the European buckling curve 'c' with reduced section properties, giving reduced strut capacity.
Dimensional stability	Not prone to twisting or distortion when heated or mechanically treated.	Can be prone to distortion when subjected to further processing due to residual stress levels.
Fire properties	Strength reduces slowly and evenly under fire conditions.	Loss of strength can be unpredictable due to cold working and residual stresses.
Testing	Testing and sampling procedures mean that mechanical test results are representative of the properties of the section as a whole.	Testing and sampling procedures mean that mechanical test results are NOT representative of the properties of the section as a whole.
Tolerance and finish	Manufactured to a high standard of surface finish with excellent control of wall thickness and shape superior to that typically offered by comparable seamless.	Manufactured to a high standard of surface finish with excellent control of wall thickness and shape.
Indicative section profile		

Cold-formed and heat-treated

Shaped at ambient temperature then stress relieved (below normalising temperature).

Non-uniform grain size and structure around the section.

Hardness and tensile properties vary around the section.

Better ductility than cold-formed sections but inferior to hot finished sections.

Improved impact properties compared to cold-formed sections but inferior to hot-finished sections.

Low levels of residual stress.

Larger radii corners than hot-finished sections to avoid brittleness, giving inferior section properties.

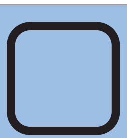
Can be designed to the European buckling 'a' curve but with reduced section properties.

Has reasonable resistance to distortion when subject to further processing.

Strength reduces slowly but unevenly under fire conditions.

Testing and sampling procedures mean that mechanical test results are NOT representative of the properties of the section as a whole.

Manufactured to a high standard of surface finish with excellent control of wall thickness and shape.



www.tatasteel.com

Tata Steel
PO Box 101
Weldon Road
Corby
Northants
NN17 5UA
United Kingdom
T: +44 (0)1536 404561
F: +44 (0)1536 404111
marketing@tatasteel.com

English Language TST05:1000:UK:03/2011