TATA STEEL

Colin Smart: Construction Services & Development

Steel grades

Together we make the difference

Steel grades

Contents

1 Steel design

2 Specification of steel

3 Steel sub-grade selection

4 Summary

Steel design: S355 or S275?

Recent changes in supply

- Tata Mills (TBM & MSM): standard feedstock S355 JR
  - Applies to all sections in the Tata Steel Advance® price list
  - Minimum quantity, cost and programme penalties for S275
- Beware sub-grade issues when substituting S355 for S275
  - Not just additional yield stress
  - Implication for limiting thickness for sub-grade selected
- Sub-grade supply
  - JR freely available from stock and the mills. J0 and J2 mill order
  - EC3 prohibits testing up
- Structural Hollow Section (SHS) – no change
  - S355 J2H (Celsius® 355 – Hybox® 355)

Summary

Default steel grades

- S355JR for open sections
- S355J2H for hollow section (hot and cold)

EN10025-2		£/tonne
S275JR*	Advance275JR	30
S275J0*	Advance275J0	40
S275J2*	Advance275J2	80
S355JR	Advance355JR	Basis
S355J0	Advance355J0	10
S355J2	Advance355J2	40
S355K2	Advance355K2	80

* Available on referral

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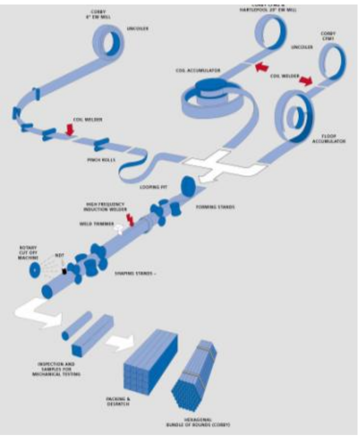
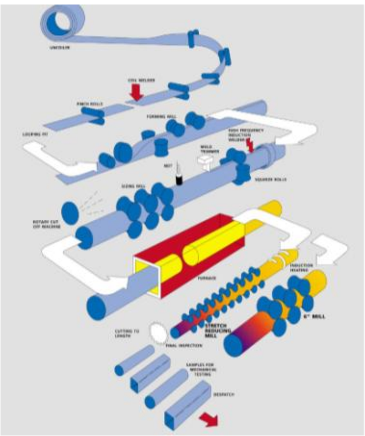
SHS: hot rolled or cold formed?

The manufacturing processes compared

Cold formed



Hot rolled



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SHS: hot rolled or cold formed?

The products compared

Cold formed

Hot rolled

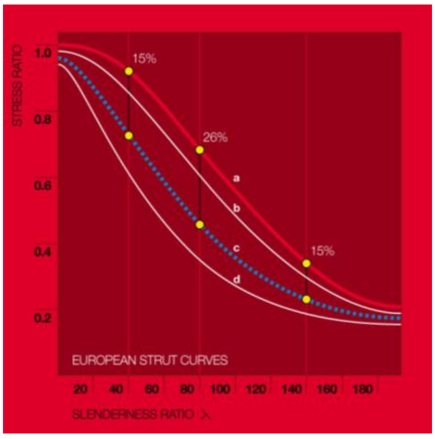
SHS: hot rolled or cold formed?

Section properties compared

Section	Area (A) cm^2	Moment of Inertia (I) cm^4	Elastic modulus (Z) cm^3
120 x 120 x 8 RHS **Hot rolled**	35.2	726	121
120 x 120 x 8 RHS **Cold formed**	33.6	677	113

SHS: hot rolled or cold formed?

Strut capacity



capacity up to 34% greater for hot!

- Hot rolled
  - Negligible residual stresses.
  - Design strength from ‘a’ curve.
- Cold formed
  - Varying residual stresses extremely high in corners.
  - Design strength from ‘c’ curve.
- At λ = 40 & 140: “a” curve values 15% higher than “c”curve
- At λ = 80: “a” curve values 26% higher than “c” curve

SHS: hot rolled or cold formed?

Strut capacity in kN (BS 5950)

	λ	Hot (S355 J2H)	Cold (S355 J2H)	Cold : Hot
120 x 120 x 5	80	533	421	0.79
120 x 120 x 10	80	1008	763	0.76
300 x 300 x 12.5	80	3337	2576	0.77
406.4 x 8	80	4606	3684	0.80

Cold formed or cold formed?

Spot the difference

- Cold formed
  - BS EN 10219
  - 3.1 Inspection certificate
  - **A structural product**

It's impossible to tell them apart without the paperwork!

- Cold formed
  - BS EN 10219
  - 2.2 Test report
  - Not manufactured for the structural market
  - **A commodity product**

Steel grades

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Specification and certification

The steel standards

10025 : part 2	Sections & Plate	Hot rolled products of structural steels. Technical delivery conditions for Non- alloy structural steels
10025 : part 5	Weathering Steel	Hot rolled products of structural steels. Technical delivery conditions for structural steels with improved atmospheric corrosion resistance
10210 : part 1	Hot rolled tubes	Hot finished structural hollow sections of non-alloy and fine grain structural steels
10219 : part 1	Cold formed tubes	Cold formed structural hollow sections of non-alloy and fine grain structural steels

Steel designation

S	Structural Steel	**JR**	Charpy impact strength 27 Joules @ + 20 °C
		J0	Charpy impact strength 27 Joules @ 0 °C
275 or 355	Min Yield Strength	**J2**	Charpy impact strength 27 Joules @ - 20 °C
W	Improved atmospheric corrosion resistance	**K2**	Charpy impact strength 40 Joules @ - 20 °C
H	Hollow section		

BS EN 10025-2 S355 JR

BS EN 10210: 2006 S355J2H

BS EN 10219: 2006 S355J2H

Inspection certificate

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
Page No. 1 of 1 A02

Date	11/10/10	Z02
Cert No.	120/1041/0079C	A03
Del. Note	EWSR/0150	

Customer A06
A.N.OTHER
XXXX TOWN
XXXX COUNTY
AB12 3CD

CE 0038 — 0840080 4004615

Tata Steel Ref.No. Sales GXA 302210 Works 29 316 A08
Customer Order No. P/O: JB B1099 OF 12/AUG/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
MADE IN UK

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.	C01 C02 C10	C11 Yield Stress Re (N/mm²)	C12 Tensile Strength Rm (N/mm²)	C13 Elong A 5.65 (%)	C01 C02	C40 C30 Test Type	C41 Width (mm)	C03 Temp (C)	C42 C31 Values (J)	C43 C32 Ave (J)	Steel Making Process C70: BASIC OXYGEN STEEL; Other Tests C50-C69 D02-D99
21	18	100.00 x 100.00 x 6.30 x 12.100M = 217.80M	7T28696	B L S	421.0	531.0	33	B L	KV	5.0	-20	97 110 106	104	WELD SEAM 100% EDDY CURRENT TESTED TO EN 10246-3 FLATTENING TEST FOR SEAM WELD QUALITY CONTROL, SATISFACTORY

END OF ITEM

END OF CERT

C71-C99 Analysis % Cast No.	C	Si	Mn	P	S	Cr	Mo	Ni	Al	B	Cu	N	Nb	Sn	Ti	V	CEV
7T28696 LADLE	0.15	0.17	1.40	0.016	0.006	0.017	0.001	0.014	0.031	0.0002	0.015	0.005	0.036	0.002	0.002	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.

Steel grades

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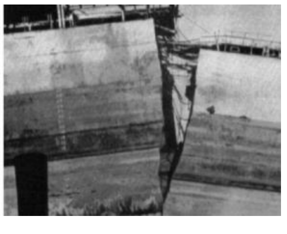
Steel specification

The Liberty Ships

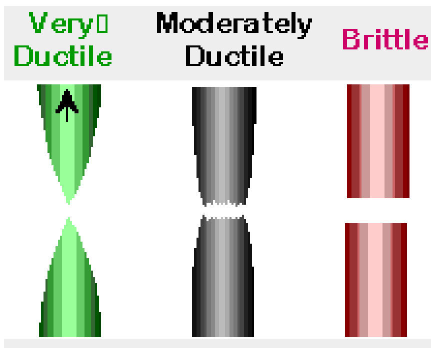
- British in concept
- Adapted by the US as quick and cheap to build
- 2,710 built between 1941 and 1945
- First all welded pre-fabricated cargo ships
- Early ships suffered hull and deck cracks!



- Constance Tipper called in to investigate
- Not caused by welding as first thought
- Critical temperature exists for steel where behaviour changes from ductile to brittle
- In other words they got steel sub-grade wrong!

Steel specification

Avoiding brittle fracture



BS 5950-1-2000, clause 2.4.4

"Brittle fracture should be avoided by using a steel quality with adequate notch toughness, taking account of:

- minimum service temperature;
- thickness;
- steel grade;
- type of detail;
- stress level;
- strain level or strain rate."

Steel specification

Avoiding brittle fracture

"The steel quality selected for each component should be such that the thickness *t* of each element satisfies:

$$t \leq K t_1$$

Where

K is a factor that depends on the type of detail, the general stress level, the stress concentration effects and the strain conditions, see table 3;

t_1 is the limiting thickness at the appropriate minimum service temperature T_{min} for a given steel grade and quality, when the factor *K*=1, from table 4 or Table 5"

BS 5950-1: 2000

Table 4 – Thickness t_1 for plates, flats and rolled sections

Product standard, steel grade and quality	Maximum thickness t_1 (mm) when K=1 according to minimum service temperature				
	Normal Temperatures		Lower Temperatures		
	Internal	External			
	- 5 ^{0}C	- 15 ^{0}C	- 25 ^{0}C	- 35 ^{0}C	- 45 ^{0}C
BS EN 10025-2:					
S 275 JR	36	20	0	0	0
S 275 J0	65	54	36	20	0
S 275 J2	94	78	65	54	36
S 355 JR	25	14	0	0	0
S 355 J0	46	38	25	14	0
S 355 J2	66	55	46	38	25
S 355 K2	79	66	55	46	38

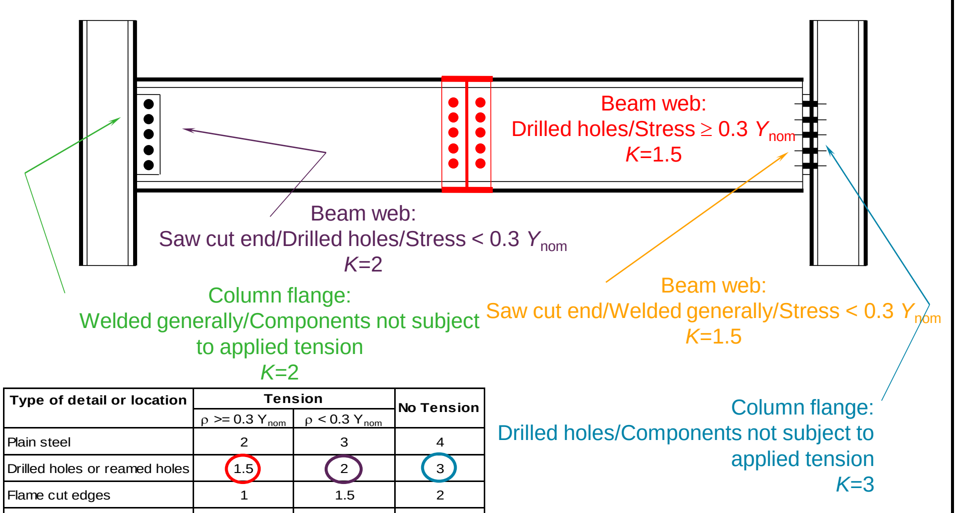
BS 5950-1: 2000

Table 3: Factor *K* for type of detail, stress level and strain conditions

Type of detail or location	Detail in tension due to factored loads		Components not subject to applied tension
	Stress ≥ $0.3Y_{nom}$	Stress < $0.3Y_{nom}$	
Plain steel	2	3	4
Drilled holes or reamed holes	1.5	2	3
Flame cut edges	1	1.5	2
Punched holes (un-reamed)	1	1.5	2
Welded, generally	1	1.5	2
Welded across ends of cover plates	0.5	0.75	1
Welded connections to unstiffened flanges, see **6.7.5**, and tubular nodal joints	0.5	0.75	1

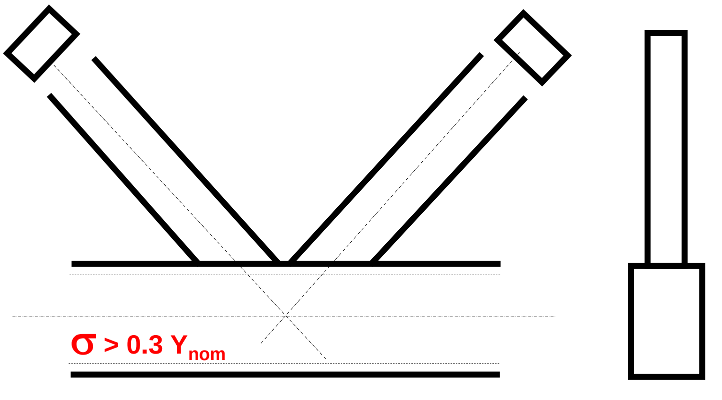
NOTE 1 Where parts are required to withstand significant plastic deformation at the minimum service temperature (such as crash barriers or crane stops) K should be halved.
NOTE 2 Baseplates attached to columns by nominal welds only, for the purpose of location in use and security in transit, should be classified as plain steel.
NOTE 3 Welded attachments not exceeding 150mm in length should not be classified as cover plates.
NOTE 4 Where abrupt changes in cross-section coincide with the detail, (other than those covered in the descriptions above), eg service openings, notched cut outs etc, the general stress level shall take into account the additional stress concentration effect
NOTE 5 The stress considered is the stress excluding residual stresses and stresses from structural integrity checks to 2.4.5.

Applying table 3



Type of detail or location	Tension		No Tension
	$\rho >= 0.3\ Y_{nom}$	$\rho < 0.3\ Y_{nom}$	
Plain steel	2	3	4
Drilled holes or reamed holes	1.5	2	3
Flame cut edges	1	1.5	2
Punched holes (un-reamed)	1	1.5	2
Welded, generally	1	1.5	2

Care with nodes!



- What value of K for the webs of the bottom chord?
- What value of K for the top flange of the bottom chord?

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K for web and flange of bottom chord

Table 3: Factor *K* for type of detail, stress level and strain conditions

Type of detail or location	Detail in tension due to factored loads		Components not
	Stress ≥ $0.3Y_{nom}$	Stress < $0.3Y_{nom}$	
Plain steel	2	3	4
Drilled holes or reamed holes	1.5	2	3
Flame cut edges	1	1.5	[illegible]
Punched holes (un-reamed)	1	1.5	2
Welded, generally	1	1.5	[illegible]
Welded across ends of cover plates	0.5	0.75	1
Welded connections to unstiffened flanges, see **6.7.5**, and tubular nodal joints	0.5	0.75	1

NOTE 1 Where parts are required to withstand significant plastic deformation at the minimum service temperature (such as crash barriers or crane stops) K should be halved.
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NOTE 5 The stress considered is the stress excluding residual stresses and stresses from structural integrity checks to 2.4.5.

Web

Flange?

FLANGE

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Internal steelwork (-5⁰C)

Attempt at a simple approach

- Take *K*=1 for UKB's as "beams" and *K*=2 for UKC's as "columns"
- Compare Kt_1 to flange thickness, T (conservative?)
- For S355 JR material 18/96 UKB's & 3/36 UKC's where T > Kt_1
  - 1016 x 305 UKB 249, 272, 314, 349, 393, 437, 487
  - 914 x 419 UKB 343, 388
  - 914 x 305 UKB 253, 289
  - 838 x 292 UKB 226
  - 762 x 267 UKB 197
  - 610 x 305 UKB 238
  - 533 x 312 UKB 219, 273
  - 457 x 191 UKB 133, 161
  - 356 x 406 UKC 467, 551, 634

For these sections: -
take a closer look at K or
specify J0/J2 (for these sections only!!)

- Therefore, specify **S355 JR** for open section

External steelwork (-15^{0}C)

Attempt at a simple approach

- Take K=1 for UKB's as "beams" and K=2 for UKC's as "columns"
- Compare Kt_1 to flange thickness, T (conservative?)
- For S355 JR material 58/96 UKB's & 12/36 UKC's where T > Kt_1
  - All 1016 x 305 UKB / 914 x 419 UKB / 914 x 305 UKB / 838 x 292 UKB / 762 x 267 UKB
  - All 686 x 254 UKB / 610 x 305 UKB / All 533 x 312 UKB
  - 610 x 178 UKB 92, 100
  - 533 x 210 UKB 92, 101, 109, 122, 138 / 533 x 165 UKB 85
  - 457 x 191 UKB 74, 82, 89, 98, 106, 133, 161 / 457 x 152 UKB 67, 74, 82
  - 406 x 178 UKB 67, 74, 85
  - 356 x 171 UKB 67
  - All 356 x 406 UKC / 305 x 305 UKC 198, 240, 283
  - 254 x 254 UKC 167 / 203 x 203 UKC 127
- Specify **S355 JR** for open section **where possible**

Specifying SHS – S355 J2H

Table 5 – Thickness t_1 for structural hollow sections

Product standard, steel grade and quality	Maximum thickness t_1 (mm) when K=1 according to minimum service temperature				
	Normal Temperatures		Lower Temperatures		
	Internal	External			
	- 5 ^{0}C	-15 ^{0}C	- 25 ^{0}C	- 35 ^{0}C	- 45 ^{0}C
BS EN 10210:					
S 275 JOH	65	54	30	0	0
S 275 J2H	94	78	65	54	30
S 275 NH	113	94	78	65	54
S 275 NLH	162	135	113	94	78
S 355 JOH	46	38	21	0	0
S 355 J2H	66	55	46	38	21
S 355 NH	79	66	55	46	38
S 355 NLH	114	95	79	66	55
S 460 NH	55	46	38	32	26
S 460 NLH	79	66	55	46	38

- With K=0.5: Kt_1=27.5: max wall thickness of standard range 20mm: OK

The EC3 approach

A little more complex in approach but …

PD6695-1-10:2009

- Alternative (& much simpler) approach recommended by SCI
- Two values for Tmd
  - -5 & -15oC
- Two "lookup" tables
  - Table 2 for Tmd = -5 ^{0}C
  - Table 3 for Tmd = -15 ^{0}C

The EC3 approach

Table 2 extract

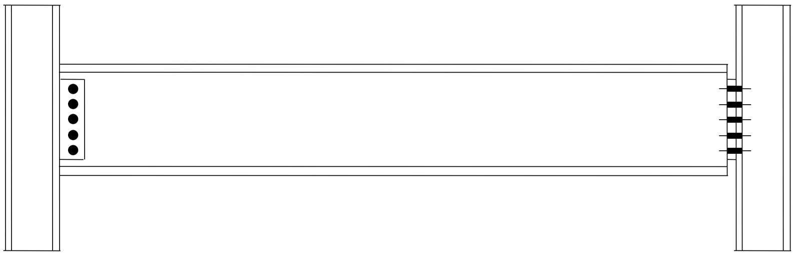
Table 2 **Maximum thicknesses for internal steelwork in buildings for T_{md} = -5 °C**

Detail type		**Tensile stress level, $\sigma_{Ed}/f_y(t)$ appropriate to stress level and detail type**									
Description	ΔT_{RD}	Comb.1	Comb.2	Comb.3	Comb.4	Comb.5	Comb.6	Comb.7	Comb.8	Comb.9	Comb.10
Plain material	+30 °C	≤ 0	0.15	0.3	≥ 0.5						
Bolted	+20 °C		≤ 0	0.15	0.3	≥ 0.5					
Welded: moderate	0 °C				≤ 0	0.15	0.3	≥ 0.5			
Welded: severe	-20 °C						≤ 0	0.15	0.3	≥ 0.5	
Welded: v severe	-30 °C							≤ 0	0.15	0.3	≥ 0.5
Steel grade	**Sub grade**	**Maximum thickness (mm) according to combination of stress level and detail type**									
		Comb.1	Comb.2	Comb.3	Comb.4	Comb.5	Comb.6	Comb.7	Comb.8	Comb.9	Comb.10
S275	JR	122.5	102.5	85	70	60	50	40	32.5	27.5	22.5
	J0	142.5	120	100	82.5	67.5	55	45	37.5	30	22.5
	J2	200	200	192.5	172.5	147.5	122.5	102.5	85	70	60
S355	JR	82.5	67.5	55	45	37.5	30	22.5	17.5	15	12.5
	J0	142.5	120	100	82.5	67.5	55	45	37.5	30	22.5
	J2	190	167.5	142.5	120	100	82.5	67.5	55	45	37.5

The EC3 approach

Example

- Stress level:
  - Simply supported. Suggest that $\sigma_{Ed}/f_y(t) < 0.15$
- Detail type:



The EC3 approach

Example

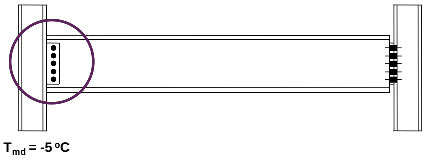


Table 2 Maximum thicknesses for internal steelwork in buildings for $T_{md} = -5\,°C$

Detail type		Tensile stress level, $\sigma_{Ed}/f_y(t)$ appropriate to stress level and detail type									
Description	ΔT_{RD}	Comb.1	Comb.2	Comb.3	Comb.4	Comb.5	Comb.6	Comb.7	Comb.8	Comb.9	Comb.10
Plain material	+30 °C	≤ 0	0.15	0.3	≥ 0.5						
Bolted	+20 °C		≤ 0	0.15	0.3	≥ 0.5					
Welded: moderate	0 °C				≤ 0	0.15	0.3	≥ 0.5			
Welded: severe	-20 °C						≤ 0	0.15	0.3	≥ 0.5	
Welded: v severe	-30 °C							≤ 0	0.15	0.3	≥ 0.5
Steel grade	**Sub grade**	**Maximum thickness (mm) according to combination of stress level and detail type**									
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	J2	190	167.5	142.5	120	100	82.5	67.5	55	45	37.5

The EC3 approach

Example

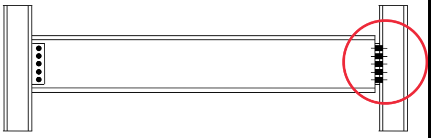

Table 2 Maximum thicknesses for internal steelwork in buildings for T_{md} = -5 °C

Detail type		Tensile stress level, $\sigma_{Ed}/f_y(t)$ appropriate to stress level and detail type									
Description	ΔT_{RD}	Comb.1	Comb.2	Comb.3	Comb.4	Comb.5	Comb.6	Comb.7	Comb.8	Comb.9	Comb.10
Plain material	+30 °C	≤ 0	0.15	0.3	≥ 0.5						
Bolted	+20 °C		≤ 0	0.15	0.3	≥ 0.5					
Welded: moderate	0 °C				≤ 0	0.15	0.3	≥ 0.5			
Welded: severe	-20 °C						≤ 0	0.15	0.3	≥ 0.5	
Welded: v severe	-30 °C							≤ 0	0.15	0.3	≥ 0.5
Steel grade	**Sub grade**	**Maximum thickness (mm) according to combination of stress level and detail type**									
		Comb.1	Comb.2	Comb.3	Comb.4	Comb.5	Comb.6	Comb.7	Comb.8	Comb.9	Comb.10
S275	JR	122.5	102.5	85	70	60	50	40	32.5	27.5	22.5
	J0	142.5	120	100	82.5	67.5	55	45	37.5	30	22.5
	J2	200	200	192.5	172.5	147.5	122.5	102.5	85	70	60
S355	JR	82.5	67.5	55	45	37.5	30	22.5	17.5	15	12.5
	J0	142.5	120	100	82.5	67.5	55	45	37.5	30	22.5
	J2	190	167.5	142.5	120	100	82.5	67.5	55	45	37.5

The EC3 approach

Technical Report ED 007

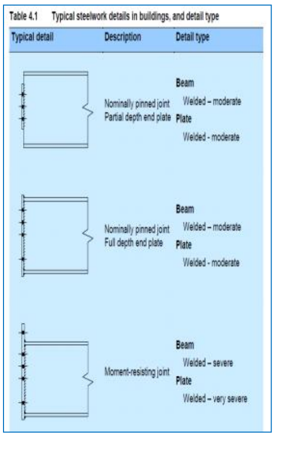

Table 4.1 Typical steelwork details in buildings, and detail type

Typical detail	Description	Detail type
	Nominally pinned joint Partial depth end plate	Beam: Welded – moderate; Plate: Welded - moderate
	Nominally pinned joint Full depth end plate	Beam: Welded – moderate; Plate: Welded - moderate
	Moment-resisting joint	Beam: Welded – severe; Plate: Welded – very severe

Steel grades

Contents

1 Steel design

2 Specification of steel

3 Steel sub-grade selection

4 Summary

Summary

- Preferred steel grades
  - S355 JR for open sections
  - S355 J2H for hollow section (hot or cold)
- Substituting cold for hot?
  - Up to 34% reduction in capacity
  - Cold formed – get the right stuff – check the certs
  - For structural steel you need a 3.1 inspection certificate
- Sub-grade selection
  - JR will cover an awful lot, but be aware of
    - External steelwork
    - Thick flanges, webs & plates (particularly in higher strength grades - S355)
    - Weld intensive details in areas of high tensile stress: $\sigma_{Ed}/f_y(t) > 0.5$)

TATA STEEL

TATA

Thank you …