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POCKET GUIDE THE CELLULAR BEAM

ENTRUSTED TO DESIGN AND DELIVER METAL SOLUTIONS

Kloeckner Metals UK | Westok are a specialist steelwork fabricator and designer who drives economy into the design of steel framed structures by providing an unrivalled range of cellular, shallow and plated beam solutions and software packages. Over the past twenty five years, we have established an impressive track record of delivery across a diverse range of sectors in the UK, Ireland and further afield.

Our engineers can call upon many years' experience to offer free and impartial advise. We provide calculations, assist with the analysis and design of the steel frame, facilitate design workshops, attend design team meetings, visit site and assist with BIM co-ordination. We also offer free CPD Seminars. To use any of these services, contact your local Technical Advisory Engineer. Free analysis, design and BIM software is available from **www.kloecknerwestok.com**

John Callanan
BA BAI MSc. CEng MIEI MIStructE
Design Team Manager
john.callanan@kloeckner.com
Tel: +44 (0)113 205 5270
Mob: +44 (0)7920 500 413

Tom Elliott
MEng
Technical Advisory Engineer
tom.elliott@kloeckner.com
Mob: +44 (0)7342 061 026

Jimmy Odejimi
MEng CEng MICE
Technical Advisory Engineer
jimmy.odejimi@kloeckner.com
Mob: +44 (0)7593 449 845

Tom Elliott
MEng
Technical Advisory Engineer
tom.elliott@kloeckner.com
Mob: +44 (0)7342 061 026

James Way
BEng ACGI CEng MICE
Technical Advisory Engineer
james.way@kloeckner.com
Mob: +44 (0)7786 701 452

Westok Design Service to NEN-EN 1993 & 1994 and Cellular, Plated & Shallow Beams now available in Netherlands and Worldwide.

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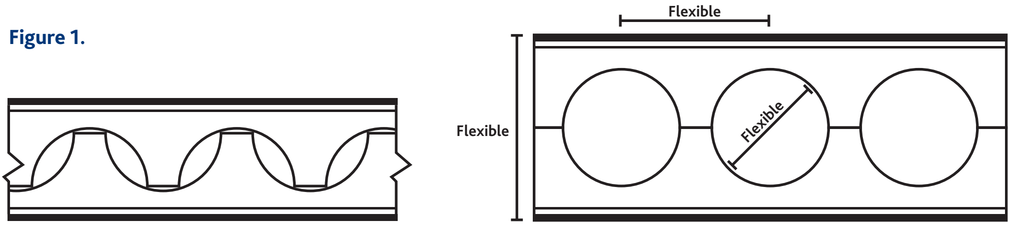
Westok cellular beams

What is a Westok cellular beam?

It is a modern version of the traditional "castellated beam", but far more flexible and with a greater range and depth of applications.

Figure 1.



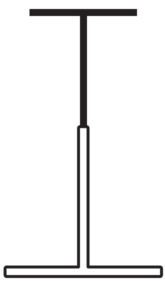
How are they manufactured?

A steel Universal Beam (UB) or Universal Column (UC) is expanded using a unique two pass cutting process that results in a beam approximately 40 - 60% deeper than the parent section from which it was made. The exact finished depth is a function of both the cell diameter and cell spacing, and all three are highly flexible. Available in increments of 1mm to optimise.

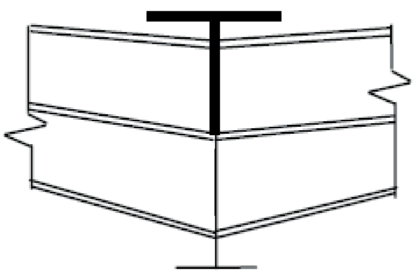
The resulting Westok cellular beam has, approximately, a 50% greater section modulus/load carrying capacity and a 125% increase in inertia/stiffness relative to the original parent section properties, but, with no increase in weight.

Asymmetric sections

When a section is split using the Westok process two identical tees are created. A further layer of flexibility can be added by combining top and bottom tees from different parent sections to create an asymmetric section. As tees are created in pairs, for efficient use of material asymmetric sections should be designed in pairs too. Asymmetric sections can be used in composite floor construction to produce very light highly design efficient beams, but they can also be useful where there is instability of the compression flange, for instance in spine beams on single storey buildings.



Asymmetric cellular beam for composite applications

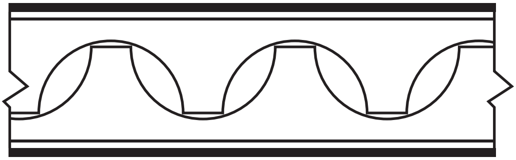


Asymmetric cellular spine beam

Design asymmetric sections in "pairs" for efficient use of material

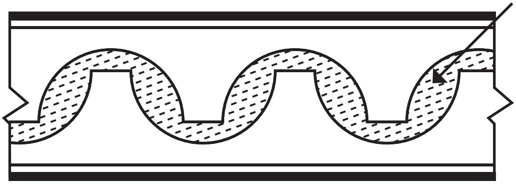
Ribbon cuts

In the splitting process used to create a Westok beam, the two cuts are separated by 10mm, and produce two identical tee sections. This separation distance is required for manufacturing purposes. The cut is a repeat pattern producing multiple cells at regular spacings throughout the beam, perfect for accommodating both current and future servicing requirements in modern commercial buildings.



The "default" ribbon cut with 10mm separation

It's a simple matter to separate the two cuts further, to create identical tees of a prescribed depth. Where depth and servicing provision are critical, this allows beams to be designed and manufactured to an exact depth and with a fixed vertical dimension to the centre of the cells.



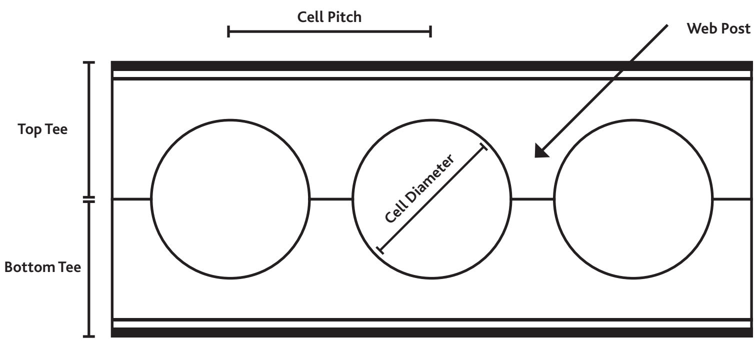
This is sometimes referred to as a 'ribbon cut' as a ribbon of material is left behind.

Bespoke ribbon cut with increased separation to create designer depth beams

Workmanship

Full penetration butt welds are used at each web-post when assembling the Westok beams. All workmanship is to BS EN 1090 and carried out to EXC 2 as standard. Westok are certified to EXC 4, and so can manufacture to more rigorous standards if required.

Terminology



Note: in asymmetric sections the top and bottom tee depths may be different, therefore the centre line of the cell may not be at the mid-depth of the section.

Applications

Floor beams

The major use of cellular beams is as simply supported secondary floor beams to achieve either clear open spans and/or service integration. Also, where a deeper beam is permitted a Westok will be more economical than a heavy UB section.

Increasing economy →

	SPAN REQUIREMENT		
Services requirement	**< 9m span**	**< 12m span**	**> 12m span**
No services	USFB	✓	✓✓
Single service opening	✓	✓✓	✓✓✓
Normal/heavy services	✓✓	✓✓✓	✓✓✓

Increasing economy ↓

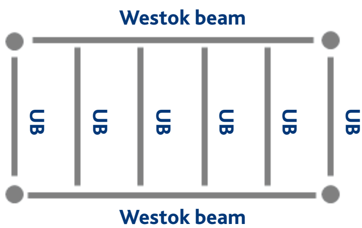
USFB = Westok Ultra Shallow Floor Beam

Clear span secondary, short span primary

Choosing the most appropriate grid layout is key to efficient and economic design. The optimum floor layout uses Westok beams as clear span secondaries; the primary member can be a plain UB, a Westok cellular beam or a Westok plate beam.

CLEAR SPAN SECONDARY LAYOUT ✓

CLEAR SPAN PRIMARY LAYOUT ✗



*** Dependent on services, load and grid dimensions**

As well as being a better technical solution, the clear span secondary layout offers: -

- **More options, either**
  - Shallow construction – beams with a span/d ratio as high as 35 possible
  - Deeper beams with large openings for services – typical span/d of 20
  - Anything in between!
- **Lower piece count therefore quicker fabrication and erection**
- **Improved footfall response**
- **More favourable A/V ratios for fire protection resulting in lower coating thicknesses and fewer coats**

Deflections

Deflections of long span beams can often require the specification of costly pre-cambers. Westok beams are pre-cambered as part of the manufacturing process without additional cost, unlike UBs and plate beams. Pre-cambers up to 50mm are free of charge.

Cambers are generally chosen to offset the deflection due to the self-weight of the composite slab and steelwork, however they should also be sufficiently pronounced so that they can easily be identified in the steelwork contractors workshop and also on site. As a guide cambers should be no less than 10mm or span/1000, whichever is the greater.

There is often concern about whether cambers will "drop out". Selecting a suitable value is something of an art, and when choosing, consideration should be given to the stiffness of the frame, type of connections and proximity to any stiff cores etc. SCI P300 (pg 59) offers the following guidance

"… a general rule of thumb is to design any pre-cambering to eliminate no more than two thirds of the dead load deflection".

Accuracy of pre-cambers

Cambers in Westok beams are "built in" as part of the assembly and manufacturing process. Consequently the accuracy of the cambers far exceeds the requirements of the National Structural Steelwork Specification (NSSS). Please consult Westok with project specific requirements.

Cast to level or cast to thickness?

Levelling of composite floors is carried out in one of three ways:-

1) **Tamping rails or levelling pins, supported on the beams acting as a datum, are set to the intended structural floor level.**
2) **Tamping rails or levelling pins, supported on the beams acting as a datum, are set to achieve a constant thickness of concrete relative to the top of the beams.**
3) **Rigid columns are used as datum points for laser levelling. Levelling equipment is then used to produce a level upper concrete surface, irrespective of the deflection of the supporting steelwork or of the specified thickness of the concrete being laid – a technique known as "flood pour".**

The relative merits of each method is discussed in SCI Advisory Desk Note AD 344. If significant cambers are being specified, method 2 (cast to thickness) will ensure that the nominal slab thickness required by design at mid-span is achieved on site.

Applications

Ponding

Westok beams are easily pre-cambered to counteract the effect of self-weight deflection of composite slab and beam. If the composite deck deflection exceeds prescribed limits at construction stage however, then an allowance in the loads should be made for "ponding". SCI publication P300 offers the following advice

"… if the central deflection of the sheeting d is greater than 1/10 of the slab thickness, ponding should be allowed for. In this situation the nominal thickness of the concrete over the complete span may be assumed to be increased by 0.7d".

Using this guidance for a 3m span slab of 150mm overall depth, if the construction stage deflection exceeds span/200 then ponding should be allowed for in the design. Most decking software automatically allows for this in the design of the metal deck, however, ponding effects are not allowed for in the Cellbeam software and need to be user defined where appropriate.

Footfall Response of Clear Span Floors

Client specifications often include a performance requirement for floors in the form of a maximum permitted response factor - low response factors indicating better performance. Clear span floors have higher modal mass than short span solutions, often double, and so easily meet the criteria for general office floors of 8. SCI publication P354 offers advice on appropriate acceptance criteria and presents a simplified hand calculation method, the basis of our freely available vibration analysis package Cellvibe, as well as advice on more rigorous FE modelling.

When considering response characteristics of a floor plate it is worth noting that: -

1) **A clear span secondary arrangement will outperform a clear span primary arrangement.**
2) **Longer spans will outperform shorter spans**
3) **Normal weight concrete will outperform lightweight concrete.**
4) **A re-entrant deck will provide an improvement of approximately 1 in the response factor relative to a trapezoidal profile - on account of the increased mass.**
5) **An increase in concrete depth of 10mm, irrespective of the decking profile used, will see an improvement of approximately 1 in the response factor.**

Typical response factors for clear span floors are given in the quick sizing guide of this booklet.

Roof beams

The perfect application for a Westok cellular beam in a roof application is as a simply supported rafter. At spans of approximately 20m or more a cellular rafter will be lighter than a plain UB section and cheaper to fabricate than a truss. If a curved section is required the cost savings are compounded compared to a curved plain UB.

	SPAN REQUIREMENT		
Rafter type	**< 20m**	**20 – 40m**	**> 40m**
Straight simply supported	✓✓	✓✓✓	✓✓✓
Curved simply supported	✓✓✓	✓✓✓	✓✓✓

A plastically designed portal frame is a very efficient structural form. Unfortunately cellular beams are not suitable for plastic analysis, but they can often offer cost and weight savings at larger spans when elastic design is more appropriate. Where curved rafters are required the in-house curving capability at Kloeckner Westok allows cost and material savings to be made.

	SPAN REQUIREMENT		
Frame type	**< 20m**	**20 – 40m**	**> 40m**
Pitched portal	✘	✓	✓✓
Curved portal	✓	✓✓	✓✓✓

Portal Frame or Braced Box?

Although extremely efficient, portal frames have one or two disadvantages. Stanchions can become relatively large, particularly for larger spans, and compromise the spatial requirements of the client. Also, haunches can become deep adding height and cost to the building. The uplift in frame weight and cost of a "braced box" approach utilising roof and wall bracing is often relatively modest. It permits the use of slender columns, maximising usable floor space, minimising building height and so reducing the area of cladding required providing savings in total build cost.

Applications

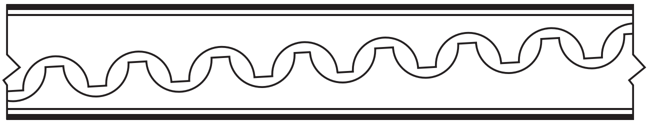
Westok Curves

Many cellular beams can be curved "in house" at little or no cost, providing significant cost savings compared to curved plain beams. However, for certain tight curves and for Westok beams manufactured from 610 UBs and above or 356 x 368 UCs and above, Westok work with a specialist section bending company. It's best to contact Westok to discuss the curving requirements on any particular project, but the rules of thumb below give an indication of what's possible for curving about the major axis.

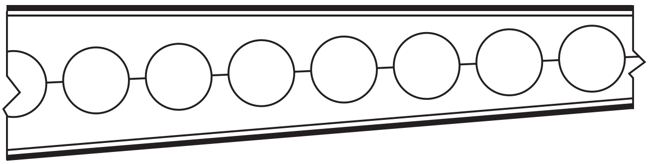
Minimum radius for an "in-house" Westok curve: 30 – 80m dependant on bar length (for all sections up to and including a 533 x 210 UB and 305 x 305 UC). Minimum radius for a curve in collaboration with a section bending company, 35 times the beam depth.

Tapered cellular beams

Cellular beams provide the most economical method to create tapered steel members.



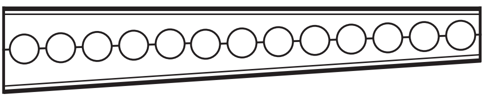
Profile at the angle of required taper



Spin one tee 180° and re-weld

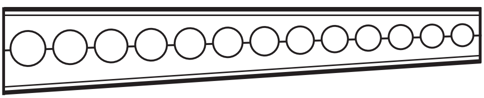
Tapered beams can have cells of uniform diameter, cells of varying diameter, or no cells. This affects the relative cost.

MINIMUM COST



Uniform diameter cells full length - provides the most efficient design, combined with the minimum amount of weld length.

MEDIUM COST



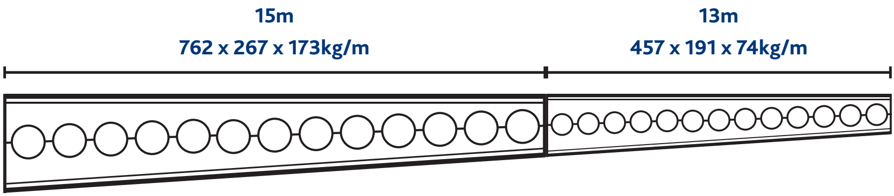
Bespoke cells that vary in diameter - also minimises weld length but the design is likely to be slightly heavier.

HIGHEST COST

No cells - The beam is not expanded so is heavier than a cellular taper. It also requires a long length of weld, and so there is difficulty in maintain straightness due to the heat input necessary.

Cantilever Roof Members

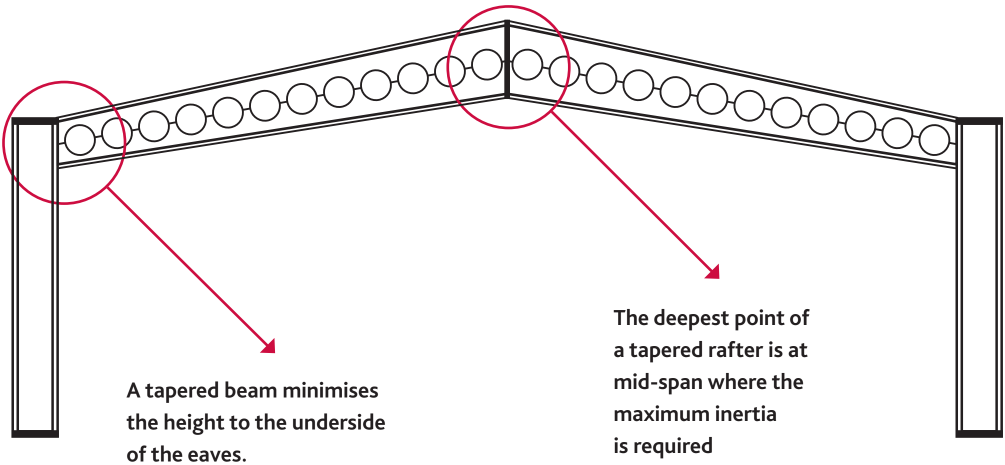
Cellular beams are frequently the preferred choice for cantilevers, providing great depth and therefore huge inertia at the support and minimum depth and therefore minimal weight at the tip. Long cantilevers are often designed using two or even three different beam sizes to minimise the overall weight of the rafter.



Cantilever compound taper used at Carlisle United FC

A Different Approach to Pitched Roofs

Where column depths need to be minimised or where eaves height is critical the traditional haunched portal frame can compromise a client's spacial requirements. A tapered cellular beam solution, as shown below, as part of a braced frame can provide a different approach, reducing the height at the eaves and allowing the use of slender columns maximising useable floor area and minimising envelope cost.



Specification

How to specify Westok beams

There are seven pieces of information required to tie down the specification of any Westok beam. They are: -

1. The overall depth

2. The top tee section size

3. The top tee depth (for ribbon cuts)

4. The bottom tee section size

5. The cell diameter

6. The cell pitch or spacing

7. The distance to the first cell from a setting out point

Simple specification for standard Westok beams

Symmetric Westok beams designed and manufactured using the standard cut can be called off on plan using a simple line specification as shown below.

overall depth   mass/m   cell diameter

WESTOK 796 X 210 X 82 CB (575/725)

Serial width of top and bottom tees   "CB" denotes cellular beam   cell pitch

If the distance to the first cell relative to an appropriate grid is indicated on the drawings, then this together with any cambering requirements gives all the information required for manufacture.

Asymmetric sections can be called off in a similar way, see below. In this case the asymmetric section comprises a 457 x 152 UB 60 top tee and a 533 x 210 UB 101. The average mass/m of the cellular beam is (60+101)/2=80.5 kg/m and is quoted in the specification.

"ACB" denotes asymmetric cellular beam

WESTOK 674 X 152/210 X 80.5 ACB (450/695)

Serial width of top tee   mass/m of cellular beam

Serial width of bottom tee

Tabular specification for more complex designs

Where the design requires the use of "ribbon cuts" or more comprehensive information needs to be communicated, such as cambers or stud data, a tabular approach to specification can be helpful. Data to assist fire applicators can easily be accommodated in a table too. The "Add-To-Table" function in the Cellbeam software automatically produces an Excel spreadsheet populated with all of the necessary information to make specification simple and straightforward.

Beam Mark	Overall Depth	TEE DETAILS			Mass	Top Tee Depth	CELL DATA				Factored Reaction	Camber	SHEAR CONNECTORS
	(mm)		Section	Grade	kg/m	(mm)	Dia (mm)	Pitch (mm)	Dist to 1st cell (mm)	Relative to grid	(kN)	(mm)	19mm dia 95mm LAW
CB1	796	TOP	533 x 210 UB 82	S355	82	398	575	725	638	A	95	50	N/A
		BOT	533 x 210 UB 82	S355									
ACB1	574	TOP	457 x 152 UB 60	S355	80.5	317	450	695	638	5	205	25	1 stud every trough
		BOT	533 x 210 UB 101	S355									

Availability

"Populars" are those steel sections up to and including a 610 x 229 UB 140 and 305 x 305 UC 283. They roll at the mills very frequently, often on a 4 week cycle, and are widely available from stock. "Heavies" are all of the deeper and heavier sections above. They tend to roll less frequently, usually a 6 to 8 week cycle, and whilst still readily available are less widely stocked and come at a cost premium compared to populars. The standard grade for both populars and heavies is S355J0.

Westok cellular beams are always made from stock sections, and so can be manufactured and delivered very quickly.

CE Marking

Westok manufacture cellular beams in accordance with the National Structural Steelwork Specification (NSSS) as standard. This covers EXC2 (Execution Class 2) requirements to BS EN-1090, which is adequate for most building structures. However, certification is held for EXC4, so projects with more demanding requirements such as stadia or nuclear work can also be catered for.

Testing

Weld testing is carried out in accordance with the frequency and requirements of BS EN 1090, but more stringent project specific testing is available.

Detailing

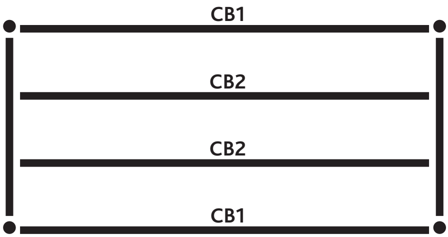
Setting out the cells

Cellular beams are often chosen for service integration, so it's crucial that appropriate attention is given to cell setting out to ensure that cells are aligned to allow the passage of services. Vertical alignment of the cells relative to the top flange of the beam is controlled by the specification of the top tee depth, which is a function of the serial size and any ribbon cut requirements. Horizontal alignment is controlled by specifying the distance to the first cell on all beams, relative to a setting out point, commonly a grid line.

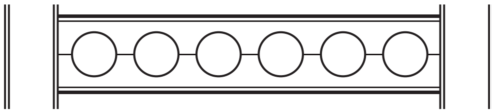
Value engineering – detailing out infills

Structural infills are those required as part of the design of the Westok beam, and with appropriate application of the product and careful application, they are easily designed out/minimised. Non-structural infills are those needed to facilitate a connection. With careful detailing they can often be eliminated altogether, and a useful rule of thumb is to ensure there is no more than one infill per beam.

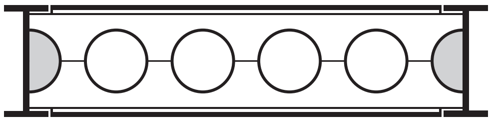
In a serviced floor the best approach is to optimise the cell pitch so that no infills are required for the beams on grid. This cell layout is also used for the intermediate beams, and ensures horizontal alignment of cells. This approach limits the infills to two half infills on each of the intermediate beams as shown in the diagram, or the fabricator can eliminate infills altogether by using extended fin plate connections between the primary and secondary beams.



CB1 (full web post)



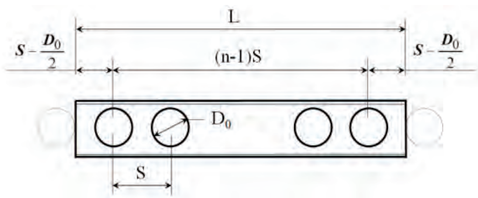
CB2 (½ infill)



Note: the ½ infills could be eliminated with use of extended fin plates

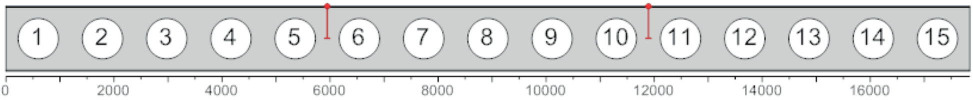
The optimum cell pitch for the beams on grid (CB1) can be found using the formula below.

$$S = \frac{L + D_0}{(n+1)}$$

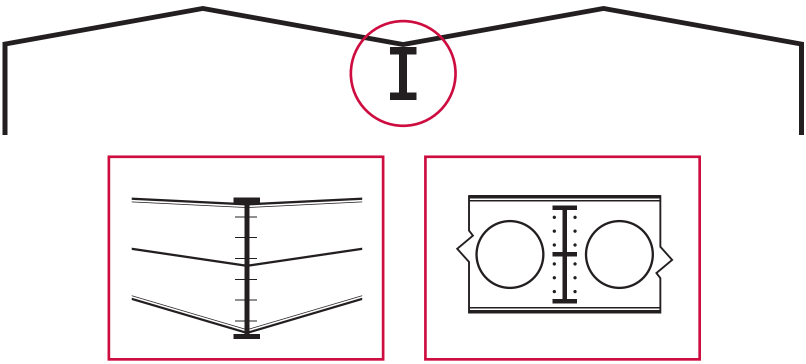


Primary beams and spine beams

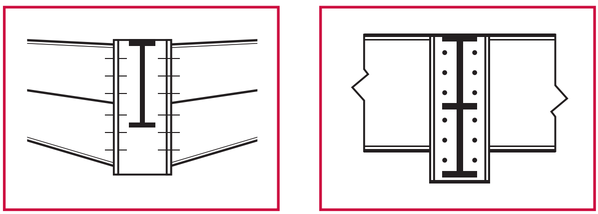
The cell pitch for a primary beam or spine beam should be chosen such that it is a multiple of the beam spacing. This, combined with a reasonably proportioned web-post should allow connections to be made without the need to infill cells.



In addition valley/spine beams in single storey buildings can be "set up" into the purlin zone and proportioned to accommodate the incoming rafter, simplifying fabrication and erection and driving out cost.



Simple connection into a cellular valley beam

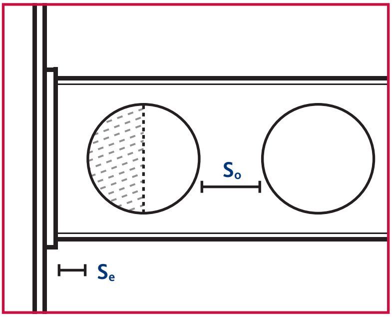


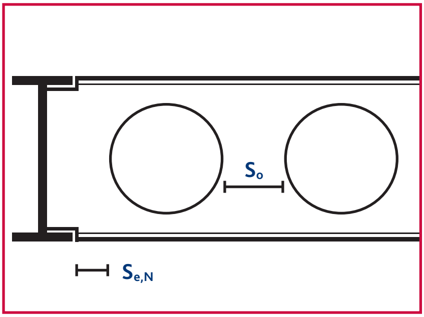
Costly dropped haunch beneath a plain valley beam

Connections

Simple shear connections

Simple shear connections in cellular beams are straightforward, and the guidance offered in the green books (P212 and P358) can very easily be adapted. The details below are in addition to the standard checking procedures for any simple beam connection. Put simply, if there is less than half a standard web-post (S_o) at the end of a beam (S_e) then provide a half infill.





Beams without notched ends

If $s_e \geq s_0/2$ no infill required

If $s_e < s_0/2$ provide half infill (dotted)

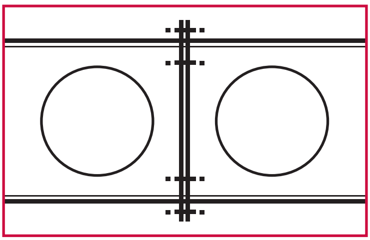
Beams with notches

If $s_{e,N} \geq s_0/2$ no infill required

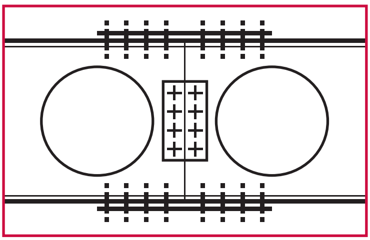
If $s_{e,N} < s_0/2$ provide half infill

Splice connections

Splice connections will more often be required for non-composite roof beams. The moment in a non-composite beam is resisted by complimentary axial compression and tension in the top and bottom tees. A connection that works in a similar way is preferred. In the case of flush end-plates, web-tension local to the cell may become critical requiring a half infill.



Extended end-plate connection



Cover plate splice connection

A 10% reduction in applied moment makes a big difference in connection design. The common practice of locating splices at third points in simple beams should be observed where possible. Specifiers should also quote the actual applied moment rather than section capacity for connection design.

Economic design of Westok beams

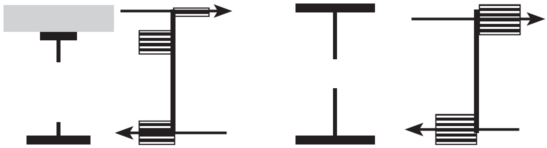
The art of economic design involves striking the right balance between efficient individual member design, and rationalising the number of different beams types for production and structural detailing efficiency.

It's good practice to size Westok beams in "pairs", particularly for asymmetric beams which have top and bottom tee's manufactured from different serial sizes, but also for cambered and curved beams too. Breaking a project down into "bays" and adopting a standard cell diameter and pitch for each "bay" can also improve production efficiency and ensure cell alignment for service routes.

Kloeckner Metals UK Westok offers a free design service and our engineers are widely experienced solving the many problems encountered by engineers as they scheme up, and design the steel frame. Talk to your local Advisory Engineer to understand how we can assist.

Understanding cellular beams

Cellular beams resist global bending by means of a simple couple that is set up between the top and bottom tees in the case of a non-composite beam, and in the case of a composite beam between the concrete slab and the steel section.



The first step in successful sizing is to ensure that the overall beam has the correct proportions. In the output panel of the Cellbeam software the "Moment Shear Utilisation" check gives a measure of how well-proportioned the beam is for overall bending. For efficient design it should be between 0.9 and 1.0. With a beam of the correct proportions for global bending attention can now be given to the secondary checks required at each cell location.

Vertical shear is resisted by the webs of the top and bottom tees. Shear capacity can be increased by decreasing the cell diameter of the cell, or choosing tee sections with thicker webs.

Horizontal shear is developed in each web-post due to the change in moment across the cell. In simply supported beams subject to uniform load, the critical web-post will always be the first web-post in from the support. Web-post shear capacity can be increased by increasing the cell pitch, decreasing the cell diameter, or choosing tee sections with thicker webs.

Vierendeel bending occurs in the top and bottom tees due to the transfer of shear force across the openings. The software then checks every cell for the combination of shear, axial force and secondary Vierrendeel bending. In simply supported beams subject to uniform load the critical cells will be those closest local to the mid-span of the beam. Vierendeel capacity can be increased by closing the cell pitch, using a smaller diameter cell, using heavier tee sections.

Web-post buckling occurs as a result of the horizontal shear at the centre line of the cell. It is a function of the web-post width and it's slenderness (effective height divided by web thickness). Web post buckling capacity can be increased by increasing the cell pitch or decreasing the cell diameter to reduce its slenderness.

Fire Protection

Fire protection of cellular beams using "passive materials" such as boards or cementitious sprays can be applied in the same way as for a plain rolled section. For intumescent, the ASFP (Association of Specialist Fire Protection) and the SCI have worked together to establish a thorough system. Westok cellular beams may be protected by any ASFP accredited material using the limiting temperatures from the Cellbeam software. Alternatively ASFP members can refer to their own publications.

The Cellbeam software calculates the critical temperature for the web and bottom flange of the cellular beam. By stating these critical temperatures on drawings the Engineer ensures maximum competition for the fire protection package. Armed with this information, any fire protection contractor or intumescent manufacturer is quickly able to calculate their optimum product and correct coating thickness.

Fire Engineering with Cellular Beams

Various options exist to "fire engineer" structural frames which use cellular beams.

• *Beam optimisation for intumescents*

It may be beneficial to slightly increase the steel section if this allows a significantly thinner coat of intumescent to be used. It is likely that this will only be viable in 120 minute fire ratings, and in very lightweight beams with high section factors.

• *Unprotected alternate floor beams*

An increasingly popular approach uses the method described in SCI publication P288, in which up to half the number of floor beams can be left unprotected, even for buildings requiring 120 minute fire period. Long span cellular beams are included in this approach.

• *Unprotected steel frames*

BS 5950 Part 8 and BS 9999 allow many steel frames requiring a fire protection period of 30 or 45 minutes to be totally designed without fire protection.

USFBs

The USFB (Ultra Shallow Floor Beam) massively extends the range of shallow steel options for the flat slab market. USFBs can be as shallow as 160mm, rising in 1mm increments. The USFB is a highly asymmetric section with a wide bottom flange on which the decking or pre-cast units can sit producing a very shallow overall solution. Cells are provided at regular centres which accommodates rebar for torsional resistance and tying requirements for disproportionate collapse. Unlike other upstand beam options, the USFB is not subject to any minimum order quantities, is available in increments of 1mm depth and does not require the costly provision of additional plates or angle sections to be welded to the beam to provide an outstand element. Therefore, the USFB is perhaps the most flexible, practical and cost-efficient approach to achieving an up-stand beam in the market.

The table below shows USFB equivalents to rolled ASB sections, based on geometric properties only. This will prove useful for engineers seeking a quick USFB alternative, to a ASB. All USFB equivalents must be proven by calculation using our Cellbeam software. Experience suggests that significant economies can be made when engineers design the USFB section *in lieu* of the ASB. Cellbeam is available, free of charge, from **www.kloecknerwestok.com**

USFB geometric equivalents to rolled ASBs

Section	Depth	TOP FLANGE		BOTTOM FLANGE		Inertia	Modulus	Area
	Depth	Width	Thickness	Width	Thickness	Inertia	Modulus	Area
	h	b_t	$t_{f,t}$	b_b	$t_{f,b}$	I_z	$W_{pl,z}$	A
	mm	mm	mm	mm	mm	cm^4	cm^3	cm^2
280 ASB 74	272	175	14.0	285	14.0	12200	978	93.7
265 x 203/305 USFB 91.5	265	209.1	20.5	305.3	15.4	14835	1171	105.2
280 ASB 100	276	184	16.0	294	16.0	15500	1290	120.9
276 x 203/305 USFB 117.6	276	209.1	20.5	304.8	19.7	17687	1289	120.9
280 ASB 105	288	176	22.0	286	22.0	19200	1440	133.0
288 x 254/368 USFB 118	288	258.8	20.5	368.6	17.5	22723	1654	136.0
280 ASB 124	296	178	26.0	288	26.0	23500	1730	158.0
296 x 254/368 USFB 130.5	296	261.3	25.3	368.6	17.5	26457	1971	151.0
280 ASB 136	288	190	22.0	300	22.0	22200	1810	174.0
288 x 254/368 USFB 130.5	288	261.3	25.3	368.6	17.5	24894	1911	150.0
300 ASB 153	310	190	24.0	300	24.0	28400	2160	195.0
310 x 254/368 USFB 172.1	310	265.2	31.7	372.2	23.8	36799	2636	199.0
300 ASB 155	326	179	32.0	289	32.0	34500	2360	198.0
326 x 254/368 USFB 172.1	326	265.2	31.2	372.6	23.8	41296	2811	201.0
300 ASB 185	320	195	29.0	305	29.0	35700	2660	235.0
320 x 305/419 USFB 270.7	320	314.5	31.4	418.5	32.0	50620	3335	266.0
300 ASB 196	342	183	40.0	293	40.0	45900	3060	249.0
342 x 305/419 USFB 291.7	342	318.4	37.7	418.5	32.0	63999	4208	294.0
300 ASB 249	342	203	40.0	313	40.0	52900	3760	318.0
342 x 305/419 USFB 335.4	342	322.2	44.1	420.5	36.6	71589	4717	339.0

Westok Plate Beams

Westok manufacture solid web and cellular beams and columns from plate: the Westok Plate Beam (WPB). The Westok Plate Beam is manufactured using advanced welding technology on a submerged-arc T & I line. It provides the optimum bespoke beam solution in shape and web aperture. The WPB is used in applications where there is a requirement to achieve one or both of the following:

- **The transfer of particularly heavy loads, where the capacity of a Westok cellular beam is exceeded**
- **A specific arrangement of web penetrations of varying size and location - "any hole, anywhere"**

Westok Plate Beams generally become more economic at beam weights of 150kg/m and above, however every project and beam application needs to be reviewed on its merits. The next section "What product where?" will assist engineers scheming a project.

Westok Plate Columns are particularly economical in situations where rolled UB or UC sections suffer from poor minor axis capacity, for example valley columns in large sheds, where heavy 610 x 305 or 914 x 419 UBs are often designed.

What product where?

Many projects benefit from the correct mix of cellular and plated beams, and/or USFBs. Westok is the only specialist steelwork fabricator in the market, who can design and manufacture these products. However, it also creates a dilemma for the Designer; what applications suit which particular products? Our Technical Advisory Engineers objectively recommend the right product for the right application based on a technical and commercial basis, but the simple guidance below will help Designers.

Westok Cellular Beams should be the first choice for:

- **Secondary floor beams**
- **Primary beams where many cells at regular spacing are required**
- **Straight roof beams**
- **Curved roof beams**
- **Tapered roof beams**

Westok Plate Beams should be considered for:

- **Beams subject to heavy point loads**
- **Primary beams where the servicing requirement can be relaxed**
- **Beams where bespoke web openings of different sizes and locations are required**
- **Beams heavier than 150 kg/m however speak to our advisory engineers as it is best to consider each project/application on its merits**
- **Westok Plate Columns should be considered for:**
- *** Applications such as high Valley Columns or Wind-Posts in single-story sheds**

Westok USFBs should be considered for:

- **Shallow floor solutions up to approximately 10m span**
- **Where a level soffit is required**

Software

SCI Cellbeam Software

Cellbeam is the only cellular beam software written and maintained by the Steel Construction Institute. It is available as a free download from **www.kloecknerwestok.com. The current version is V10.3.1 and includes design capabilities to EC - UK, IRL & NEN annexes, as well as BS.**

Westok's Advisory Engineers also use the same software to design cellular beams. Westok has no access to the source code of the program and SCI's decisions are final on a ll aspects of the design rules employed within it.

USFB™ Software

SCI and Westok have also released software to software to aid design of Ultra Shallow Floor Beams (USFBs). This is embedded within Cellbeam.

CellVibe software

Client specifications often include a performance requirement for the structural floors in the form of a maximum permitted response factor. CellVibe is an extremely quick and easy tool to use that determines the response characteristics of a floor in accordance with SCI publication P354.

Westok Plate Beam software

Plate beams can be designed quickly and easily using the Westok Plate Beam software. The software is written by Tekla, and is the same design engine that is used in Tekla Structural Designer and Fastrak Building Designer.

All software is available as a free download from www.kloecknerwestok.com

Cellbeam Integration with other Design Software packages

The most efficient way to design Westok cellular beams is to use Westok's Cellbeam package. Cellbeam is regularly upgraded, and represents the most up to date understanding of the structural behaviour of Westok products. Use of Cellbeam will ensure the most economic design of a Westok beam.

Through our collaboration with structural software houses, Westok Cellular Beams can also be defined and analysed in 3rd party software packages, such as Fastrak Building Designer (FBD), Tekla Structural Designer (TSD), and Bentley RAM Structural Systems. Engineers can take advantage of import/export functionality within these 3rd party packages, to send beams from the model to Cellbeam. The load from the model is "decomposed" into a series of line loads and point loads onto the Westok beam, and can be exported to Cellbeam. Following economic sizing, the user can opt to import the newly designed Westok beam from Cellbeam back to the model.

Under certain circumstances, BS codified design can also be carried out in these 3rd party packages, although users are likely to find more efficient designs by using Cellbeam. FBD and TSD design takes place using design rules outlined in SCI's P100 document, which was published in 1990. RAM's design engine was developed around 2005.

Alternatively, the engineer can opt to use Cellbeam as a standalone package to design a range of Westok beams. Without employing an import/export design process, these Westok beam sizes can be directly adopted in the model.

BIM/Autodesk Revit Integration

There a are a number of ways designers can integrate Westok cellular beams into a building model.

- If using a package, such as Tekla Structural Designer (TSD) or Fastrak Building Designer (FBD) simply build the model and export to Revit
- Build the model in Revit and then send a beam from the model to Cellbeam via the Westok Revit Integrator package. The beam is then designed and sized in Cellbeam, and then exported back to the model with all of the relevant info contained therein.
- Download our Westok Revit Family files from our website.

All our free software packages are available here: **www.kloecknerwestok.com**

Quick Sizing Guide

Composite secondary floor beams

Westok cellular beams perform best as simply supported secondary floor beams to achieve either long spans and/or service integration. This table attempts to show some of the possible solutions using Westok cellular beams. Many, many more are possible as the cell diameter, cell spacing and beam depth are all highly flexible parameters specified by the designer.

Beams should **always** be designed using the Cellbeam software and/or Westok's free design service on 0113 205 5270.

Optioneering – same spans different sizes

Preliminary composite cellular beam sizing table for S355 steel and normal weight concrete 1kN/m^2 for ceiling, services and finishes: 4 + 1kN/m^2 variable/live.

	Depth mm	Top tee Bottom tee	Mass kg/m	Top tee Depth mm	Cell Data dia/pitch mm	Deflections Const'n/variable mm	Footfall response
12m span secondary							
Minimum depth (span/d: approx. 35)	350	356 x 171 UB 67 254 x 254 UC 89	78	177	225/345	65/31	6.0
Lightest weight	546	406 x 140 UB 46 406 x 178 UB 60	53	273	350/525	40/17	7.9
Large cell (span/d: approx. 20)	637	457 x 152 UB 52 457 x 152 UB 60	56	317	450/675	29/13	7.3
15m span secondary							
Minimum depth (span/d: approx. 35)	425	533 x 210 UB 92 305 x 305 UC 118	105	214	275/417	88/35	3.5
Lightest weight	655	457 x 152 UB 60 533 x 210 UB 82	71	312	400/600	53/25	4.7
Large cell (span/d: approx. 20)	750	457 x 152 UB 67 533 x 210 UB 82	74.5	352	565/750	40/19	5.6
18m span secondary							
Minimum depth (span/d: approx. 35)	525*	533 x 210 UB 109 356 x 368 UC 153	131	291	350/530	96/42	2.6
Lightest weight	739*	457 x 191 UB 74 610 x 229 UB 113	93.5	340	500/750	68/34	3.3
Large cell (span/d: approx. 20)	895	610 x 229 UB 101 610 x 229 UB 113	107	446	700/1060	41/24	3.2

Basis of design:

140 composite slab on Tata CF51 deck. Beam centres at 3m. The footfall response has been determined based on a 7.5m grid/bay and a minimum of 4 bays. Damping has been allowed at 3% "Fully fitted out floors, normal use". * beam NF < 4Hz.

Floor grids

Preliminary composite cellular beam sizing table for S355 steel and normal weight concrete 1kN/m^2 for ceiling, services and finishes: 4 + 1kN/m^2 variable/live.

			PRIMARY BEAM					SECONDARY BEAM						
Prim span m	Sec span m	Sec crs m	Depth mm	Top tee / Bottom tee	Mass kg/m	Top tee depth mm	Cell data dia/pitch mm	Depth mm	Top tee / Bottom tee	Mass kg/m	Top tee depth mm	Cell data dia/pitch mm	Steel Weight kN/m^2	Footfall response
7.5	12	2.5	662	457 x 152 UB 82 533 x 210 UB 101	91.5	313	400/610	590	406 x 140 UB 46 457 x 152 UB 52	49.0	283	400/600	0.27	7.9
		3.75	656	457 x 152 UB 67 533 x 210 UB 92	79.5	309	400/610	617	457 x 152 UB 60 457 x 191 UB 67	63.5	309	400/600	0.24	9.0
7.5	15	2.5	761	610 x 229 UB 101 610 x 229 UB 113	107	379	400/625	618	457 x 152 UB 52 457 x 191 UB 82	67	307	400/600	0.34	4.9
		3.75	812	610 x 229 UB 101 610 x 229 UB 113	107	405	500/750	737	457 x 152 UB 67 610 x 229 UB 101	84	332	500/750	0.30	6.6
7.5	18	2.5	770	610 x 229 UB 125 610 x 229 UB 140	132.5	384	400/625	737	457 x 152 UB 67 610 x 229 UB 101	84	332	500/750	0.41	3.2
		3.75	859	610 x 229 UB 113 610 x 229 UB 140	126.5	427	550/750	819	533 x 210 UB 92 610 x 229 UB 125	108.5	390	550/750	0.36	4.2

This table attempts to show some of the possible solutions using Westok cellular beams. Many, many more are possible as the cell diameter, cell spacing and beam depth are all highly flexible parameters specified by the designer. Beams should always be designed using the Cellbeam software and/or Westok's free design service on 0113 205 5270.

Basis of design:

- 140 composite slab on Tata steel CF51 steel decking allowed for 2.5m secondary beam spacing.
- 140 composite slab on Tata steel CF60 steel decking allowed for 3.75m secondary beam spacing.
- The footfall response has been determined based on 6m grid/bay and a minimum of 4 bays. Damping has been allowed at 3% "Fully fitted out floors, normal use".

Quick Sizing Guide

Roof Beams

Westok cellular beams will typically have 50% greater strength and 125% greater stiffness compared to the parent section from which they were made. In lightly loaded long span roof applications they are the perfect solution, being lighter than a plain UB and cheaper to fabricate and paint than a truss.

The table below gives an indication of the spans achievable. Project specific sizes should always be designed using the Cellbeam software and/or Westok's free design service.

Guide roof beam sizes

Preliminary cellular beam sizing table for simply supported roof beams in S355 steel

Span m	Section	Cell Data dia/ pitch mm	Deflections variable load mm	Span/200 mm
15	Westok 442 x 165 x 40 CB	325/455	62	75
20	Westok 669 x 191 x 67 CB	475/625	55	100
25	Westok 738 x 210 x 82 CB	550/700	83	125
30	Westok 887 x 229 x 101 CB	625/835	108	150
35	Westok 909 x 229 x 125 CB	650/865	170	151
40	Westok 1123 x 267 x 147 CB	780/960	151	200
45	Westok 1144 x 267 x 173 CB	800/960	195	225
50	Westok 1323 x 305 x 201 CB	875/1040	196	250

Basis of design:

• Beam centres at 6m
• 0.5kN/m2 for cladding, purlins & services and finishes
• 0.6kN/m2 variable/live: 0.5kN/m2 wind pressure

SCI Publication P100 (1990)
Design of Composite and Non-Composite Cellular Beams

SCI Publication P212 (2002, 2009)
Joints in Steel Construction: Simple Connections

SCI Publication P288 (2006)
Fire Safe Design – A new approach to multi-storey steel framed buildings (Second Edition)

MCRMA/SCI Publication P300 (2009)
Composite slabs and beams using steel decking: Best practice for design and construction

SCI Publication P354 (2009)
Design of Floors for Vibration: A New Approach: Revised Edition

SCI Publication P355 (2011)
Design of Composite Beams with Large Web Openings

SCI Publication P358 (2011)
Joints in Steel Construction: Simple Joints to Eurocode 3

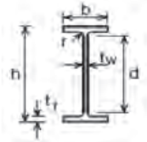
SCI Publication P405 (2015)
Minimum degree of shear connection rules for UK Construction to EC4

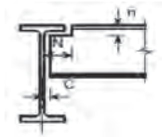
AD 344
Levelling techniques for composite floors

The Westok Cellular Beam Pocket Guide
Version 1.01: June 2016
Version 1.02: January 2016 – Company name and details on back page updated to suit re-brand
Version 1.03: June 2016 – Page 2 map updated and other minor amendments
Version 1.04: April 2017 – minor text corrections, update to software and map
Version 1.05: April 2018 - update to software and map
Version 1.06 Jan 2020 & 1.07 July 2020 - map updates

UK Beams: Dimensions

Standard(s): EN 1993-1-1: 2005, BS 4-1: 2005



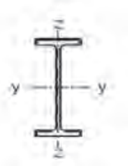


Section Designation	Mass per Metre	Depth of Section	Width of Section	Thickness Web	Thickness Flange	Root Radius	Depth between Fillets	Ratios for Local Buckling Web	Ratios for Local Buckling Flange	Dimensions for Detailing End Clearance	Dimensions for Detailing Notch	Dimensions for Detailing Notch	Surface Area Per Metre	Surface Area Per Tonne
		h	b	t_w	t_f	r	d	c_w / t_w	c_f / t_f	C	N	n		
	kg/m	mm	mm	mm	mm	mm	mm			mm	mm	mm	m^2	m^2
1016 x 305 x 487 +	486.7	1036.3	308.5	30	54.1	30	868.1	28.9	2.02	17	150	86	3.2	6.58
x 437 +	437	1026.1	305.4	26.9	49	30	868.1	32.3	2.23	15	150	80	3.17	7.25
x 393 +	392.7	1015.9	303	24.4	43.9	30	868.1	35.6	2.49	14	150	74	3.14	8
x 349 +	349.4	1008.1	302	21.1	40	30	868.1	41.1	2.76	13	152	70	3.13	8.96
x 314 +	314.3	999.9	300	19.1	35.9	30	868.1	45.5	3.08	12	152	66	3.11	9.89
x 272 +	272.3	990.1	300	16.5	31	30	868.1	52.6	3.6	10	152	62	3.1	11.4
x 249 +	248.7	980.1	300	16.5	26	30	868.1	52.6	4.3	10	152	56	3.08	12.4
x 222 +	222	970.3	300	16	21.1	30	868.1	54.3	5.31	10	152	52	3.06	13.8
914 x 419 x 388	388	921	420.5	21.4	36.6	24.1	799.6	37.4	4.79	13	210	62	3.44	8.87
x 343	343.3	911.8	418.5	19.4	32	24.1	799.6	41.2	5.48	12	210	58	3.42	9.96
914 x 305 x 289	289.1	926.6	307.7	19.5	32	19.1	824.4	42.3	3.91	12	156	52	3.01	10.4
x 253	253.4	918.4	305.5	17.3	27.9	19.1	824.4	47.7	4.48	11	156	48	2.99	11.8
x 224	224.2	910.4	304.1	15.9	23.9	19.1	824.4	51.8	5.23	10	156	44	2.97	13.2
x 201	200.9	903	303.3	15.1	20.2	19.1	824.4	54.6	6.19	10	156	40	2.96	14.7
838 x 292 x 226	226.5	850.9	293.8	16.1	26.8	17.8	761.7	47.3	4.52	10	150	46	2.81	12.4
x 194	193.8	840.7	292.4	14.7	21.7	17.8	761.7	51.8	5.58	9	150	40	2.79	14.4
x 176	175.9	834.9	291.7	14	18.8	17.8	761.7	54.4	6.44	9	150	38	2.78	15.8
762 x 267 x 197	196.8	769.8	268	15.6	25.4	16.5	686	44	4.32	10	138	42	2.55	13
x 173	173	762.2	266.7	14.3	21.6	16.5	686	48	5.08	9	138	40	2.53	14.6
x 147	146.9	754	265.2	12.8	17.5	16.5	686	53.6	6.27	8	138	34	2.51	17.1
x 134	133.9	750	264.4	12	15.5	16.5	686	57.2	7.08	8	138	32	2.51	18.7
686 x 254 x 170	170.2	692.9	255.8	14.5	23.7	15.2	615.1	42.4	4.45	9	132	40	2.35	13.8
x 152	152.4	687.5	254.5	13.2	21	15.2	615.1	46.6	5.02	9	132	38	2.34	15.4
x 140	140.1	683.5	253.7	12.4	19	15.2	615.1	49.6	5.55	8	132	36	2.33	16.6
x 125	125.2	677.9	253	11.7	16.2	15.2	615.1	52.6	6.51	8	132	32	2.32	18.5
610 x 305 x 238	238.1	635.8	311.4	18.4	31.4	16.5	540	29.3	4.14	11	158	48	2.45	10.3
x 179	179	620.2	307.1	14.1	23.6	16.5	540	38.3	5.51	9	158	42	2.41	13.5
x 149	149.2	612.4	304.8	11.8	19.7	16.5	540	45.8	6.6	8	158	38	2.39	16
610 x 229 x 140	139.9	617.2	230.2	13.1	22.1	12.7	547.6	41.8	4.34	9	120	36	2.11	15.1
x 125	125.1	612.2	229	11.9	19.6	12.7	547.6	46	4.89	8	120	34	2.09	16.7
x 113	113	607.6	228.2	11.1	17.3	12.7	547.6	49.3	5.54	8	120	30	2.08	18.4
x 101	101.2	602.6	227.6	10.5	14.8	12.7	547.6	52.2	6.48	7	120	28	2.07	20.5
610 x 178 x 100 +	100.3	607.4	179.2	11.3	17.2	12.7	547.6	48.5	4.14	8	94	30	1.89	18.8
x 92 +	92.2	603	178.8	10.9	15	12.7	547.6	50.2	4.75	7	94	28	1.88	20.4
x 82 +	81.8	598.6	177.9	10	12.8	12.7	547.6	54.8	5.57	7	94	26	1.87	22.9
533 x 312 x 272 +	273.3	577.1	320.2	21.1	37.6	12.7	476.5	22.6	3.64	13	160	52	2.37	8.67
x 219 +	218.8	560.3	317.4	18.3	29.2	12.7	476.5	26	4.69	11	160	42	2.33	10.7
x 182 +	181.5	550.7	314.5	15.2	24.4	12.7	476.5	31.3	5.61	10	160	38	2.31	12.7
x 150 +	150.6	542.5	312	12.7	20.3	12.7	476.5	37.5	6.75	8	160	34	2.29	15.2

+ These sections are in addition to the BS4 range

UK Beams: Properties

Standard(s): EN 1993-1-1: 2005, BS 4-1: 2005

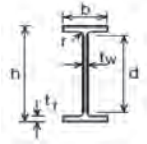


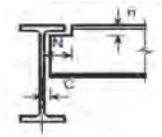
Section Designation	Second Moment of Area y-y	Second Moment of Area z-z	Radius of Gyration y-y	Radius of Gyration z-z	Elastic Modulus y-y	Elastic Modulus z-z	Plastic Modulus y-y	Plastic Modulus z-z	Buckling Paramete U	Torsional Index X	Warping Constant I_w	Torsional Constant I_T	Area of Section A
	cm^4	cm^4	cm	cm	cm^3	cm^3	cm^3	cm^3			dm^6	cm^4	cm^2
1016 x 305 x 487 +	1020000	26700	40.6	6.57	19700	1730	23200	2800	0.867	21.1	64.4	4300	620
x 437 +	910000	23400	40.4	6.49	17700	1540	20800	2470	0.868	23.1	56	3190	557
x 393 +	808000	20500	40.2	6.4	15900	1350	18500	2170	0.868	25.5	48.4	2330	500
x 349 +	723000	18500	40.3	6.44	14300	1220	16600	1940	0.872	27.9	43.3	1720	445
x 314 +	644000	16200	40.1	6.37	12900	1080	14800	1710	0.872	30.7	37.7	1260	400
x 272 +	554000	14000	40	6.35	11200	934	12800	1470	0.872	35	32.2	835	347
x 249 +	481000	11800	39	6.09	9820	784	11300	1240	0.861	39.9	26.8	582	317
x 222 +	408000	9550	38	5.81	8410	636	9810	1020	0.85	45.7	21.5	390	283
914 x 419 x 388	720000	45400	38.2	9.59	15600	2160	17700	3340	0.885	26.7	88.9	1730	494
x 343	626000	39200	37.8	9.46	13700	1870	15500	2890	0.883	30.1	75.8	1190	437
914 x 305 x 289	504000	15600	37	6.51	10900	1010	12600	1600	0.867	31.9	31.2	926	368
x 253	436000	13300	36.8	6.42	9500	871	10900	1370	0.865	36.2	26.4	626	323
x 224	376000	11200	36.3	6.27	8270	739	9530	1160	0.86	41.3	22.1	422	286
x 201	325000	9420	35.7	6.07	7200	621	8350	982	0.853	46.9	18.4	291	256
838 x 292 x 226	340000	11400	34.3	6.27	7980	773	9160	1210	0.869	35	19.3	514	289
x 194	279000	9070	33.6	6.06	6640	620	7640	974	0.862	41.6	15.2	306	247
x 176	246000	7800	33.1	5.9	5890	535	6810	842	0.856	46.5	13	221	224
762 x 267 x 197	240000	8170	30.9	5.71	6230	610	7170	958	0.869	33.1	11.3	404	251
x 173	205000	6850	30.5	5.58	5390	514	6200	807	0.865	38	9.39	267	220
x 147	169000	5460	30	5.4	4470	411	5160	647	0.858	45.2	7.4	159	187
x 134	151000	4790	29.7	5.3	4020	362	4640	570	0.853	49.8	6.46	119	171
686 x 254 x 170	170000	6630	28	5.53	4920	518	5630	811	0.872	31.8	7.42	308	217
x 152	150000	5780	27.8	5.46	4370	455	5000	710	0.871	35.4	6.42	220	194
x 140	136000	5180	27.6	5.39	3990	409	4560	638	0.87	38.6	5.72	169	178
x 125	118000	4380	27.2	5.24	3480	346	3990	542	0.863	43.8	4.8	116	159
610 x 305 x 238	209000	15800	26.3	7.23	6590	1020	7490	1570	0.886	21.3	14.5	785	303
x 179	153000	11400	25.9	7.07	4930	743	5550	1140	0.885	27.7	10.2	340	228
x 149	126000	9310	25.7	7	4110	611	4590	937	0.886	32.7	8.17	200	190
610 x 229 x 140	112000	4510	25	5.03	3620	391	4140	611	0.875	30.6	3.99	216	178
x 125	98600	3930	24.9	4.97	3220	343	3680	535	0.875	34	3.45	154	159
x 113	87300	3430	24.6	4.88	2870	301	3280	469	0.87	38	2.99	111	144
x 101	75800	2910	24.2	4.75	2520	256	2880	400	0.863	43	2.52	77	129
610 x 178 x 100 +	72500	1660	23.8	3.6	2390	185	2790	296	0.854	38.7	1.44	95	128
x 92 +	64600	1440	23.4	3.5	2140	161	2510	258	0.85	42.7	1.24	71	117
x 82 +	55900	1210	23.2	3.4	1870	136	2190	218	0.843	48.5	1.04	48.8	104
533 x 312 x 272 +	199000	20600	23.9	7.69	6890	1290	7870	1990	0.891	15.9	15	1290	348
x 219 +	151000	15600	23.3	7.48	5400	982	6120	1510	0.884	19.8	11	642	279
x 182 +	123000	12700	23.1	7.4	4480	806	5040	1240	0.886	23.4	8.77	373	231
x 150 +	101000	10300	22.9	7.32	3710	659	4150	1010	0.885	27.8	7.01	216	192

Source: Tata Steel sections interactive 'blue book' version 5.5 - reproduced with kind permision of Tata Steel

UK Beams: Dimensions

Standard(s): EN 1993-1-1: 2005, BS 4-1: 2005



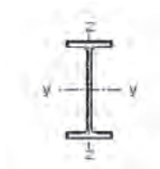


Section Designation	Mass per Metre	Depth of Section	Width of Section	Thickness		Root Radius	Depth between Fillets	Ratios for Local Buckling		Dimensions for Detailing			Surface Area	
				Web	Flange			Web	Flange	End Clearance	Notch		Per Metre	Per Tonne
		h	b	t_w	t_f	r	d	c_w / t_w	c_f / t_f	C	N	n		
	kg/m	mm	mm	mm	mm	mm	mm			mm	mm	mm	m^2	m^2
533 x 210 x 138 +	138.3	549.1	213.9	14.7	23.6	12.7	476.5	32.4	3.68	9	110	38	1.9	13.7
x 122	122	544.5	211.9	12.7	21.3	12.7	476.5	37.5	4.08	8	110	34	1.89	15.5
x 109	109	539.5	210.8	11.6	18.8	12.7	476.5	41.1	4.62	8	110	32	1.88	17.2
x 101	101	536.7	210	10.8	17.4	12.7	476.5	44.1	4.99	7	110	32	1.87	18.5
x 92	92.1	533.1	209.3	10.1	15.6	12.7	476.5	47.2	5.57	7	110	30	1.86	20.2
x 82	82.2	528.3	208.8	9.6	13.2	12.7	476.5	49.6	6.58	7	110	26	1.85	22.5
533 x 165 x 85 +	84.8	534.9	166.5	10.3	16.5	12.7	476.5	46.3	3.96	7	90	30	1.69	19.9
x 74 +	74.7	529.1	165.9	9.7	13.6	12.7	476.5	49.1	4.81	7	90	28	1.68	22.5
x 66 +	65.7	524.7	165.1	8.9	11.4	12.7	476.5	53.5	5.74	6	90	26	1.67	25.4
457 x 191 x 161 +	161.4	492	199.4	18	32	10.2	407.6	22.6	2.52	11	102	44	1.73	10.7
x 133 +	133.3	480.6	196.7	15.3	26.3	10.2	407.6	26.6	3.06	10	102	38	1.7	12.8
x 106 +	105.8	469.2	194	12.6	20.6	10.2	407.6	32.3	3.91	8	102	32	1.67	15.8
x 98	98.3	467.2	192.8	11.4	19.6	10.2	407.6	35.8	4.11	8	102	30	1.67	17
x 89	89.3	463.4	191.9	10.5	17.7	10.2	407.6	38.8	4.55	7	102	28	1.66	18.6
x 82	82	460	191.3	9.9	16	10.2	407.6	41.2	5.03	7	102	28	1.65	20.1
x 74	74.3	457	190.4	9	14.5	10.2	407.6	45.3	5.55	7	102	26	1.64	22.1
x 67	67.1	453.4	189.9	8.5	12.7	10.2	407.6	48	6.34	6	102	24	1.63	24.3
457 x 152 x 82	82.1	465.8	155.3	10.5	18.9	10.2	407.6	38.8	3.29	7	84	30	1.51	18.4
x 74	74.2	462	154.4	9.6	17	10.2	407.6	42.5	3.66	7	84	28	1.5	20.2
x 67	67.2	458	153.8	9	15	10.2	407.6	45.3	4.15	7	84	26	1.5	22.3
x 60	59.8	454.6	152.9	8.1	13.3	10.2	407.6	50.3	4.68	6	84	24	1.49	24.9
x 52	52.3	449.8	152.4	7.6	10.9	10.2	407.6	53.6	5.71	6	84	22	1.48	28.3
406 x 178 x 85 +	85.3	417.2	181.9	10.9	18.2	10.2	360.4	33.1	4.14	7	96	30	1.52	17.8
x 74	74.2	412.8	179.5	9.5	16	10.2	360.4	37.9	4.68	7	96	28	1.51	20.4
x 67	67.1	409.4	178.8	8.8	14.3	10.2	360.4	41	5.23	6	96	26	1.5	22.3
x 60	60.1	406.4	177.9	7.9	12.8	10.2	360.4	45.6	5.84	6	96	24	1.49	24.8
x 54	54.1	402.6	177.7	7.7	10.9	10.2	360.4	46.8	6.86	6	96	22	1.48	27.3
406 x 140 x 53 +	53.3	406.6	143.3	7.9	12.9	10.2	360.4	45.6	4.46	6	78	24	1.35	25.3
x 46	46	403.2	142.2	6.8	11.2	10.2	360.4	53	5.13	5	78	22	1.34	29.1
x 39	39	398	141.8	6.4	8.6	10.2	360.4	56.3	6.69	5	78	20	1.33	34.1
356 x 171 x 67	67.1	363.4	173.2	9.1	15.7	10.2	311.6	34.2	4.58	7	94	26	1.38	20.6
x 57	57	358	172.2	8.1	13	10.2	311.6	38.5	5.53	6	94	24	1.37	24.1
x 51	51	355	171.5	7.4	11.5	10.2	311.6	42.1	6.25	6	94	22	1.36	26.7
x 45	45	351.4	171.1	7	9.7	10.2	311.6	44.5	7.41	6	94	20	1.36	30.2
356 x 127 x 39	39.1	353.4	126	6.6	10.7	10.2	311.6	47.2	4.63	5	70	22	1.18	30.2
x 33	33.1	349	125.4	6	8.5	10.2	311.6	51.9	5.82	5	70	20	1.17	35.4
305 x 165 x 54	54	310.4	166.9	7.9	13.7	8.9	265.2	33.6	5.15	6	90	24	1.26	23.3
x 46	46.1	306.6	165.7	6.7	11.8	8.9	265.2	39.6	5.98	5	90	22	1.25	27.1
x 40	40.3	303.4	165	6	10.2	8.9	265.2	44.2	6.92	5	90	20	1.24	30.8

+ These sections are in addition to the BS4 range

UK Beams: Properties

Standard(s): EN 1993-1-1: 2005, BS 4-1: 2005

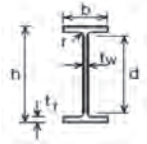


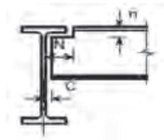
Section Designation	Second Moment of Area y-y	Second Moment of Area z-z	Radius of Gyration y-y	Radius of Gyration z-z	Elastic Modulus y-y	Elastic Modulus z-z	Plastic Modulus y-y	Plastic Modulus z-z	Buckling Paramete U	Torsional Index X	Warping Constant I_w	Torsional Constant I_T	Area of Section A
	cm^4	cm^4	cm	cm	cm^3	cm^3	cm^3	cm^3			dm^6	cm^4	cm^2
533 x 210 x 138 +	86100	3860	22.1	4.68	3140	361	3610	568	0.874	24.9	2.67	250	176
x 122	76000	3390	22.1	4.67	2790	320	3200	500	0.878	27.6	2.32	178	155
x 109	66800	2940	21.9	4.6	2480	279	2830	436	0.875	30.9	1.99	126	139
x 101	61500	2690	21.9	4.57	2290	256	2610	399	0.874	33.1	1.81	101	129
x 92	55200	2390	21.7	4.51	2070	228	2360	355	0.873	36.4	1.6	75.7	117
x 82	47500	2010	21.3	4.38	1800	192	2060	300	0.863	41.6	1.33	51.5	105
533 x 165 x 85 +	48500	1270	21.2	3.44	1820	153	2100	243	0.861	35.5	0.857	73.8	108
x 74 +	41100	1040	20.8	3.3	1550	125	1810	200	0.853	41.1	0.691	47.9	95.2
x 66 +	35000	859	20.5	3.2	1340	104	1560	166	0.847	47	0.566	32	83.7
457 x 191 x 161 +	79800	4250	19.7	4.55	3240	426	3780	672	0.881	16.5	2.25	515	206
x 133 +	63800	3350	19.4	4.44	2660	341	3070	535	0.879	19.6	1.73	292	170
x 106 +	48900	2510	19	4.32	2080	259	2390	405	0.876	24.4	1.27	146	135
x 98	45700	2350	19.1	4.33	1960	243	2230	379	0.881	25.8	1.18	121	125
x 89	41000	2090	19	4.29	1770	218	2010	338	0.878	28.3	1.04	90.7	114
x 82	37100	1870	18.8	4.23	1610	196	1830	304	0.879	30.8	0.922	69.2	104
x 74	33300	1670	18.8	4.2	1460	176	1650	272	0.877	33.8	0.818	51.8	94.6
x 67	29400	1450	18.5	4.12	1300	153	1470	237	0.873	37.8	0.705	37.1	85.5
457 x 152 x 82	36600	1180	18.7	3.37	1570	153	1810	240	0.872	27.4	0.591	89.2	105
x 74	32700	1050	18.6	3.33	1410	136	1630	213	0.872	30.1	0.518	65.9	94.5
x 67	28900	913	18.4	3.27	1260	119	1450	187	0.868	33.6	0.448	47.7	85.6
x 60	25500	795	18.3	3.23	1120	104	1290	163	0.868	37.5	0.387	33.8	76.2
x 52	21400	645	17.9	3.11	950	84.6	1100	133	0.859	43.8	0.311	21.4	66.6
406 x 178 x 85 +	31700	1830	17.1	4.11	1520	201	1730	313	0.88	24.4	0.728	93	109
x 74	27300	1550	17	4.04	1320	172	1500	267	0.882	27.5	0.608	62.8	94.5
x 67	24300	1360	16.9	3.99	1190	153	1350	237	0.88	30.4	0.533	46.1	85.5
x 60	21600	1200	16.8	3.97	1060	135	1200	209	0.88	33.7	0.466	33.3	76.5
x 54	18700	1020	16.5	3.85	930	115	1050	178	0.871	38.3	0.392	23.1	69
406 x 140 x 53 +	18300	635	16.4	3.06	899	88.6	1030	139	0.87	34.1	0.246	29	67.9
x 46	15700	538	16.4	3.03	778	75.7	888	118	0.871	39	0.207	19	58.6
x 39	12500	410	15.9	2.87	629	57.8	724	90.8	0.858	47.4	0.155	10.7	49.7
356 x 171 x 67	19500	1360	15.1	3.99	1070	157	1210	243	0.886	24.4	0.412	55.7	85.5
x 57	16000	1110	14.9	3.91	896	129	1010	199	0.882	28.8	0.33	33.4	72.6
x 51	14100	968	14.8	3.86	796	113	896	174	0.881	32.1	0.286	23.8	64.9
x 45	12100	811	14.5	3.76	687	94.8	775	147	0.874	36.8	0.237	15.8	57.3
356 x 127 x 39	10200	358	14.3	2.68	576	56.8	659	89	0.871	35.2	0.105	15.1	49.8
x 33	8250	280	14	2.58	473	44.7	543	70.2	0.863	42.1	0.081	8.79	42.1
305 x 165 x 54	11700	1060	13	3.93	754	127	846	196	0.889	23.6	0.234	34.8	68.8
x 46	9900	896	13	3.9	646	108	720	166	0.89	27.1	0.195	22.2	58.7
x 40	8500	764	12.9	3.86	560	92.6	623	142	0.889	31	0.164	14.7	51.3

Source: Tata Steel sections interactive 'blue book' version 5.5 - reproduced with kind permision of Tata Steel

UK Beams: Dimensions

Standard(s): EN 1993-1-1: 2005, BS 4-1: 2005



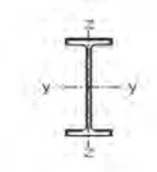


Section Designation	Mass per Metre	Depth of Section	Width of Section	Thickness		Root Radius	Depth between Fillets	Ratios for Local Buckling		Dimensions for Detailing			Surface Area	
				Web	Flange			Web	Flange	End Clearance	Notch		Per Metre	Per Tonne
		h	b	t_w	t_f	r	d	c_w / t_w	c_f / t_f	C	N	n		
	kg/m	mm	mm	mm	mm	mm	mm			mm	mm	mm	m^2	m^2
305 x 127 x 48	48.1	311	125.3	9	14	8.9	265.2	29.5	3.52	7	70	24	1.09	22.7
x 42	41.9	307.2	124.3	8	12.1	8.9	265.2	33.2	4.07	6	70	22	1.08	25.8
x 37	37	304.4	123.4	7.1	10.7	8.9	265.2	37.4	4.6	6	70	20	1.07	28.9
305 x 102 x 33	32.8	312.7	102.4	6.6	10.8	7.6	275.9	41.8	3.73	5	58	20	1.01	30.8
x 28	28.2	308.7	101.8	6	8.8	7.6	275.9	46	4.58	5	58	18	1	35.5
x 25	24.8	305.1	101.6	5.8	7	7.6	275.9	47.6	5.76	5	58	16	0.992	40
254 x 146 x 43	43	259.6	147.3	7.2	12.7	7.6	219	30.4	4.92	6	82	22	1.08	25.1
x 37	37	256	146.4	6.3	10.9	7.6	219	34.8	5.73	5	82	20	1.07	28.9
x 31	31.1	251.4	146.1	6	8.6	7.6	219	36.5	7.26	5	82	18	1.06	34
254 x 102 x 28	28.3	260.4	102.2	6.3	10	7.6	225.2	35.7	4.04	5	58	18	0.904	31.9
x 25	25.2	257.2	101.9	6	8.4	7.6	225.2	37.5	4.8	5	58	16	0.897	35.7
x 22	22	254	101.6	5.7	6.8	7.6	225.2	39.5	5.93	5	58	16	0.89	40.5
203 x 133 x 30	30	206.8	133.9	6.4	9.6	7.6	172.4	26.9	5.85	5	74	18	0.923	30.8
x 25	25.1	203.2	133.2	5.7	7.8	7.6	172.4	30.2	7.2	5	74	16	0.915	36.5
203 x 102 x 23	23.1	203.2	101.8	5.4	9.3	7.6	169.4	31.4	4.37	5	60	18	0.79	34.2
178 x 102 x 19	19	177.8	101.2	4.8	7.9	7.6	146.8	30.6	5.14	4	60	16	0.738	38.7
152 x 89 x 16	16	152.4	88.7	4.5	7.7	7.6	121.8	27.1	4.48	4	54	16	0.638	40
127 x 76 x 13	13	127	76	4	7.6	7.6	96.6	24.2	3.74	4	46	16	0.537	41.4

+ These sections are in addition to the BS4 range

UK Beams: Properties

Standard(s): EN 1993-1-1: 2005, BS 4-1: 2005

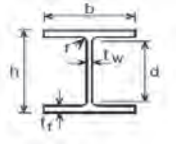


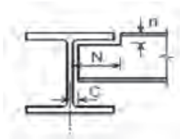
Section Designation	Second Moment of Area y-y	Second Moment of Area z-z	Radius of Gyration y-y	Radius of Gyration z-z	Elastic Modulus y-y	Elastic Modulus z-z	Plastic Modulus y-y	Plastic Modulus z-z	Buckling Paramete U	Torsional Index X	Warping Constant I_w	Torsional Constant I_T	Area of Section A
	cm^4	cm^4	cm	cm	cm^3	cm^3	cm^3	cm^3			dm^6	cm^4	cm^2
305 x 127 x 48	9570	461	12.5	2.74	616	73.6	711	116	0.873	23.3	0.102	31.8	61.2
x 42	8200	389	12.4	2.7	534	62.6	614	98.4	0.872	26.5	0.0846	21.1	53.4
x 37	7170	336	12.3	2.67	471	54.5	539	85.4	0.872	29.7	0.0725	14.8	47.2
305 x 102 x 33	6500	194	12.5	2.15	416	37.9	481	60	0.867	31.6	0.0442	12.2	41.8
x 28	5370	155	12.2	2.08	348	30.5	403	48.4	0.859	37.3	0.0349	7.4	35.9
x 25	4460	123	11.9	1.97	292	24.2	342	38.8	0.846	43.4	0.027	4.77	31.6
254 x 146 x 43	6540	677	10.9	3.52	504	92	566	141	0.891	21.1	0.103	23.9	54.8
x 37	5540	571	10.8	3.48	433	78	483	119	0.89	24.3	0.0857	15.3	47.2
x 31	4410	448	10.5	3.36	351	61.3	393	94.1	0.879	29.6	0.066	8.55	39.7
254 x 102 x 28	4000	179	10.5	2.22	308	34.9	353	54.8	0.873	27.5	0.028	9.57	36.1
x 25	3410	149	10.3	2.15	266	29.2	306	46	0.866	31.4	0.023	6.42	32
x 22	2840	119	10.1	2.06	224	23.5	259	37.3	0.856	36.3	0.0182	4.15	28
203 x 133 x 30	2900	385	8.71	3.17	280	57.5	314	88.2	0.882	21.5	0.0374	10.3	38.2
x 25	2340	308	8.56	3.1	230	46.2	258	70.9	0.876	25.6	0.0294	5.96	32
203 x 102 x 23	2100	164	8.46	2.36	207	32.2	234	49.7	0.888	22.4	0.0154	7.02	29.4
178 x 102 x 19	1360	137	7.48	2.37	153	27	171	41.6	0.886	22.6	0.0099	4.41	24.3
152 x 89 x 16	834	89.8	6.41	2.1	109	20.2	123	31.2	0.89	19.5	0.0047	3.56	20.3
127 x 76 x 13	473	55.7	5.35	1.84	74.6	14.7	84.2	22.6	0.894	16.3	0.002	2.85	16.5

Source: Tata Steel sections interactive 'blue book' version 5.5 - reproduced with kind permision of Tata Steel

UK Columns: Dimensions

Standard(s): EN 1993-1-1: 2005, BS 4-1: 2005





Section Designation	Mass per Metre	Depth of Section	Width of Section	Thickness Web	Thickness Flange	Root Radius	Depth between Fillets	Ratios for Local Buckling Web	Ratios for Local Buckling Flange	Dimensions for Detailing End Clearance	Dimensions for Detailing Notch	Dimensions for Detailing Notch	Surface Area Per Metre	Surface Area Per Tonne
		h	b	t_w	t_f	r	d	c_w / t_w	c_f / t_f	C	N	n		
	kg/m	mm	mm	mm	mm	mm	mm			mm	mm	mm	m^2	m^2
356 x 406 x 634	633.9	474.6	424	47.6	77	15.2	290.2	6.1	2.25	26	200	94	2.52	3.98
x 551	551	455.6	418.5	42.1	67.5	15.2	290.2	6.89	2.56	23	200	84	2.47	4.48
x 467	467	436.6	412.2	35.8	58	15.2	290.2	8.11	2.98	20	200	74	2.42	5.18
x 393	393	419	407	30.6	49.2	15.2	290.2	9.48	3.52	17	200	66	2.38	6.06
x 340	339.9	406.4	403	26.6	42.9	15.2	290.2	10.9	4.03	15	200	60	2.35	6.91
x 287	287.1	393.6	399	22.6	36.5	15.2	290.2	12.8	4.74	13	200	52	2.31	8.05
x 235	235.1	381	394.8	18.4	30.2	15.2	290.2	15.8	5.73	11	200	46	2.28	9.7
356 x 368 x 202	201.9	374.6	374.7	16.5	27	15.2	290.2	17.6	6.07	10	190	44	2.19	10.8
x 177	177	368.2	372.6	14.4	23.8	15.2	290.2	20.2	6.89	9	190	40	2.17	12.3
x 153	152.9	362	370.5	12.3	20.7	15.2	290.2	23.6	7.92	8	190	36	2.16	14.1
x 129	129	355.6	368.6	10.4	17.5	15.2	290.2	27.9	9.37	7	190	34	2.14	16.6
305 x 305 x 283	282.9	365.3	322.2	26.8	44.1	15.2	246.7	9.21	3	15	158	60	1.94	6.86
x 240	240	352.5	318.4	23	37.7	15.2	246.7	10.7	3.51	14	158	54	1.91	7.96
x 198	198.1	339.9	314.5	19.1	31.4	15.2	246.7	12.9	4.22	12	158	48	1.87	9.44
x 158	158.1	327.1	311.2	15.8	25	15.2	246.7	15.6	5.3	10	158	42	1.84	11.6
x 137	136.9	320.5	309.2	13.8	21.7	15.2	246.7	17.9	6.11	9	158	38	1.82	13.3
x 118	117.9	314.5	307.4	12	18.7	15.2	246.7	20.6	7.09	8	158	34	1.81	15.4
x 97	96.9	307.9	305.3	9.9	15.4	15.2	246.7	24.9	8.6	7	158	32	1.79	18.5
254 x 254 x 167	167.1	289.1	265.2	19.2	31.7	12.7	200.3	10.4	3.48	12	134	46	1.58	9.46
x 132	132	276.3	261.3	15.3	25.3	12.7	200.3	13.1	4.36	10	134	38	1.55	11.7
x 107	107.1	266.7	258.8	12.8	20.5	12.7	200.3	15.6	5.38	8	134	34	1.52	14.2
x 89	88.9	260.3	256.3	10.3	17.3	12.7	200.3	19.4	6.38	7	134	30	1.5	16.9
x 73	73.1	254.1	254.6	8.6	14.2	12.7	200.3	23.3	7.77	6	134	28	1.49	20.4
203 x 203 x 127 +	127.5	241.4	213.9	18.1	30.1	10.2	160.8	8.88	2.91	11	108	42	1.28	10
x 113 +	113.5	235	212.1	16.3	26.9	10.2	160.8	9.87	3.26	10	108	38	1.27	11.2
x 100 +	99.6	228.6	210.3	14.5	23.7	10.2	160.8	11.1	3.7	9	108	34	1.25	12.6
x 86	86.1	222.2	209.1	12.7	20.5	10.2	160.8	12.7	4.29	8	110	32	1.24	14.4
x 71	71	215.8	206.4	10	17.3	10.2	160.8	16.1	5.09	7	110	28	1.22	17.2
x 60	60	209.6	205.8	9.4	14.2	10.2	160.8	17.1	6.2	7	110	26	1.21	20.2
x 52	52	206.2	204.3	7.9	12.5	10.2	160.8	20.4	7.04	6	110	24	1.2	23.1
x 46	46.1	203.2	203.6	7.2	11	10.2	160.8	22.3	8	6	110	22	1.19	25.8
152 x 152 x 51 +	51.2	170.2	157.4	11	15.7	7.6	123.6	11.2	4.18	8	84	24	0.935	18.3
x 44 +	44	166	155.9	9.5	13.6	7.6	123.6	13	4.82	7	84	22	0.924	21
x 37	37	161.8	154.4	8	11.5	7.6	123.6	15.5	5.7	6	84	20	0.912	24.7
x 30	30	157.6	152.9	6.5	9.4	7.6	123.6	19	6.98	5	84	18	0.901	30
x 23	23	152.4	152.2	5.8	6.8	7.6	123.6	21.3	9.65	5	84	16	0.889	38.7

+ These sections are in addition to the BS4 range

UK Columns: Properties

Standard(s): EN 1993-1-1: 2005, BS 4-1: 2005

Section Designation	Second Moment of Area		Radius of Gyration		Elastic Modulus		Plastic Modulus		Buckling Paramete	Torsional Index	Warping Constant	Torsional Constant	Area of Section
	y-y	z-z	y-y	z-z	y-y	z-z	y-y	z-z	U	X	I_w	I_T	A
	cm^4	cm^4	cm	cm	cm^3	cm^3	cm^3	cm^3			dm^6	cm^4	cm^2
356 x 406 x 634	275000	98100	18.4	11	11600	4630	14200	7110	0.843	5.46	38.8	13700	808
x 551	227000	82700	18	10.9	9960	3950	12100	6060	0.841	6.05	31.1	9240	702
x 467	183000	67800	17.5	10.7	8380	3290	10000	5030	0.839	6.86	24.3	5810	595
x 393	147000	55400	17.1	10.5	7000	2720	8220	4150	0.837	7.86	18.9	3550	501
x 340	123000	46900	16.8	10.4	6030	2330	7000	3540	0.836	8.85	15.5	2340	433
x 287	99900	38700	16.5	10.3	5070	1940	5810	2950	0.835	10.2	12.3	1440	366
x 235	79100	31000	16.3	10.2	4150	1570	4690	2380	0.834	12.1	9.54	812	299
356 x 368 x 202	66300	23700	16.1	9.6	3540	1260	3970	1920	0.844	13.4	7.16	558	257
x 177	57100	20500	15.9	9.54	3100	1100	3460	1670	0.844	15	6.09	381	226
x 153	48600	17600	15.8	9.49	2680	948	2960	1430	0.844	17	5.11	251	195
x 129	40200	14600	15.6	9.43	2260	793	2480	1200	0.844	19.9	4.18	153	164
305 x 305 x 283	78900	24600	14.8	8.27	4320	1530	5110	2340	0.855	7.65	6.35	2030	360
x 240	64200	20300	14.5	8.15	3640	1280	4250	1950	0.854	8.74	5.03	1270	306
x 198	50900	16300	14.2	8.04	3000	1040	3440	1580	0.854	10.2	3.88	734	252
x 158	38700	12600	13.9	7.9	2370	808	2680	1230	0.851	12.5	2.87	378	201
x 137	32800	10700	13.7	7.83	2050	692	2300	1050	0.851	14.2	2.39	249	174
x 118	27700	9060	13.6	7.77	1760	589	1960	895	0.85	16.2	1.98	161	150
x 97	22200	7310	13.4	7.69	1450	479	1590	726	0.85	19.3	1.56	91.2	123
254 x 254 x 167	30000	9870	11.9	6.81	2080	744	2420	1140	0.851	8.49	1.63	626	213
x 132	22500	7530	11.6	6.69	1630	576	1870	878	0.85	10.3	1.19	319	168
x 107	17500	5930	11.3	6.59	1310	458	1480	697	0.848	12.4	0.898	172	136
x 89	14300	4860	11.2	6.55	1100	379	1220	575	0.85	14.5	0.717	102	113
x 73	11400	3910	11.1	6.48	898	307	992	465	0.849	17.3	0.562	57.6	93.1
203 x 203 x 127 +	15400	4920	9.75	5.5	1280	460	1520	704	0.854	7.38	0.549	427	162
x 113 +	13300	4290	9.59	5.45	1130	404	1330	618	0.853	8.11	0.464	305	145
x 100 +	11300	3680	9.44	5.39	988	350	1150	534	0.852	9.02	0.386	210	127
x 86	9450	3130	9.28	5.34	850	299	977	456	0.85	10.2	0.318	137	110
x 71	7620	2540	9.18	5.3	706	246	799	374	0.853	11.9	0.25	80.2	90.4
x 60	6130	2070	8.96	5.2	584	201	656	305	0.846	14.1	0.197	47.2	76.4
x 52	5260	1780	8.91	5.18	510	174	567	264	0.848	15.8	0.167	31.8	66.3
x 46	4570	1550	8.82	5.13	450	152	497	231	0.847	17.7	0.143	22.2	58.7
152 x 152 x 51 +	3230	1020	7.04	3.96	379	130	438	199	0.848	10.1	0.061	48.8	65.2
x 44 +	2700	860	6.94	3.92	326	110	372	169	0.848	11.5	0.0499	31.7	56.1
x 37	2210	706	6.85	3.87	273	91.5	309	140	0.848	13.3	0.0399	19.2	47.1
x 30	1750	560	6.76	3.83	222	73.3	248	112	0.849	16	0.0308	10.5	38.3
x 23	1250	400	6.54	3.7	164	52.6	182	80.1	0.84	20.7	0.0212	4.63	29.2

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Kloeckner Metals UK | Westok, Valley Farm Way, Stourton, Leeds LS10 1SE, UK
t: +44 (0)113 205 5270 | f: +44 (0)113 254 1862 | e: info.westok@kloeckner.com

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