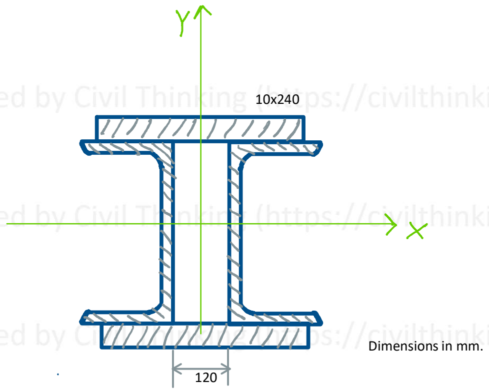
Problem Solution of finding the load bearing capacity of a Column as per Eurocode-3 cross-section C300

Find the load-bearing capacity as per Eurocode of a column loaded axially with the cross-section, as a complex section made of two C300 sections and two cover plates as shown below. The column is 6,00m high with pivots at the ends. Steel grade S355, strength f_{yd}=355Mpa, E= 210Gpa.



Solution:
The load bearing capacity of a column as per Eurocode is determined on the basis of slenderness, $\bar{\lambda}$ (*Pronounced as lamda bar*)

If $\bar{\lambda} \leq 0.2$ the column's bearing capacity is such so that the column is safe against **crushing/compression**. (Reference:Eurcode-3: EN 1993-1-1: Section 6.3.1.2 (4))

If $\bar{\lambda} > 0.2$ the bearing capacity of column is such so that the column is safe againest **Buckling**.

First we need to find the value of $\bar{\lambda}$, to check if its value is > 2 or ≤ 2:

$\bar{\lambda} = \sqrt{\frac{A.f_y}{N_{cr}}}$ *for Class 1,2, and 3 cross-sections* (Reference: Eurocode-3: EN 1993-1-1: Section 6.3.1.2 (1))

$\bar{\lambda} = \sqrt{\frac{A_{eff}.f_y}{N_{cr}}}$ *for Class 4 cross-sections* (Reference: Eurocode-3: EN 1993-1-1: Section 6.3.1.2 (1))

We don't know the Class of our cross-section, so let's find it first:

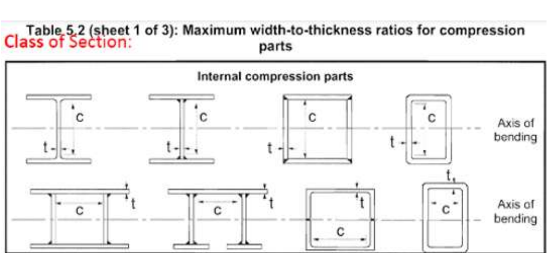
The class of a cross-section as per Eurocode is found using the **Table 5.2** (sheet 1, sheet 2 and sheet 3) on Eurocode-3 EN 1993-1-1.

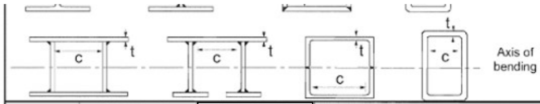
According to this we have to find slenderness ratio(which is effective length/thickness) of each part.
Eurocode denotes this length as c and thickness as t. After finding c/t ratio of all parts compare it to
As a complex section, like in this problem, is made of multiple parts I denoted length of each as c_1 , c_2 etc., and thickness as t_1, t_2, etc. of each part respectively.
Eurocode divides cross section elements as "Internal compression parts" and "Outstanding flanges". Weird right? Yes! Eurocode have its own world. But how will we understand which part is what? Simple rule: if some element is supported at only one end, its "outstanding flange". If a part is closed/fixed on both sides, it's "compression part".
And most importantly since our problem Is a column in compression, so we have to focus on c/t values in Eurocode table 5.2, "part subject to compression" column only.
In Eurocode, sheet 1 of 3, the c/t ratio of "Part subjected to Internal compression" only are provided and in sheet 2 of 3, c/t ratio of "Outstanding flanges" only are provided.
Also we have to find the value of ε (pronounced as epsilon).

$\varepsilon = \sqrt{\frac{235}{f_y}}$ where f_y = yield strength of material in Mpa.
In this problem, Steel grade is S355 which means f_y is 355Mpa
=> $\varepsilon = \sqrt{\frac{235}{355}} \approx$ 0.814
Once we find c/t ratio of all parts, we check if its less than or equal to 33ε for "Internal Compression parts" and if true then class is 1. similarly for "Outstanding part" if its less than or equal to 9ε, if true, this part is class 1 too (As shown in Table 5.2 sheets). This way we find class of all parts of our cross-section. And the class of whole cross-section is the highest class among classes of all parts.
Example: if we find part-1 is class 2 and part-2 is class 1, then class of whole cross-section is class-2.

Now let's actually find class of each part of cross-section, in our problem:

Class of Section:





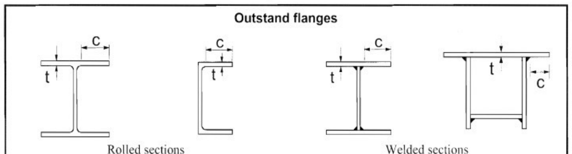
Class	Part subject to bending	Part subject to compression	Part subject to bending and compression					
Stress distribution in parts (compression positive)								
1	$c/t \le 72\varepsilon$	$c/t \le 33\varepsilon$	when $\alpha > 0{,}5$: $c/t \le \frac{396\varepsilon}{13\alpha - 1}$ when $\alpha \le 0{,}5$: $c/t \le \frac{36\varepsilon}{\alpha}$					
2	$c/t \le 83\varepsilon$	$c/t \le 38\varepsilon$	when $\alpha > 0{,}5$: $c/t \le \frac{456\varepsilon}{13\alpha - 1}$ when $\alpha \le 0{,}5$: $c/t \le \frac{41{,}5\varepsilon}{\alpha}$					
Stress distribution in parts (compression positive)								
3	$c/t \le 124\varepsilon$	$c/t \le 42\varepsilon$	when $\psi > -1$: $c/t \le \frac{42\varepsilon}{0{,}67 + 0{,}33\psi}$ when $\psi \le -1^{*)}$: $c/t \le 62\varepsilon(1-\psi)\sqrt{(-\psi)}$					
$\varepsilon = \sqrt{235/f_y}$	f_y	235	275	355	420	460		
	ε	1,00	0,92	0,81	0,75	0,71		

*) $\psi \le -1$ applies where either the compression stress $\sigma \le f_y$ or the tensile strain $\varepsilon_y > f_y/E$

EN 1993-1-1:2005 (E)

Table 5.2 (sheet 2 of 3): Maximum width-to-thickness ratios for compression parts

Outstand flanges



Class	Part subject to compression	Part subject to bending and compression: Tip in compression	Part subject to bending and compression: Tip in tension
Stress distribution in parts (compression positive)			
1	$c/t \le 9\varepsilon$	$c/t \le \frac{9\varepsilon}{\alpha}$	$c/t \le \frac{9\varepsilon}{\alpha\sqrt{\alpha}}$
2	$c/t \le 10\varepsilon$	$c/t \le \frac{10\varepsilon}{\alpha}$	$c/t \le \frac{10\varepsilon}{\alpha\sqrt{\alpha}}$
Stress distribution in parts (compression positive)			
3	$c/t \le 14\varepsilon$	$c/t \le 21\varepsilon\sqrt{k_\sigma}$ For k_σ see EN 1993-1-5	

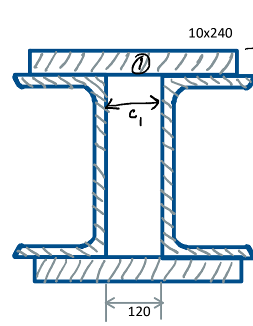
$\varepsilon = \sqrt{235/f_y}$						
	f_y	235	275	355	420	460
	ε	1,00	0,92	0,81	0,75	0,71

Shape-1: Rectangular cover plate (10x240) is "Internal compression part as per Eurocode because it's fixed on both sides by channel C sections (As shown in diagram on right):
Because it's "Internal Compression part" we have to see if its c/t value is less than or equal to 33ε as mentioned in sheet 1 of 3 of table 5.2 above.

C_1/t_1= 120mm/10mm= 12

We already found ε =0.814 => 33ε =33*0.814=26.862

As 12 <26.862 => part 1 is Class-1.



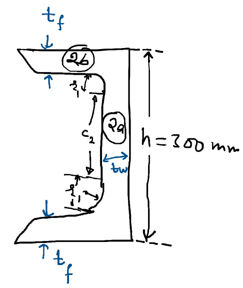
Dimensions in mm.

Shape-2: C300 channel section: We have two channels with same conditions so we will find Class of only one, then class of other one is the same.
Then channel have two parts the web which is "internal compression part" as per the Eurocode because both sides are fixed(on top and bottom flanges), lets name it 2a.
The other part of C300 channel section is the flange, which is called "Outstanding flange" as per

Shape-2: C300 channel section: We have two channels with same conditions so we will find Class of only one, then class of other one is the same.
Then channel have two parts the web which is "internal compression part" as per the Eurocode because both sides are fixed(on top and bottom flanges), lets name it 2a.
The other part of C300 channel section is the flange, which is called "Outstanding flange" as per Eurocode because its fixed to the web on one end and the other end is free, we will call it 2b.

Class of 2a:

$$\frac{C_{2a}}{t_{2a}} = \frac{300mm - 2t_f - 2r_1}{t_w}$$



Why is C_{2a}= 300mm-$2t_f$-$2r_1$?

Because c is the "straight" length of a member without any radial part.
If you look at the C section to the right, you will know the total depth off C section is 300mm because by definition of Eurocode, C300 means channel section of total depth (or total length of web) is 300mm. So C300 means h=300mm. Because t_f in both top and bottom flange is included in total depth, h, we have to subtract 2*t_f from h, then we have to again subtract r_1 two times because radial part is on both top and bottom, eventually we will get c_{2a} which is pure straight.

$$\frac{C_{2a}}{t_{2a}} = \frac{300mm - 2t_f - 2r_1}{t_w}$$

t_f= thickness of flange of C300 channel section. If you look up in any standard table, t_f for C300 is 16mm (I have attached a table for your reference below)
r_1= Internal radius of C300 channel section, which is again, from standard tables, = 16mm
t_w= Thickness of web of C300 = 10mm, from standard tables(below).

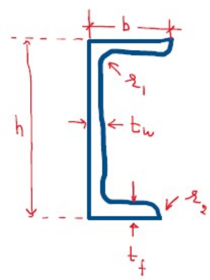
$$\Rightarrow \frac{C_{2a}}{t_{2a}} = \frac{300mm - 2.16 - 2.16}{10} = 23.6$$

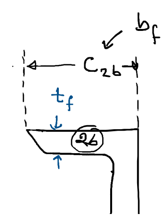
We already found 33ε =33*0.814=26.862
Since 23.6<26.862 => Class 1 (see Table 5.2 Sheet 1 of 3, attached above). ``

UPN European standard chann

Designation		Dimensions							Dim for det	
	G	h	b	tw	tf	r1	r2	A	d	?
	kg/m	mm	mm	mm	mm	mm	mm	cm2	mm	
UPN 80	8.64	80	45	6	8	8	4	11	46	-
UPN 100	10.6	100	50	6	8.5	8.5	4.5	13.5	64	M
UPN 120	13.4	120	55	7	9	9	4.5	17	82	M
UPN 140	16	140	60	7	10	10	5	20.4	98	M
UPN 160	18.8	160	65	7.5	10.5	10.5	5.5	24	115	M
UPN 180	22	180	70	8	11	11	5.5	28	133	M
UPN 200	25.3	200	75	8.5	11.5	11.5	6	32.2	151	M
UPN 220	29.4	220	80	9	12.5	12.5	6.5	37.4	167	M
UPN 240	33.2	240	85	9.5	13	13	6.5	42.3	184	M
UPN 260	37.9	260	90	10	14	14	7	48.3	200	M
UPN 280	41.8	280	95	10	15	15	7.5	53.3	216	M
UPN 300	46.2	300	100	10	16	16	8	58.8	232	M
UPN 320	59.5	320	100	14	17.5	17.5	8.75	75.8	246	M
UPN 350	60.6	350	100	14	16	16	8	77.3	282	M
UPN 380	63.1	380	102	13.5	16	16	8	80.4	313	M
UPN 400	71.8	400	110	14	18	18	9	91.5	324	M

C300 section → (b_f, t_w, t_f, r_1 marked on the UPN 300 row)





Class of 2b:
As I said earlier, 2b is "outstanding flange" as per Eurocode, so we have to check its c/t value according to sheet 2 of 3 of Table 5.2(above).

$$\frac{c_{2b}}{t_f} = \frac{b_f}{t_f} = \frac{100mm}{16mm} = 6.25$$

Class of 2b:
As I said earlier, 2b is "outstanding flange" as per Eurocode, so we have to check its c/t value according to sheet 2 of 3 of Table 5.2(above).

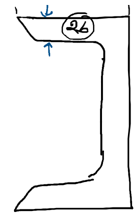
$\frac{c_{2b}}{t_f} = \frac{b_f}{t_f} = \frac{100mm}{16mm} = 6.25$

We have to use

9ε as per sheet 2 of 3 of Table 5.2 because its the first condition. If it fails we will move down to 10ε (see sheet 2 of 3, above).

We already found ε =0.814 => 9ε = 9 * 0.814 = 7.326

6.25 < 7.326 => Class 1



Now all of our parts: 1, 2a, 2b are Class 1 which means:

Our Cross-section is Class 1.

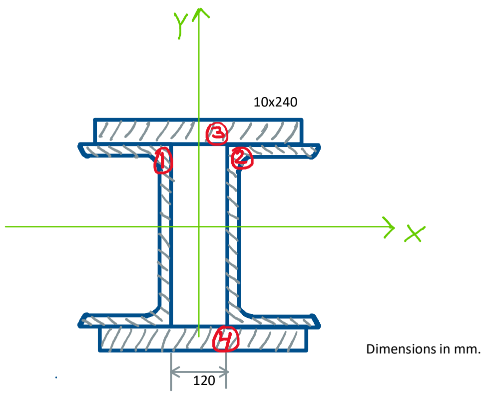
Since we know the Eurocode Classification of our cross-section is class 1 we can use:

$\bar{\lambda} = \sqrt{\frac{A.f_y}{N_{cr}}}$ *for Class 1,2, and 3 cross-sections* (Reference: Eurocode-3: EN 1993-1-1: Section 6.3.1.2 (1))

N_{cr} is the Critical load from Euler's Formula in Buckling:

$$N_{cr} = \frac{\pi^2 E\, I_{min}}{L_{eff}^2}$$

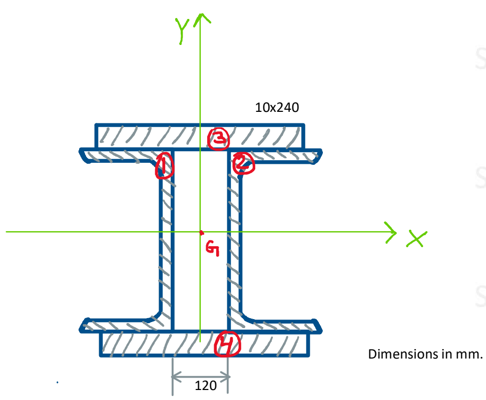
I_{min}= minimum moment of Inertia of our cross-section.
i.e. I_{min}= min(I_x,I_y)



Let's name each shape as 1, 2, 3 and 4. The two C sections shapes as 1 and 2, and the two cover plates as 3 and 4.

Moment of Inertia of a complex section, like this one, is the sum of moment of inertias of each shape.
i.e. Moment of Inertia of whole section about x axis= sum of moment of inertia of each shape about x axis.

Please be careful here. It's not as simple as this sounds. We can only add or subtract moment of inertias of different shapes if all of them are about the same axis(x and y axis). The moment of Inertia provided in tables for different basic shapes is moment of inertia about the axes passing through **their own center of gravities**. As you can see on the left side, the X and Y axes shown pass through the center of gravity (centroid) of the whole complex section. So we must first find moment of inertia of each shape (1,2,3, and 4) about these X and Y axis, and then add them to find Moment of Inertia of the whole complex section.
The first step in finding moment of inertia of simple shapes or complex shapes is always to locate the center of gravity (centroid) of the given shape. The given cross-section, as you can see on left, is *Symmetric* about both X and Y axes. Therefore the center of Gravity, G (some books denote it by C or O, but it doesn't matter).

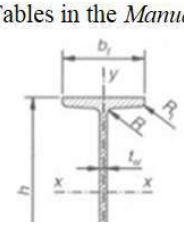


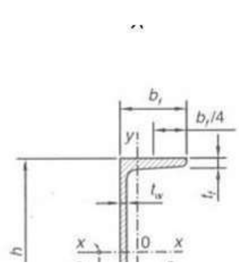
$I_x = I_{1x}+I_{2x}+I_{3x}+I_{4x}$

I_{1x}= moment of Inertia of shape 1 (left C section) about X axis.
As we can see in table 6, shown below, this X axis (I mean the X axis of the whole section as you can see, in green color), coincide with X axis in the table 6 (which is x axis of C section passing through its own G), as shown below. Which means I_{1x} is same as I_x from table of this C300 cross-section.

Table 6:

Tables in the *Manual of Steel Construction:*





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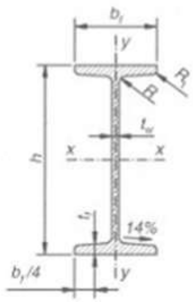
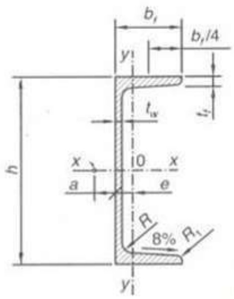
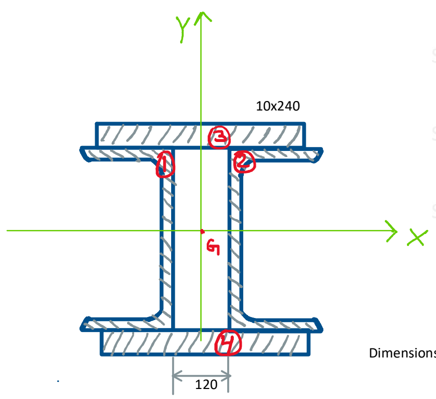




I-section, double-tee bar							
I			Area	Moments of inertia		Section modulus	
	h	b_f	A	I_x	I_y	W_x	W_y
			cm²	cm⁴		cm³	
80	80	42	7,57	77,8	6,29	19,5	3,00
100	100	50	10,6	171	12,2	34,2	4,88
120	120	58	14,2	328	21,5	54,7	7,41
140	140	66	18,2	573	35,2	81,9	10,7
160	160	74	22,8	935	54,7	117	14,8
180	180	82	27,9	1450	81,3	161	19,8
200	200	90	33,4	2140	117	214	26,0
220	220	98	39,5	3060	162	278	33,1
240	240	106	46,1	4250	221	354	41,7
260	260	113	53,3	5740	288	442	51,0
300	300	125	69,0	9800	451	653	72,2
340	340	137	86,7	15700	674	923	98,4
360	360	143	97,0	19610	818	1090	114
400	400	155	118	29210	1160	1460	149
450	450	170	147	45850	1730	2040	203
500	500	185	179	68740	2480	2750	268
550	550	200	212	99180	3490	3610	349
600	600	215	254	139000	4670	4630	434

channel section								
C			Area		Moments of inertia		Section modulus	
	h	b_f	A	e	I_x	I_y	W_x	W_y
			cm²		cm⁴		cm³	
40	40	20	3,51	0,65	7,26	1,06	3,63	0,78
50	50	38	7,12	1,37	26,4	9,12	10,6	3,75
65	65	42	9,03	1,42	57,5	14,1	17,7	5,07
80	80	45	11,0	1,45	106	19,4	26,5	6,36
100	100	50	13,5	1,55	206	29,3	41,2	8,49
120	120	55	17,0	1,60	364	43,2	60,7	11,1
140	140	60	20,4	1,75	605	62,7	86,4	14,8
160	160	65	24,0	1,84	925	85,3	116	18,3
180	180	70	28,0	1,92	1350	114	150	22,4
200	200	75	32,2	2,01	1910	148	191	27,0
220	220	80	37,4	2,14	2690	197	245	33,6
240	240	85	42,3	2,23	3600	248	300	39,6
260	260	90	48,3	2,36	4820	317	371	47,7
280	280	95	53,3	2,53	6280	399	448	57,2
300	300	100	58,8	2,70	8030	495	535	67,8
320	320	100	75,8	2,60	10870	597	679	80,6
350	350	100	77,3	2,40	12840	570	734	75,0
380	380	102	80,4	2,38	15760	615	829	78,7
400	400	110	91,5	2,65	20350	846	1020	102,0

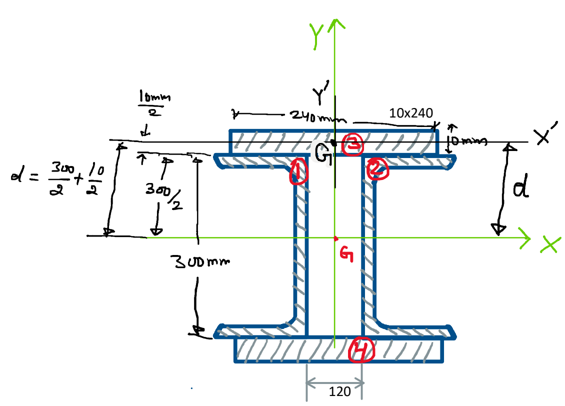


Dimensions in mm.

$I_x = I_{1x} + I_{2x} + I_{3x} + I_{4x}$

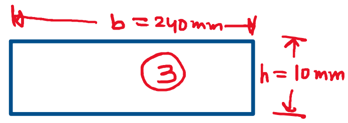
$I_{1x} = 8030\ cm^4 (from\ Table\ 6\ above) = 8030.(10mm)^4 = 8030.10^4 mm^4$ $(\because 1cm = 10mm)$

$I_{2x} = same\ as\ I_{1x} = 8030.10^4 mm^4$



I_{3x} is moment of Inertia of cover plate (rectangular shape 3) about green color X axis. But we only know moment of inertia of a rectangle about the axes passing through its own center of gravity, but our green X is not passing through center of gravity of the shape 3 rectangle, as you can see on the left! So what do we do..?

We will use the Theorem of Parallel axis, which says moment of inertia of a shape about an axis which does not pass through its center of gravity= moment of inertia about axis passing through its center of gravity plus (its Area multiplied by the square of the distance between the two axis). i.e. Square of normal distance between the axis passing through its G and another axis about which we want to find moment of inertia).



the distance between the two axis). i.e. Square of normal distance between the axis passing through its G and another axis about which we want to find moment of inertia).

$I_{3x} = I_{3x'} + (A * d^2)$

$I_{3x'}$ = *moment of inertia of rectangular shape 3 about x' axis passing through its own G.*

$I_{3x'} = \frac{bh^3}{12} = \frac{240*10^3}{12} = 20{,}000mm^4$

d= normal(perpendicular) distance between X' and X. If you look carefully at the diagram on left, we can find d as 300/2+ 10/2 = 155 mm

*A= Area of shape 3 rectangle= 240*10=*$2{,}400\ mm^2$

$\Rightarrow I_{3x} = 20{,}000 + (2400 * 155^2) = 57{,}680{,}000\ mm^4$

(Why did I wrote unit of $I_{1x} as\ mm^4$?

look at $\frac{bh^3}{12}$ formula, b is mm, h is mm^4 therefore total is $mm * mm^3 = mm^4$

Unit of Moment of Inertia is always $length^4$

Since the cross-section is symmetric, Moment of inertia of shape 4 rectangular cover plate, I_{4x} is same as I_{3x}

$\Rightarrow I_{4x} = 57{,}680{,}000\ mm^4$

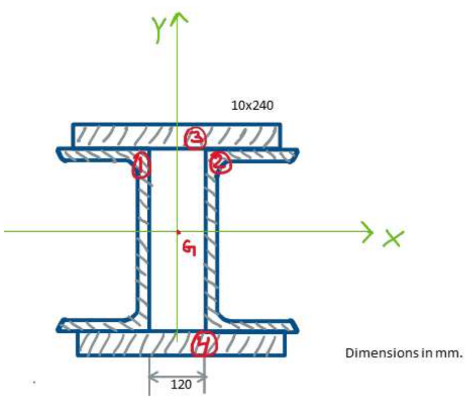
Finally we will be able to find I_x of our complex section:

$I_x = I_{1x}+I_{2x}+I_{3x}+I_{4x}$

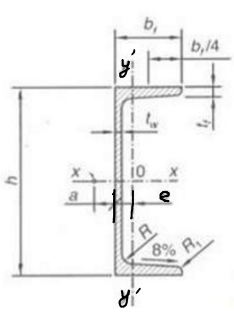
$= 8030.10^4 + 8030.10^4 + 57{,}680{,}000 + 57{,}680{,}000 = 275960000mm^4$

$I_x = 275960.10^4 mm^4$

Now let's find I_y of our complex section:



$I_y = I_{1y} + I_{2y} + I_{3y} + I_{4y}$



(Figure-8: Table Diagram)

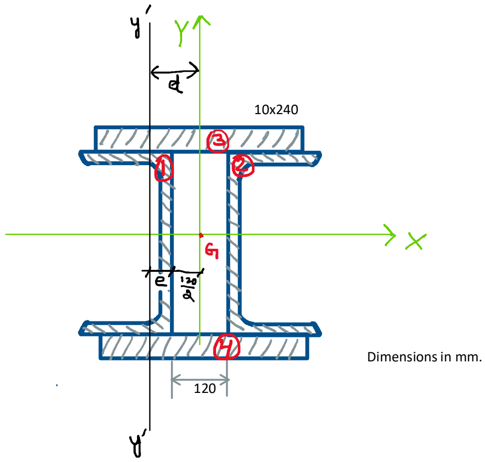
I_{1y} = *Moment of Inertia of shape* 1 *channel* 300 *section*
About global Y axis of our complex shape(green Y axis).
As you can see, from the diagram in the table 6, shown above (also shown on left- Figure 8), Y axis of c section is different than our global green Y axis.

$I_{1y'} = 495\ cm^4 (from\ table\ 6\ above) = 495(10mm)^4 = 495.10^4 mm^4$

We can also see "e" (eccentricity) is the distance between y' and extreme web side.

e= 2.70cm (From Table 6 above)= 27mm

A=58.8cm^2(From Table 6 above) $= 58.8(10mm)^2 = 58{,}8.10^2 mm^2 = 5880mm^2$



$I_{1y} = I_{1y'} + (A.d^2)$

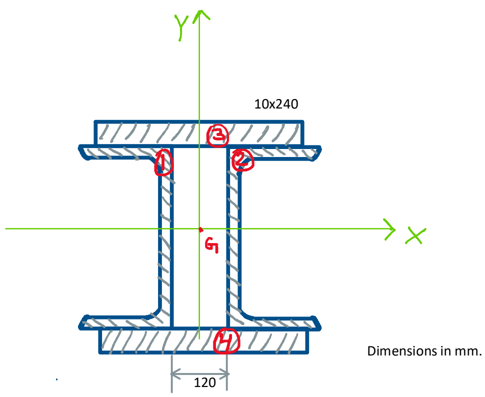
d= distance between y' axis and global (green) Y axis.
If you look carefully on diagram to the left, you will understand, $d = e + \frac{120}{2} = 27 + 60 = 87mm$

Plugging the values in I_{1y} *, we get:*

$I_{1y} = 495.10^4 + (5880.87^2) = 49455720mm^4$

Because the cross-section is symmetric:

$\Rightarrow I_{2y} = I_{1y} = 49455720mm^4$



$I_{3y} = moment\ of\ inertia\ of\ shape\ 3\ rectangle\ about\ global\ green\ Y\ axis.$

But the Y axis of shape 3 rectangle coincide with our global Y axis

$\Rightarrow I_{3y} = \frac{hb^3}{12} = \frac{10 * 240^3}{12} = 11{,}520{,}000mm^4$

Since our cross-section is symmetric:

$\Rightarrow I_{4y} = I_{3y} = 11{,}520{,}000mm^4$

Now, let's find I_y of whole cross-section:

$I_y = I_{1y} + I_{2y} + I_{3y} + I_{4y}$

$= 49455720mm^4 + 49455720mm^4 + 11{,}520{,}000mm^4 + 11{,}520{,}000mm^4$

$= 121951440mm^4 = 12195.10^4mm^4$

Since we found both I_x and I_y let's now find I_{min}:

$I_{min} = \min(I_x, I_y)$

$I_x = 275960.10^4mm^4, I_y = 12195.10^4mm^4$

$\Rightarrow I_{min} = I_y = 12195.10^4mm^4$

We found I_{min}, now we can find critical load, N_{cr} from Euler's Equation of Buckling:

$$N_{cr} = \frac{\pi^2 E\ I_{min}}{L_{eff}^2}$$

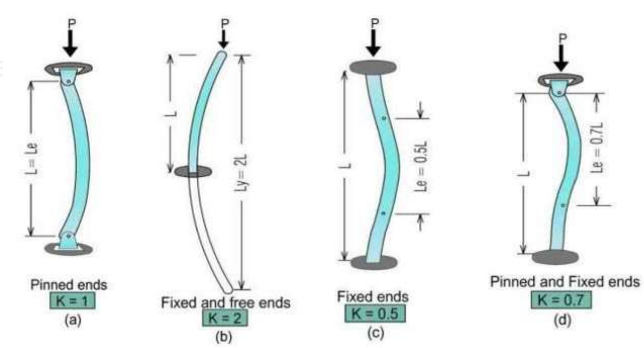
E= Modulus of Elasticity of material. Since the material in this problem is S355, from any table, we can find E= 210 Gpa= $210.10^3 Mpa$

$\pi = 3.14$

$L_{eff}^2 = square\ of\ effective\ length\ of\ our\ column = kL$

k= coefficient that depends on end support conditions of columns.

Below is a figure showing different values of k depending on different support conditions.



In our problem, both sides are pivoted(pinned), means we are in case (a) in above diagram. => k=1 => L_{eff}= k.L= L= 6m= 6000mm (provided in our problem).

$$\Rightarrow N_{cr} = \frac{\pi^2 E\, I_{min}}{L_{eff}^2} = \frac{\pi^2 * 210.10^3 Mpa * 12195.10^4 \text{mm}^4}{6000mm^2}$$
$$= 7021000N$$

$\bar{\lambda} = \sqrt{\frac{A.f_y}{N_{cr}}}$ *for Class 1,2, and 3 cross-sections* (Eurocode-3)

A= Total Area of whole cross-section= sum of areas of each shape (we already found earlier)

=> A= $5880mm^2 + 5880mm^2 + 2{,}400\ mm^2 + 2{,}400\ mm^2 = 16560mm^2$

$f_y = 355$Mpa

$\Rightarrow \bar{\lambda} = \sqrt{\frac{16560mm^2.355MPa}{7021000N}}$ =*0.9*

*Since $\bar{\lambda}$ is >0.2 means we have to find the bearing capacity so that the column is safe against buckling, as mentioned earlier (*Eurocode-3: EN 1993-1-1: Section 6.3.1.2 (4))

As per Eurocode, Bearing capacity of a column in Buckling is given as :

$$N_{b,Rd} = \frac{\chi A f_y}{\gamma_{M1}}$$ (Reference: Eurocode-3 clause 6.3.1.1(3))

γ_{M1} *is material factor of safety in Eurocode and can be taken as* 1.

χ (pronoucned as chi)is an Eurocode factor found using buckling curve or below equations:

$$\chi = \frac{1}{\phi + \sqrt{\phi^2 - \bar{\lambda}^2}}$$ (Reference: Eurocode-3 clause 6.3.1.2)

where

$\phi = 0.5\left(1 + \alpha\left(\bar{\lambda} - 0.2\right) + \bar{\lambda}^2\right)$ (Reference: Eurocode-3 clause 6.3.1.2)

α is called imperfection factor in Eurocode and is found using a Table in Eurocode shown below:

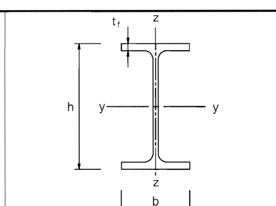
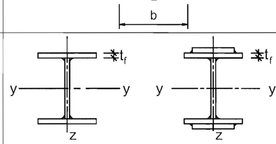
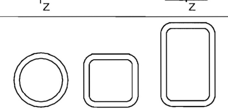
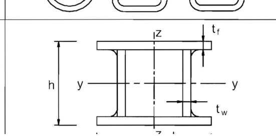
Eurocode-3: Table 6.1: Imperfection factors for buckling curves:

Buckling curve	a_0	a	b	c	d
Imperfection factor, α	0.13	0.21	0.34	0.49	0.76

First of all, we have to find what kind of Buckling curve(a_0, a, b, c, or d) is suitable for cross-section in our problem. We can find that from Eurocode, Table 6.2 as shown below:

BS EN 1993-1-1:2005
EN 1993-1-1:2005 (E)

Table 6.2: Selection of buckling curve for a cross-section

	Cross section		Limits	Buckling about axis	Buckling curve S 235 S 275 S 355 S 420	Buckling curve S 460
Rolled sections		h/b > 1,2	$t_f \le 40$ mm	y – y z – z	a b	a_0 a_0
			40 mm < $t_f \le 100$	y – y z – z	b c	a a
		h/b ≤ 1,2	$t_f \le 100$ mm	y – y z – z	b c	a a
			$t_f > 100$ mm	y – y z – z	d d	c c
Welded I-sections			$t_f \le 40$ mm	y – y z – z	b c	b c
			$t_f > 40$ mm	y – y z – z	c d	c d
Hollow sections			hot finished	any	a	a_0
			cold formed	any	c	c
Welded box sections			generally (except as below)	any	b	b
			thick welds: a > 0,5t_f $b/t_f < 30$	any	c	c

Welded box sections		generally (except as below)	any	b	b
		thick welds: a > 0,5t_f b/t_f < 30 h/t_w <30	any	c	c
U-, T- and solid sections			any	c	c
L-sections			any	b	b

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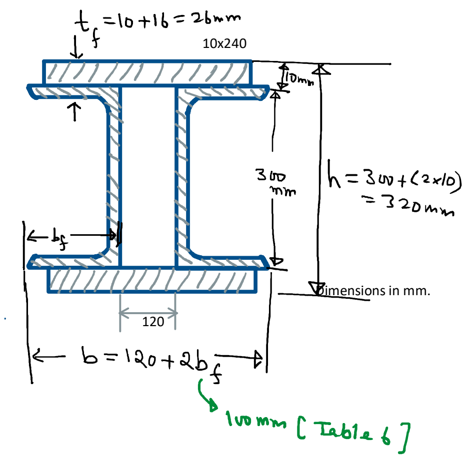
Our cross-section is box type
So we have to find the b/t_f and h/t_w
and the steel grade used is S355, so as per the Table 6.2 as shown below



Welded box sections		generally (except as below)	any	b	b
		thick welds: a > 0,5t_f b/t_f < 30 h/t_w <30	any	c	c

From diagram in left:
b=120+2*100= 320mm
t_f= 26mm
=> b/t_f= 320/26=12.3077 <30
h=300mm + (2*10mm)= 320mm
t_w= 10mm
=> h/t_w= 320/10=32≮30
As this condition is false so we are in general,
Therefore our buckling curve is b
So as per Table 6.1, $\alpha = 0.34$

$$\phi = 0.5\left(1 + \alpha\left(\bar{\lambda} - 0.2\right) + \bar{\lambda}^2\right)$$

ϕ = 0.5(1+0.34(0.9-0.2)+ 0.9²)=1.024

$$\chi = \frac{1}{\phi + \sqrt{\phi^2 - \bar{\lambda}^2}}$$

$$\chi = \frac{1}{1.024 + \sqrt{1.024^2 - 0.9^2}} = 0.66$$

$$N_{b,Rd} = \frac{\chi A f_y}{\gamma_{M1}} = \frac{0.66 * 16560mm^2 * 355Mpa}{1} = 3880008N$$
$$= 3880kN$$

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Therefore the bearing capacity of the column in our problem, as per Eurocode is 3880kN

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