THE OPEN UNIVERSITY OF SRI LANKA
Department of Civil Engineering
Bachelor of Technology (Civil) - Level 6

CEX6332 - Structural Design

FINAL EXAMINATION – 2013/2014

Time Allowed: Four (04) Hours

Date: 2014 - 09 - 03 (Wednesday) Time: 0930 - 1330 hrs.

Paper consists of five (05) questions. Answer any four (04) questions.
You may use the booklet named "Extracts From Relevant Standards" provided to you with the course material, which also contain concrete design charts & steel sectional properties
You may assume and state reasonable values for any factors not provided.

Q1.

A part structural plan for a typical floor in a multi-storey office building constructed using structural steel is shown in Figure 1, indicating the general arrangement of beams and columns. The floor slabs consist of precast concrete units which are supported on the secondary beams (B2). The dead weight of the floor slab including finishes is 4.0 kN/m² and the imposed load is 5.0 kN/m². Both the secondary (B2) and main beams (B1) may be assumed as laterally restrained and have simple end connections. The height of each storey of the building is 3.8 m. Conduct the following steps using Grade S-275 structural steel in accordance with BS5950-1:2000,

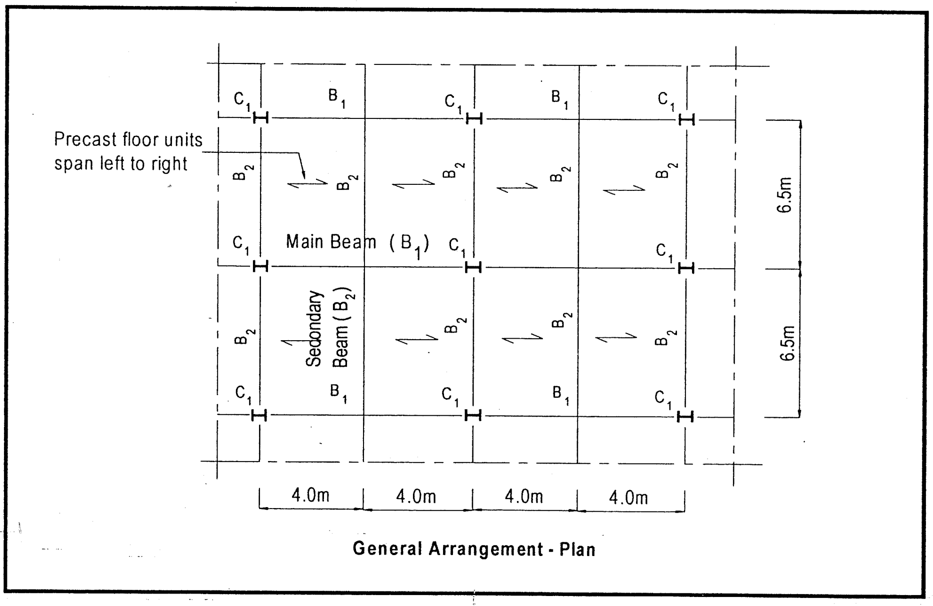


Figure 1 – Plan of the building

Take modulus of elasticity of steel = 205 x 10³ N/mm². Maximum moments and deflections of simply supported beams and Steel section properties are available at the end of this paper.

i.) Calculate the uniformly distributed service dead load and service imposed load acting on a secondary beam B2. (02 marks)

ii.) Secondary beams B2: Verify that 406 x 178 x 60 UB can be used as secondary beams to resist the applied bending moment and check the shear capacity and deflection. (07 marks)

iii.) Calculate the service dead and live loads acting on a main beam B1. (02 marks)

iv.) Main beams B1: Examine the design adequacy of a 533 x 210 x 109 UB making all necessary code checks. (07 marks)

v.) Internal column C1: If the factored load on each of the ground floor columns is estimated as 4,200 kN, check the adequacy of a 305 x 305 x 198 UC. Assume the column to be held in position at both ends with no restraint in direction at either end. (07 marks)

00061

Q2.

A typical layout plan and a cross section of a two storey housing unit for a proposed scheme is shown in Figure 2. The layout plan for the upper floor is identical to the lower floor and the structural Engineer has decided that masonry walls would be load bearing.

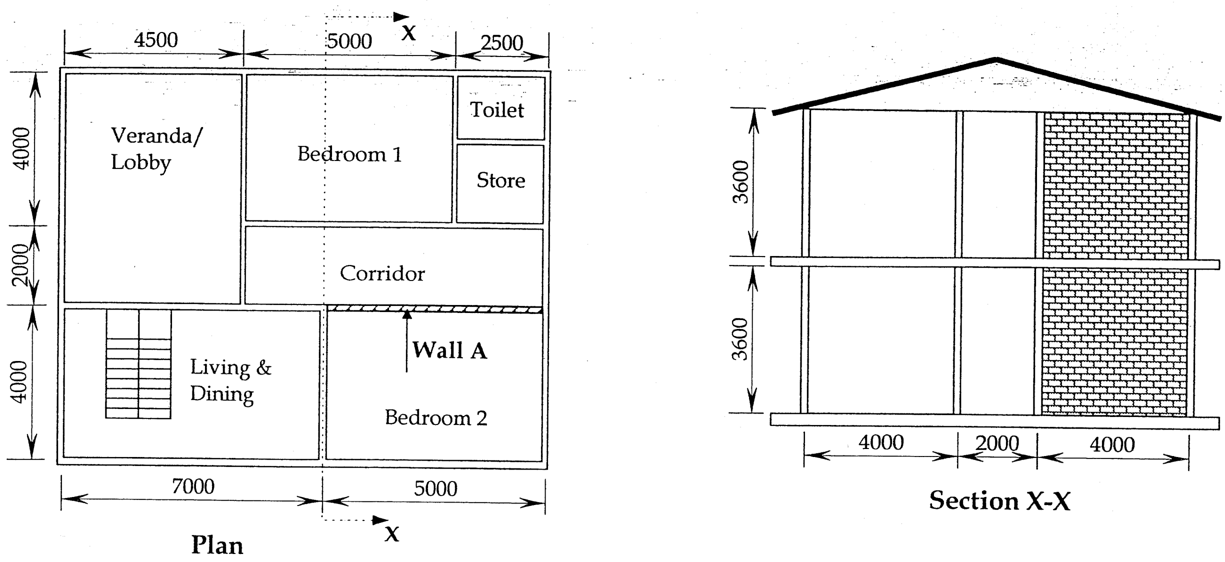


Figure 2 - Proposed masonry building

Walls are to be constructed with locally made bricks and their dimensions are 200x100x50 mm, length, breath, height, respectively. Half brick wall construction is 100 mm and full brick wall construction is 200 mm thick. Wall A at ground to upper floor is to be full brick while upper floor to roof level is to be half brick. Due to the nature of the roof you may assume that roof loads are uniformly shared by longitudinal walls (like Wall A) based on effective plan area. Indicate any used assumptions clearly.

Loads

Dead load of the roof (Plan area) = 0.5 kN/m^2
Imposed load on the floor = 2.0 kN/m^2
Dead load due to slab finishes = 0.5 kN/m^2
No effect of wind load

Geometry

Thickness of floor slab = 125 mm
Floor to floor clear height = 3600 mm

Weights of Materials

Unit weight of RC = 24.0 kN/m^3
Unit weight of masonry = 18.0 kN/m^3
Mortar Designation = IV

Compressive Strength of Brick = 2.0 N/mm^2
γ_m = 3.5
Water absorption >12%

i.) Evaluate characteristic dead and live loads acting on the internal Wall A between the ground floor and upper floor level.

(05 Marks)

ii.) Find different load combinations and corresponding design loads and eccentricities. (05 Marks)

iii.) Determine the slenderness ratio of the wall and compare with its permissible value. (05 Marks)

iv.) Check whether the internal Wall A is able to carry the design loads considering vertical load resistance of the wall.

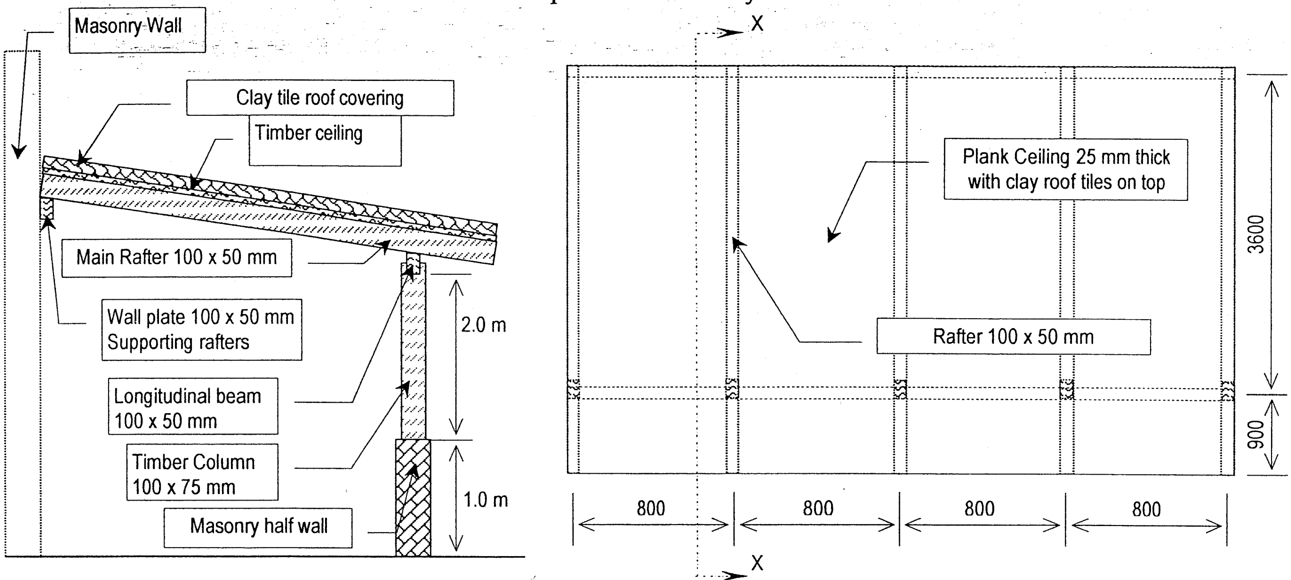
(05 Marks)

v.) Determine the magnitude of the shear resistance of the ground floor Wall A at the slab level in the longitudinal direction.

(05 Marks)

Q3.

A lean-to roof is to be provided for the verandah of a house. The roof structure consist of a wodden plank decking supported by a timber rafter framework as shown in Figure 3, below. Timber rafters are supported on a wall plate fixed to a masonry wall at one end and timber columns at the other end. Structural dimensions and sectional sizes are given in the figures. The imposed load on the roof can be neglected. For load as well as other structural calculations the slope of the roof may be assumed as zero.



Cross section X-X of the Lean-to roof

Plan of the Lean-to roof

Figure 3 - Plan & a Cross Section of the Lean-to Roof

Design Engineers have assumed Strength Class C27 timber for all timber members. Dry exposure condtion with medium term loading had been assumed in the original design calculations. The unit weight of clay tile roof covering had been taken as 0.9 kN/m^2 You are required to check the design of a rafter and a structural timber column according to BS 5268:Part 2:1996.

Section A Use the following steps in checking adequacy of a rafter. You may aasume that rafters are simply supported.

i.) Evaluate the loading on the rafter due to **live and dead** loads. [02 marks]

ii.) Check the proposed beam against **lateral stability** criteria. [01 marks]

iii.) Compute the applied **bending stress** at the critical section and check whether this is within the permissible limit. [03 marks]

iv.) Check whether the **maximum allowable deflection** is within the permissible limit (0.003L). [03 marks]

v.) Check whether the beam is safe against failure due to **shear.** [03 marks]

vi.) Check whether applied **bearing stresses** at supports are within the permissible limit. [03 marks]

Section B For checking a supporting column design, use the following steps.

i.) Evaluate the loading on the column due to **live and dead** loads as a total axial load and a bending moment. (You may neglect the load by the facia.) [04 marks]

ii.) Compute the applied maximum **compressive stress** in the column and check whether this is within the permissible limit. [03 marks]

iii.) Check the column for combined flexural and compressive stresses. [03 marks]

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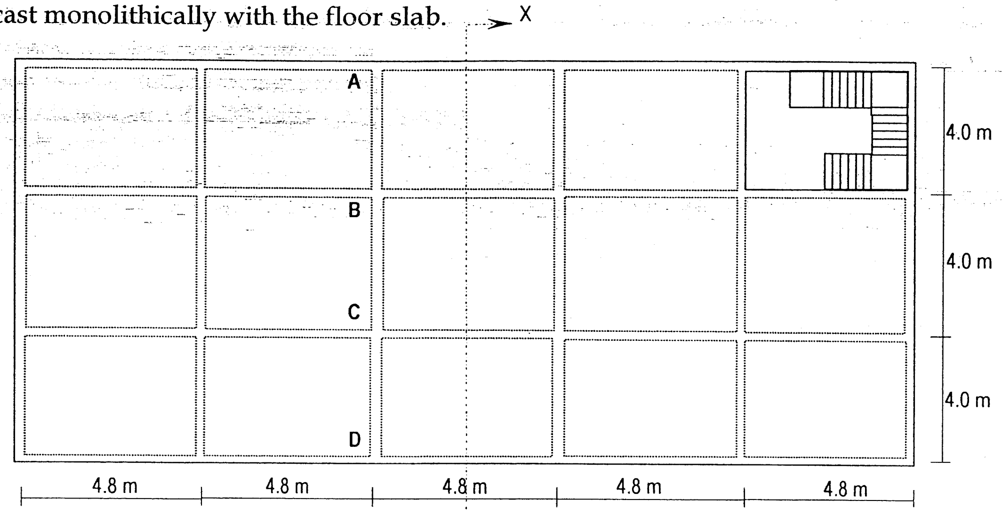
Q4.

A typical floor plan and a sectional view of a three storey commercial building is shown in Figure 4. The beams are cast monolithically with the floor slab.



Plan of the proposed building

Loads on the structure;

Imposed load on the roof	= 1.0 kN/m^2
Dead load by finishes on floors & roof	= 1.5 kN/m^2
Imposed load on floors	= 2.0 kN/m^2

** You may neglect the effects of Wind

Thickness of floor & roof slabs	= 125 mm

Weights of materials

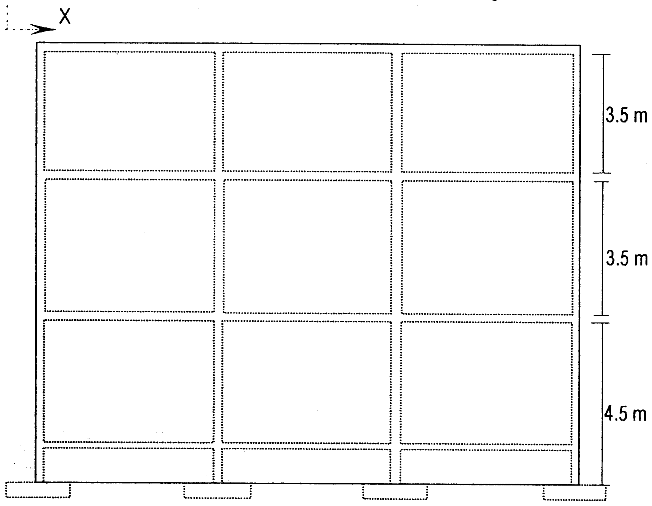
Unit weight of RC	= 24.0 kN/m^3

Strength of materials;

Grade of concrete	= 30
Characteristic strength of steel	
Main r/f	= 460 N/mm^2
Shear r/f	= 250 N/mm^2
Nominal cover for reinforcement	= 20 mm

Order of floors – Ground, 1st , 2nd , Roof

* Required design charts are provided *



Section X-X

Figure 4 – Plan & Cross section of the Building

i.) Evaluate the design ultimate load acting on the slab. Compute the bending moments at critical locations along section 'X-X' using bending moment coefficients from the Code and design reinforcements accordingly to satisfy Code requirements. Draw a typical plan showing reinforcement detail for the short span direction only (Indicate curtailment of reinforcements without dimensions). (06 marks)

ii.) Evaluate the design ultimate load on beam ABCD, 350x300 mm (you may assume that there are no masonry walls supported on the beam and the loads transferred to the beam are uniformly distributed along its span) and calculate the ultimate bending moments and shear forces at critical locations using the design formula given in BS8110-1:1997 for uniformly loaded continuous beams. (05 marks)

iii.) Design the required reinforcements for the beam ABCD to resist bending and shear forces at critical locations and indicate the proposed reinforcement detail (indicate curtailment of reinforcements without dimensions) in a sketch. (06 marks)

iv.) Assuming the column at B (250 x 250) is unbraced and no bending moments are transferred from beams framing into the column, evaluate the design ultimate axial load on the column at ground floor level and the slenderness condition of the column segment between ground and first floor. (04 marks)

v.) Evaluate the generated bending moments (if any) and design required reinforcements for the same column segment. Sketch elevation and a cross section of the column segment using the standard method of detailing. (04 Marks)

Q5.

The post tensioned beam shown in Figure 5 is used for an auditorium. The beam can be considered as a simply supported beam with effective span of 18 m. The beam carries only its own weight at transfer. The beam has to be of type 2. Proposed section of the pre stress beam, material properties and the loading on the beam are as follows.

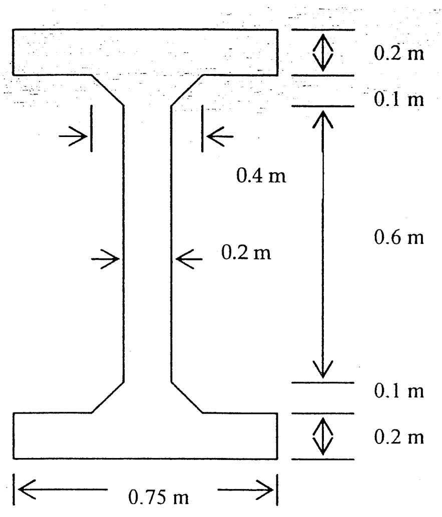


Figure 5

Sectional properties

$A = 0.48\ m^2$, $I = 0.09188\ m^4$

Loss of prestress

at transfer = 10 %
at service = 20 %

Strengths

f_{cu} at 28 days = 35 N/mm²
f_{ci} at 7 days (transfer) = 28 N/mm²

Transfer is 7 day after casting

f_{pu} Super strand 20.0 mm dia. tendons = 1600 N/mm²

Loads

Unit weight of concrete = 24 kN/m³
Dead load other than self weight = 10.0 kN/m
Imposed load = 11.0 kN/m
(Assuming loads to be distributed evenly.)

Allowable concrete stresses for Class 2 members

at transfer		at service	
$f'_{max} = 0.5 f_{ci}$	$f'_{min} = -0.36\sqrt{f_{ci}}$	$f_{max} = 0.33 f_{cu}$	$f'_{min} = -0.36\sqrt{f_{cu}}$

You may use following inequalities (in standard notation) for your calculations

$Z_t \geq (\alpha M_s - \beta M_i) / (\alpha f_{max} - \beta f'_{min})$
$Z_b \geq (\alpha M_s - \beta M_i) / (\beta f'_{max} - \alpha f_{min})$

$P_i \geq (Z_t f'_{min} - M_i) \ / \ \alpha(Z_t/A_c - e)$	$e \leq (M_i - Z_t f'_{min}) / \alpha P_i + Z_t/A_c$
$P_i \leq (Z_b f'_{max} + M_i) \ / \ \alpha(Z_b/A_c + e)$	$e \leq (M_i + Z_b f'_{max}) / \alpha P_i - Z_b/A_c$
$P_i \leq (Z_t f_{max} - M_s) \ / \ \beta(Z_t/A_c - e)$	$e \geq (M_s - Z_t f_{max}) / \beta P_i + Z_t/A_c$
$P_i \geq (Z_b f_{min} + M_s) \ / \ \beta(Z_b/A_c + e)$	$e \geq (M_s + Z_b f_{min}) / \beta P_i - Z_b/A_c$

Using above data, design the beam according to the following steps;

i.) Using given sectional properties of the beam find Z_t and Z_b (01 Mark)

ii.) Evaluate the dead and imposed loads on the beam at transfer and in service and calculate the critical bending moments at the two instances. (04 Marks)

iii.) Check the adequacy of the section in carrying the stresses at **transfer** and in **service** for the range of spans. (04 Marks)

iv.) Determine the range of prestress force required at the mid span assuming e = 500 mm (05 Marks)

v.) Suggest the minimum possible number of tendons (and corresponding initial prestress force) and sketch a suitable physical arrangement for them (Assume $f_{pi} = 0.7 f_{pu}$). (02 Marks)

vi.) Check whether the prestress force calculated above allows for same location of tendon centroid at the supports of the beam (In other words check whether straight tendons could be used without de-bonding). If de-bonding has to be carried out, evaluate how many tendons should be de-bonded at the supports of the slab segments so that straight tendons could be used. (04 Marks)

vii). Check the suitability of the section respect to Ultimate Moment Capacity. (05 Marks)

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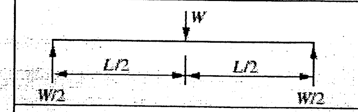
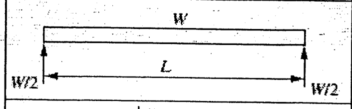
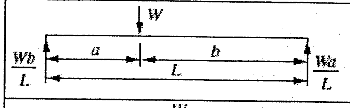
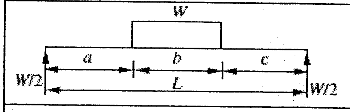
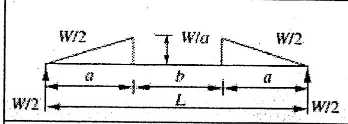
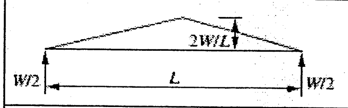
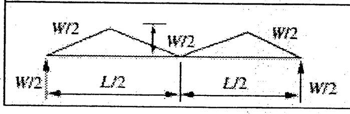
For question Q1.

Simply supported beam maximum moments and deflections

Beam and load	Maximum moment	Deflection at centre
	$WL/4$	$\frac{WL^3}{48\,EI}$
	$WL/8$	$\frac{5\,WL^3}{384\,EI}$
	Wab/L	$\frac{WL^3}{48\,EI}\left[\frac{3a}{L}-4\left(\frac{a}{L}\right)^3\right]$
	$W(a/2+b/8)$	$\frac{W}{384\,EI}\,[8L^3-4Lb^2+b^3]$
	$Wa/3$	$\frac{Wa}{120\,EI}\,[16a^2-20ab+5b^2]$
	$WL/6$	$\frac{WL^3}{60\,EI}$
	$WL/8$	$\frac{WL^3}{73.14\,EI}$

UNIVERSAL BEAMS

Designation		Depth of section D	width of section B	Thickness		Ratios For Local Bucking		Second Mo't of Area		Radius of Gyration		Elastic Modulus		Plastic Modulus		Buckling parameter μ	Area of section A cm²
Serial size	Mass per m			Web t	Flange T	Flange b/T	Web d/T	Axis x-x	Axis y-y	Axis x-x	Axis y-y	Axis x-x	Axis y-y	Axis x-x	Axis y-y		
mm	Kg	mm	mm	mm	mm			cm⁴	cm⁴	cm	cm	cm³	cm³	cm³	cm³		
533x210	138	549.1	213.9	14.7	23.6	4.53	32.4	86100	3860	22.1	4.68	3140	361	3610	568	0.873	176.0
	122	544.5	211.9	12.7	21.3	4.93	37.5	76000	3390	22.1	4.87	2790	320	3200	500	0.877	155.0
	109	539.5	210.8	11.6	18.8	5.61	41.1	66800	2940	21.9	4.60	2480	276	2830	436	0.875	139.0
	101	536.7	210.0	10.8	17.4	6.03	44.1	61500	2690	21.9	4.57	2290	256	2610	399	0.874	129.0
	92	533.1	209.3	10.1	15.6	6.71	47.2	55200	2390	21.7	4.51	2070	228	2360	355	0.872	117.0
	82	528.3	208.8	9.6	13.2	7.91	49.6	47500	2010	21.3	4.38	1800	192	2060	300	0.864	105.0
406x178	74	412.8	179.7	9.7	16.0	5.62	37.2	27 300	1505	17.0	4.04	1320	172	1500	267	0.882	94.5
	67	409.4	178.8	8.8	14.3	6.24	41.0	24 300	1360	16.9	3.99	1190	153	1350	237	0.880	85.5
	60	406.4	177.8	7.8	12.8	6.95	46.2	21 500	1200	16.8	3.97	1060	135	1200	209	0.880	76.5
	54	402.6	177.6	7.6	10.9	8.15	47.4	18 600	1020	16.5	3.85	930	115	1050	178	0.871	69.0

UNIVERSAL COLUMNS

Designation		Depth of section D	width of section B	Thickness		Ratios For Local Bucking		Second Moment of Area		Radius of Gyration		Elastic Modulus		Plastic Modulus		Buckling parameter μ	Area of section A cm²
Serial size	Mass per m			Web t	Flange T	Flange b/T	Web d/T	Axis x-x	Axis y-y	Axis x-x	Axis y-y	Axis x-x	Axis y-y	Axis x-x	Axis y-y		
mm	Kg	mm	mm	mm	mm			cm⁴	cm⁴	cm	cm	cm³	cm³	cm³	cm³		
305x305	283	365.3	321.8	26.9	44.1	3.65	9.21	78900	24600	14.8	8.27	4320	1530	5110	2340	0.855	360
	240	352.5	317.9	23.0	37.7	4.22	10.7	64200	20300	14.5	8.15	3640	1280	4250	1950	0.854	306
	198	339.9	314.1	19.2	31.4	5.01	12.9	50900	16300	14.2	8.04	3000	1040	3440	1580	0.854	252
	158	327.1	310.6	15.7	25.0	6.22	15.7	38700	12600	13.9	7.90	2370	808	2680	1230	0.851	201
	137	320.5	308.4	13.8	21.7	7.12	17.9	32800	10700	13.7	7.83	2050	692	2300	1050	0.851	174
	118	314.5	306.8	12.0	18.7	8.22	20.7	27700	9060	13.6	7.77	1760	589	1960	895	0.850	150
	97	307.9	304.8	9.9	15.4	9.91	24.9	22200	7310	13.4	7.69	1450	479	1590	726	0.850	123