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

CEX6332 – Structural Design

FINAL EXAMINATION – 2014/2015

Time Allowed: **Four (04) Hours**

Date: 2015 - 09 - 16 (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) A part cross section of the canopy structure of a railway station constructed using structural steel is shown in Figure Q1, indicating the general arrangement of steel purlins and the connection to the rafter. Purlins are at 2.0 m centres and are simply supported on rafters spaced at 6.0 m intervals. Roof slope equals to 20°. Purlins may be considered to have lateral restraint of the top flange due to the presence of cladding based on adequate fixing. Following loads are acting on the roof.

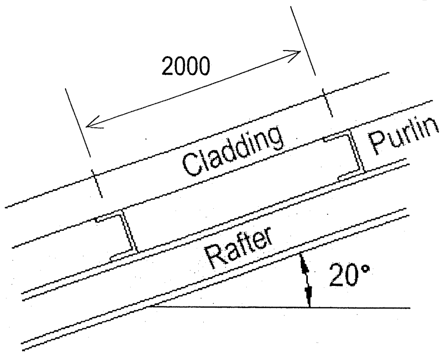


Figure Q1

Dead load (cladding + insulation panels) = 0.15 kN/m^2
Imposed load = 0.75 kN/m^2 (on plan)
Wind load = 0.40 kN/m^2 (suction)

Conduct the following steps using Grade S-275 structural steel in accordance with BS5950-1:2000,

i.) Calculate the service values of uniformly distributed dead, imposed and wind loads acting on a purlin. (03 Marks)

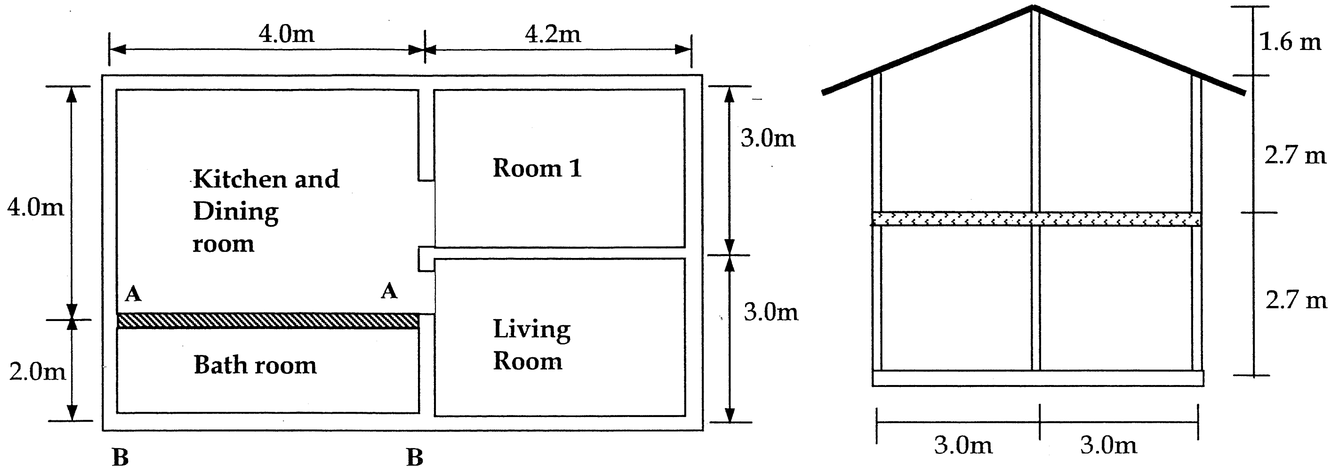
ii.) Evaluate the ultimate uniformly distributed load acting on a purlin for the following load cases:
- Dead load acting with imposed load. (02 Marks)
- Dead load acting with wind load and imposed load. (02 Marks)

iii.) Verify the suitability of Channel Section 150 x 75 x 18 for the purlin making all necessary code checks. (10 Marks)

b) A 406 x 178 x 74 Rolled I section of height 3.1m is subjected to a central axial load. Assume that the column is held in position at both ends with no restraint in direction at either end. Calculate the compressive resistance. Take the design strength of steel, p_y, as 275 N/mm^2. (08 Marks)

00072

Q2.



(a) **Plan of one unit** (b) **Elevation**

Figure Q2: Proposed masonry building

An apartment building has been proposed to be constructed in Colombo City. It is a two story masonry wall construction. Ground and first floors consist of number of living units and typical unit is shown in Figure Q2(a). The elevation of the building is shown in Figure Q2(b).
Walls are constructed with locally made high quality bricks and dimensions are 200mm*100mm*50mm, length, breath, height, respectively. Half brick wall construction is 100mm, one brick wall construction is 210 mm, one and half brick wall construction is 320mm. Further, external and internal wall thicknesses are 350 mm and 240mm, respectively.

Loads Dead load of the roof (Plan area)=0.5 kN/m^2 Imposed load on the roof (Plan area) = 0.25 kN/m^2 Imposed load on the floor = 2.0 kN/m^2 Dead load due to finishes on slab = 0.5 kN/m^2 **Geometry** Thickness of floor slab = 125mm Floor to floor clear height = 2.7m Eave of the roof = 1.0m	**Weights of Materials** Unit weight of RC = 24.0 kN/m^2 Unit weight of masonry = 18.0 kN/m^2 Mortar Designation = IV Compressive Strength of Brick = 5.0 N/mm^2 Partial safety factor for brick material (γ_m) = 3.5 Water absorption >12%

I. Evaluate characteristic dead and live loads acting on the **internal wall A-A** in the ground floor level. (04 Marks)

II. Find different load combinations and corresponding design loads and eccentricities. (04 Marks)

III. Determine the slenderness ratio of the wall and compare with its permissible value. (02 Marks)

IV. Check whether the internal wall is able to carry the design compressive load considering vertical load resistance of the wall. (03 Marks)

V. Draw a figure showing boundary conditions for **the external wall (B-B)** in 1st floor level. (04 Marks)

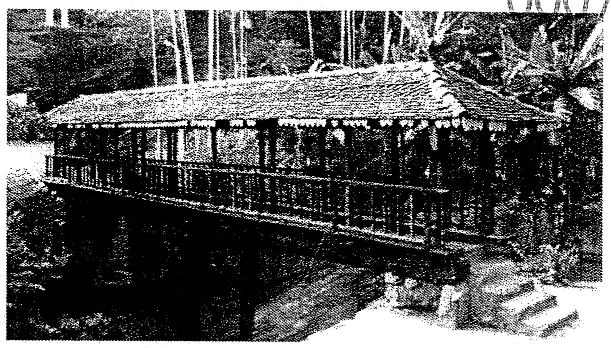
VI. Determine the bending moments parallel and perpendicular to the bed joint if it is subjected a lateral load of 2.5 kN/m^2. (05 Marks)

VII. Check the safety of the external wall panel under the given lateral load. (03 Marks)

Indicate whatever your assumptions used clearly.

00072

Q3.

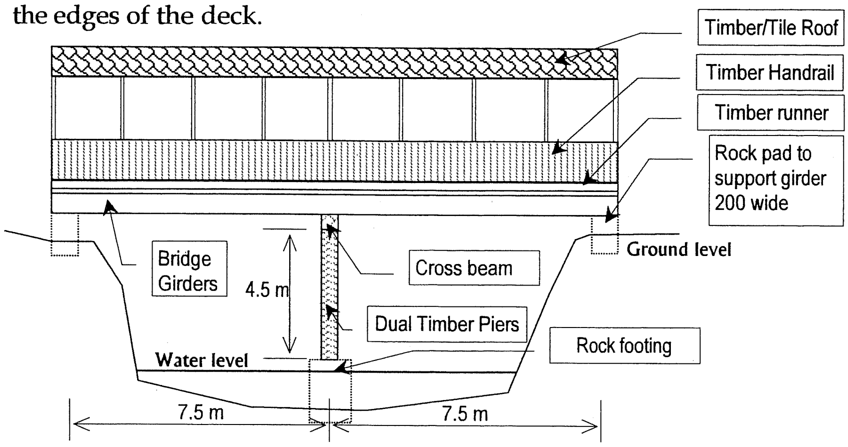


The photograph shows the 'Bogoda Bridge', constructed in the 16th century, which is supposed to be the oldest surviving timber bridge in Sri Lanka.

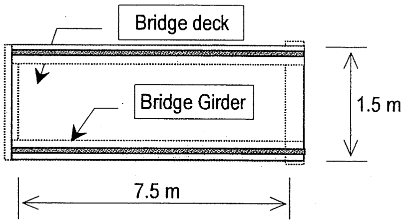
It is a double span timber bridge with dual central support piers, constructed over 'Gallanda Oya' for pedestrian traffic. Simply supported dual timber bridge girders are supported on a rock pad at the bank side of the stream and on a cross beam at the center support. A planked deck is supported on the two girders and timber handrails and clay tiled roof are supported on runners at the edges of the deck.

Loads
Combined load by the roof, roof pillers, handrails and runners = 1.2 kN/m²
Imposed load on the deck = 1.0 kN/m²

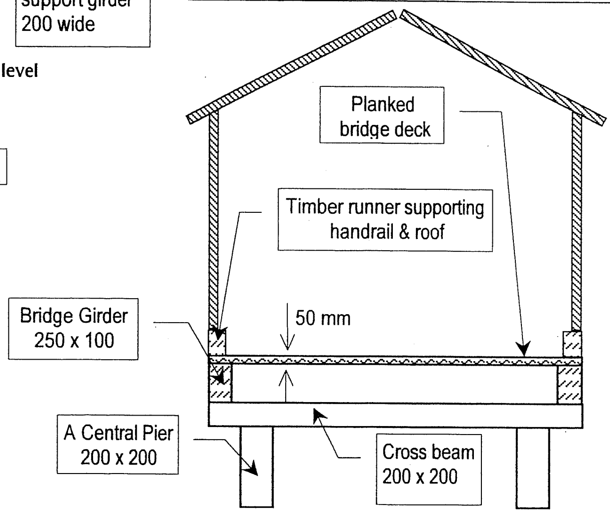
* Weight of cross beam & wind loads can be neglected



Side Elevation



Half plan of the Bridge



Cross section of the Bridge

Assuming that the **Strength Class** of the used timber (Kumbuk) is **D40**, environmental conditions to be **wet exposure** and **roof structure loading to be an area loading (kN/m²)** (you have to evaluate the dead loads by timber deck and the self weight of the girder), check the design of the bridge girder and the central pier according to BS 5268.

Section A Use following steps in checking adequacy of the bridge girder.

i.) Evaluate the loading on the girder due to **dead and live** loads and check against **lateral stability** criteria. (03 marks)

ii.) Compute the applied **bending stress** at the critical section for both load combinations (DL only & DL+ IL conditioons) and check whether they are within the permissible limits. (03 marks)

iii.) For DL + IL condition check whether the **maximum allowable deflection** is within the permissible limit (0.003L). (03 marks)

iv.) For DL + IL condition check whether the beam is safe against failure due to **shear.** (03 marks)

v.) For DL + IL condition check whether applied **bearing stress** is within the permissible limit. (03 marks)

Section B Use following steps in checking the adequacy of a pier.

i.) Evaluate the axial load & critical moment on a pier due to **dead & live** load combinations. (03 marks)

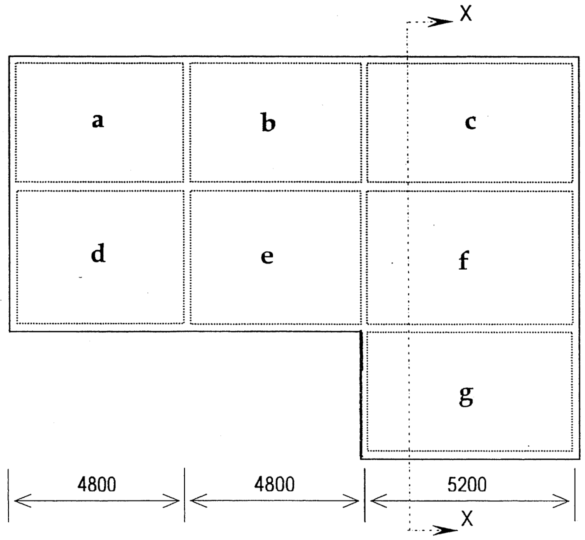
ii.) Compute the applied maximum **compressive stress** in the pier and check whether this is within the permissible limit. (03 marks)

iii.) Check the pier for combined flexural and compressive stresses. (04 marks)

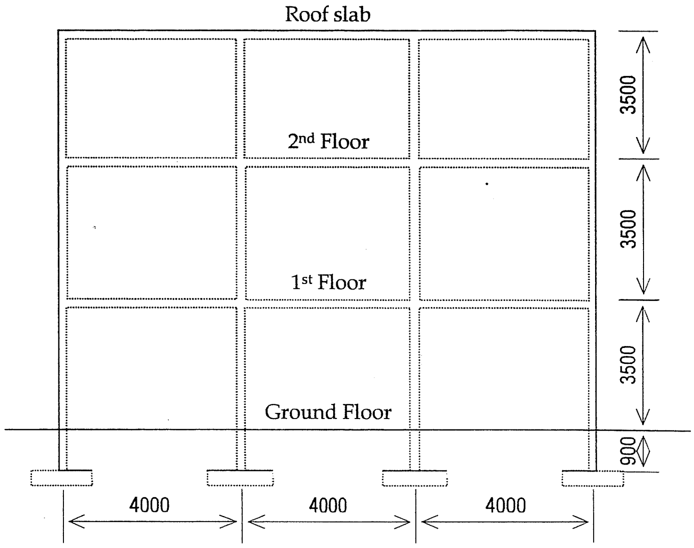
00072

Q4.

A typical floor plan (and a sectional view) of a three storied commercial building is shown in plan below. The beams are cast monolithically with the floor slab. Disregard the location of the staircase.



Plan of the Building



Section X-X

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
Unit weight of Masonry = 20.0 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 *

i.) Identify the most critical slab panel giving reasons. Evaluate the ultimate design load acting on the 1st floor slab and compute the bending moments acting on the identified slab panel using the bending moment coefficients from the code (balancing of bending moments at common boundaries is not required). Design reinforcements only for this panel to satisfy code requirements and draw a typical plan showing the reinforcement detail. Indicate curtailment of reinforcements without dimensions.

(06 Marks)

ii.) Evaluate the ultimate design load acting on the beam ABCD, 400x300 mm (you may assume that a 225mm thick masonry wall is supported on the beam and the loads transferred to the beam are uniformly distributed along its span) and calculate the ultimate bending moments at critical locations using the design table 3.5 given in BS8110-1:1997 for uniformly loaded continuous beams.

(04 Marks)

iii.) Draw the bending moment diagram for the beam ABCD using the bending moments computed above. Design the required reinforcements for the beam ABCD to resist bending at critical locations for one span and indicate how you would curtail reinforcements in the bending moment diagram.

(05 Marks)

iv.) Compute the ultimate load acting on the foundation of column C (300 x 300).

(03 Marks)

v.) Design a square pad footing to support the column C assuming the allowable bearing capacity of soil to be 150 kN/m^2 (Assume no bending moment is acting on the footing).

(07 Marks)

00072

Q5.

The post tensioned beam shown in Figure Q5 is used for a bridge with medium span. The beam can be considered as simply supported beam with effective span of 15 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.

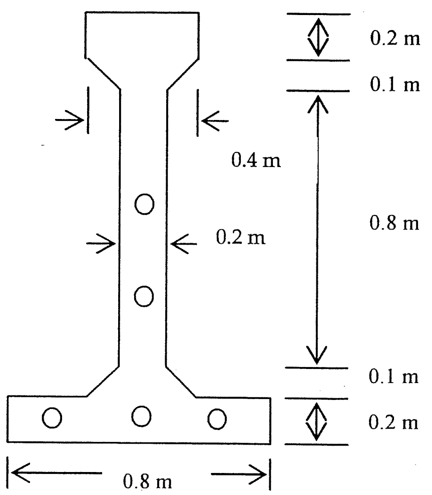


Figure Q5

Strengths

f_{cu} at 28 days = 35 N/mm²
f_{ci} at 7 days (transfer) = 28 N/mm²
f_{pu} Super strand 20.0 mm dia. tendons = 1600 N/mm²
Transfer is 7 day after casting

Sectional properties

I = 0.085 m⁴
Y_B = 0.565 m

Loads

Unit weight of concrete = 24 kN/m³
Dead load other than self weight = 12.0 kN/m
Imposed load = 10.0 kN/m
(Assuming loads to be distributed evenly.)

Loss of prestress

at transfer = 10 %
at service = 20 %

Allowable concrete stresses for Class 2 members

at transfer

$f'_{max} = 0.5 f_{ci}$ $\quad f'_{min} = -0.36\sqrt{f_{ci}}$

at service

$f_{max} = 0.33 f_{cu}$ $\quad f'_{min} = -0.36\sqrt{f_{cu}}$

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.) Show that cross sectional are of the given beam is 0.46 m². Using given sectional properties of the beam find the Z_t and Z_b (02 Marks)

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. (03 Marks)

iii.) Check the adequacy of the section in carrying the stresses at **transfer** and in **service** for the range of spans. (03 Marks)

iv.) State the four stress conditions applied in the beam for mid span critical section. (03 Marks)

v.) Figure Q5 shows tendon arrangement proposed for mid span section. According to the given arrangement; Vertical spacing centre to centre – 0.3 m
Horizontal spacing centre to centre – 0.3 m
Centers of bottom tendons are placed 0.1 m above the bottom of the beam.

a). Find total pre stress force and eccentricity of the given arrangement. (Assu. $f_{pi} = 0.7 f_{pu}$). (02 Marks)
b). Show that the given arrangement satisfy all the relevant stress conditions. (04 Marks)

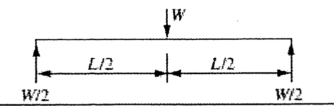
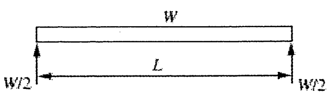
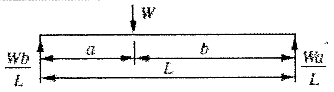
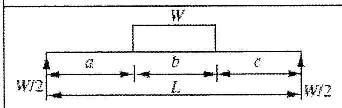
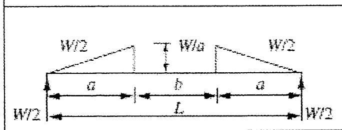
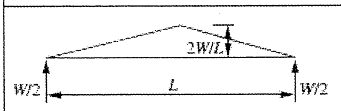
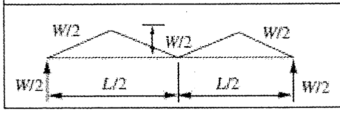
vi.) Check whether the given tendon arrangement is suitable for the supports of the beam. If not suggest the new arrangement using same number of tendons. (03 Marks)

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

For question Q1.

00072

Simply supported beam maximum moments and deflections

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

UNIVERSAL BEAMS/CHANNELS

Designation: Serial size mm	Designation: Mass per m Kg	Depth of section D mm	width of section B mm	Thickness: Web t mm	Thickness: Flange T mm	Ratios For Local Bucking: Flange b/T	Ratios For Local Bucking: Web d/t	Second Mo't of Area: Axis x-x cm^4	Second Mo't of Area: Axis y-y cm^4	Radius of Gyration: Axis x-x cm	Radius of Gyration: Axis y-y cm	Elastic Modulus: Axis x-x cm^3	Elastic Modulus: Axis y-y cm^3	Plastic Modulus: Axis x-x cm^3	Plastic Modulus: Axis y-y cm^3	Buckling parameter µ	Area of section A cm^2
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
150x75x 18 (Ch.)	17.9	150.0	75.0	5.5	10.0	7.5	19.3	861	131	6.15	2.40	115	26.6	132	47.2	0.945	22.8

UNIVERSAL COLUMNS

Designation: Serial size mm	Designation: Mass per m Kg	Depth of section D mm	width of section B mm	Thickness: Web t mm	Thickness: Flange T mm	Ratios For Local Bucking: Flange b/T	Ratios For Local Bucking: Web d/t	Second Moment of Area: Axis x-x cm^4	Second Moment of Area: Axis y-y cm^4	Radius of Gyration: Axis x-x cm	Radius of Gyration: Axis y-y cm	Elastic Modulus: Axis x-x cm^3	Elastic Modulus: Axis y-y cm^3	Plastic Modulus: Axis x-x cm^3	Plastic Modulus: Axis y-y cm^3	Buckling parameter µ	Area of section A cm^2
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