2305/303
2307/303
2308/303
STRUCTURES
Oct./Nov. 2009
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN BUILDING
DIPLOMA IN CIVIL ENGINEERING
DIPLOMA IN HIGHWAY ENGINEERING

STRUCTURES

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:
Answer booklet
Mathematical tables/Pocket calculator
Drawing instruments.

Answer any ***FIVE*** *of the* ***EIGHT*** *questions in this paper.*
ALL *questions carry equal marks.*
Maximum marks for each part of a question are as shown.

Relevant design tables are provided.

This paper consists of 11 printed pages.

Candidates should check the question paper to ascertain that all the pages are printed as indicated and that no questions are missing.

1. (a) Using the method of sections, determine the magnitude and nature of forces in the members of the frame shown in figure 1. (7 marks)

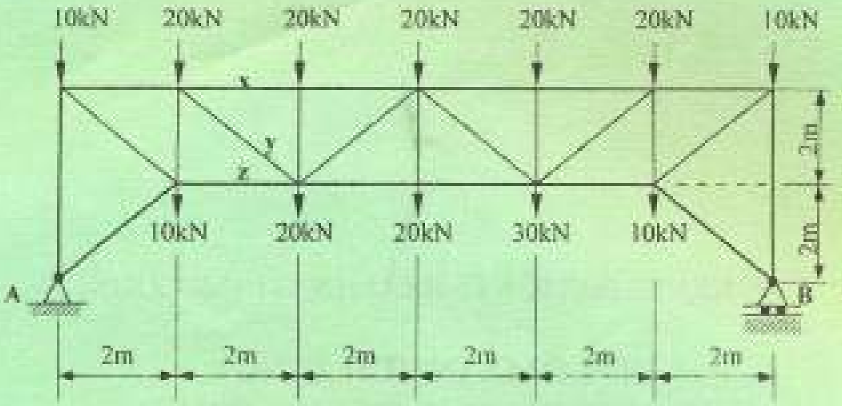


Fig 1

(b) A composite bar is made up of two materials as shown in figure 2. If the bars are stress free at 40°C, determine the stresses developed in the bars when temperature drops to 20°C, when:

(i) the supports are unyielding

(ii) the supports come nearer to each other by 0.12mm.

Given: (13 marks)

Aluminium: $E_a = 70kN/mm^2$

$\alpha_a = 23.4 \times 10^{-6}$ per °C

Steel: $E_s = 210kN/mm^2$

$\alpha_s = 11.7 \times 10^{-6}$ per °C

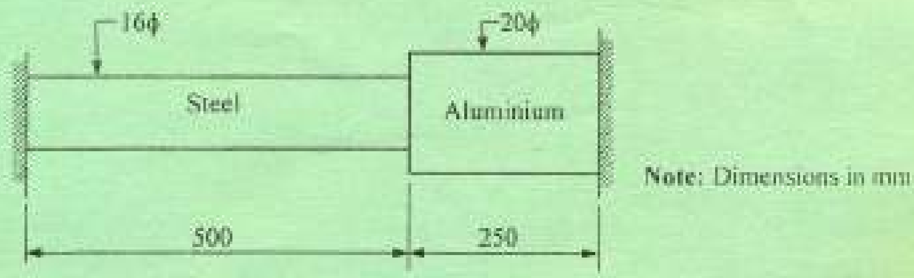


Fig 2

2. Figure 3 shows a beam ABCDE build in at A and supported on rollers at B, C and D, with DE being an overhung. The values of moment of inertia of the section over each of these lengths are 3I, 2I, I and I respectively, the loading being as shown. Analyse the beam using the three moments theorem, and hence draw the bending moment diagram, indicating all the critical values. (20 marks)

Fig 3

3. Using the method of moment distribution, analyse the frame shown in figure 4 and plot the bending moment diagram indicating all the critical values. (20 marks)

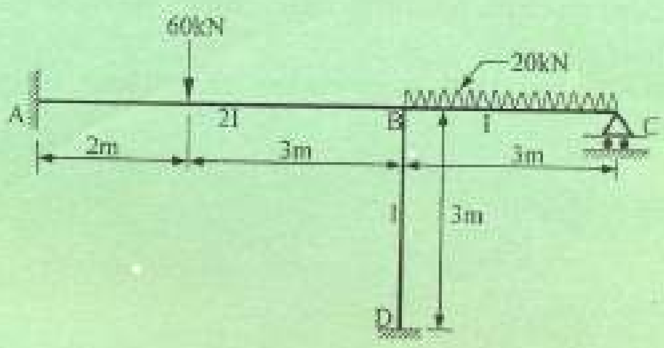


Fig 4

4. (a) A horizontal simply supported girder 14m long is of uniform section, and carries two point loads as shown in figure 5. Using Macaulay's method, determine the deflection under each point load.
Take $I = 1.6 \times 10^9 mm^4$, and $E = 210 kN/mm^2$. (9 marks)

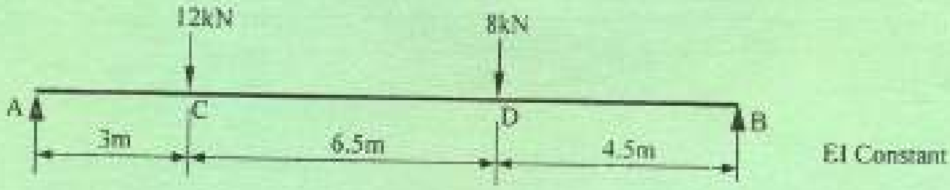


Fig 5

(b) Figure 6 shows a loaded simply supported beam and its cross-section. Draw the shear stress distribution diagram indicating the critical values for the maximum shear force. (11 marks)

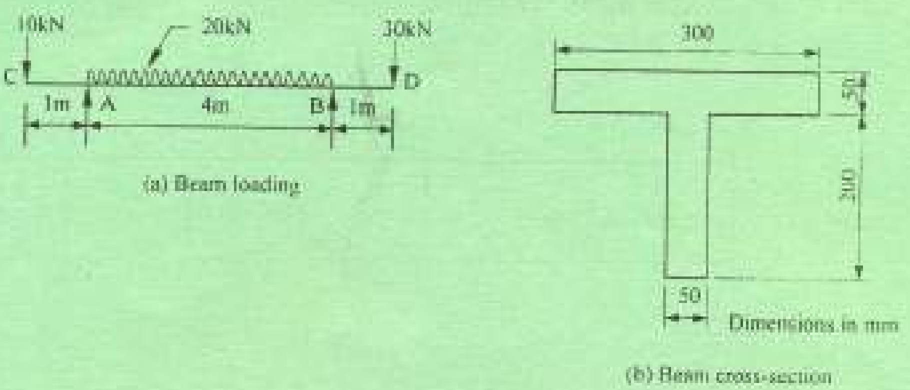


Fig 6

5. Figure 7 shows the plan and section through a precast concrete floor. Using the load factor method, design the bean given the following information:
- Concrete mix 1:24
- Beams are 200mm wide and simply supported on 200mm load bearing walls.
- live load = 3 kN/m^2
- Finishes = $1kN/m^2$
- Density of concrete = $2400kg/m^3$
- Pst = $230N/mm^2$.

(20 marks)

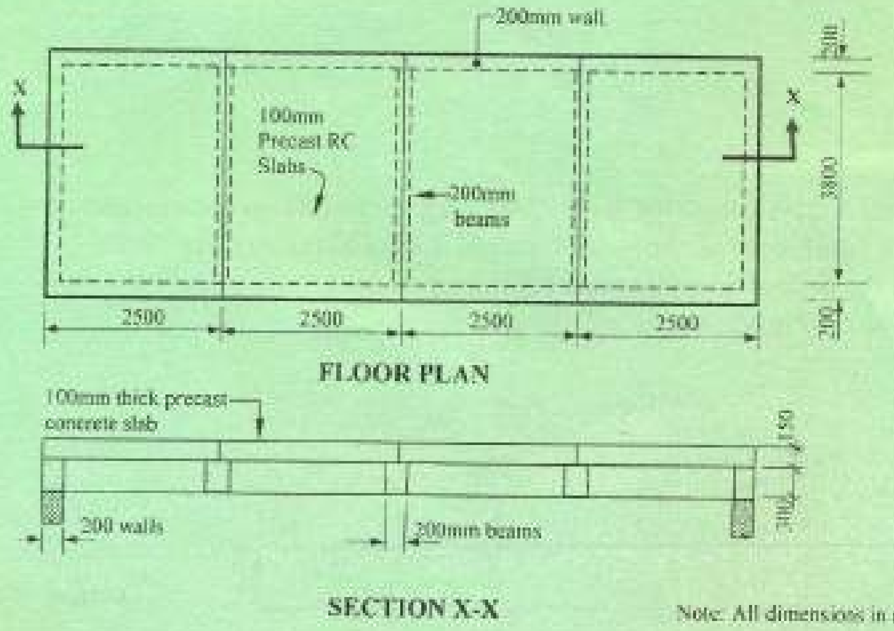


Fig 7

6. (a) A square column of size 300 X 300mm is to transmit an axial load of 700kN to its base. The column height centre to centre of floors is 3m, and is properly restrained at both ends in position and direction. Design the column and its base given the following information:

- concrete mix 1:1½:3
- Pst = 140N/mm²
- Pcc = 6.5N/mm²
- Psc = 125N/mm²
- m = 15
- bearing capacity of soil = 250kN/m²
- Assume any other relevant information. (18 marks)

(b) Detail the reinforcement for the column and its base as designed in (a). (2 marks)

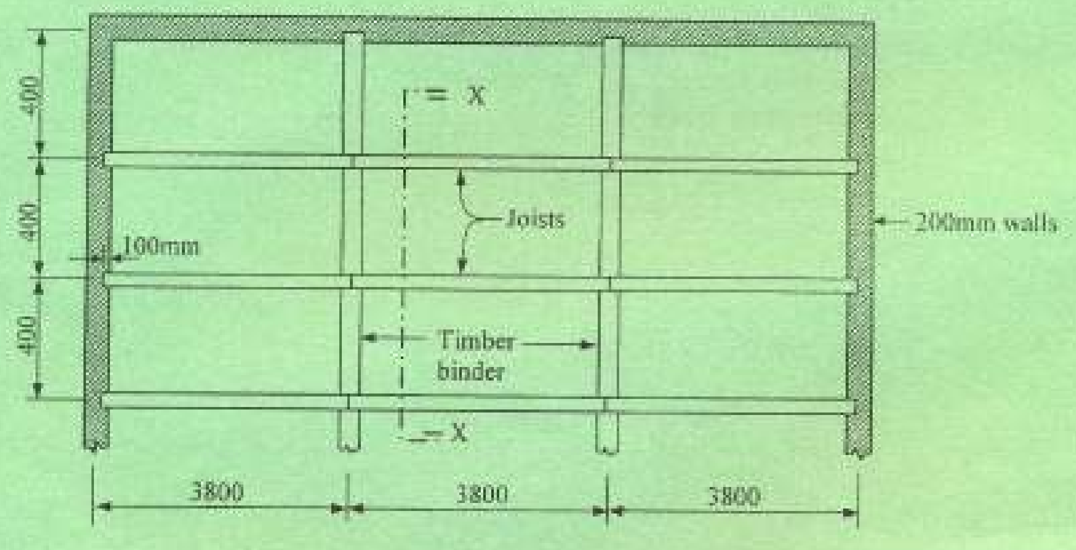
7. (a) (i) Differentiate between 'basic stress' and 'green stress' as applied to timber.

(ii) Explain each of the following in stress grading of timber:
- visual stress grading
- machine stress grading. (6 marks)

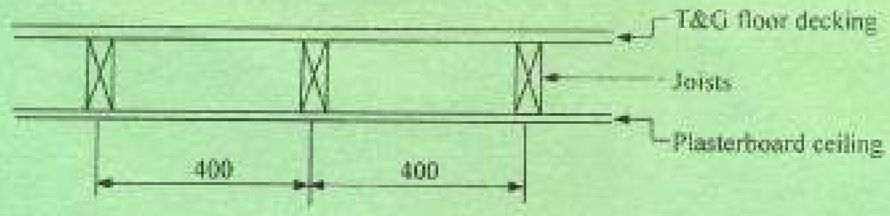
(b) Figure 8 shows the plan and section through a timber floor for a domestic dwelling. Design the timber joists for strength class SC2 given the following information:

- Joists are spaced at 400mm centres
- Joists have an effective span of 3.8m
- Self weight of T & G boards = 0.1kN/m^2
- Self weight of plasterboard ceiling = 0.2 kN/m^2
- Imposed loading on floor = 1.5kN/m^2
- Depth of joist limited to 200mm
- Density of timber of SC2 class = 540kg/m^3
- Modification factor K3 is as given in Table 1
- Modification factor for load sharing systems, K8 = 1.1
- Depth factor, $K7 = \left(\frac{300}{h}\right)^{0.11}$, where h = depth of beam
- Maximum depth to breath ratio is as given in Table 2
- Grade stresses and modulus of elasticity for SC2 class is as given in Table 3.

(14 marks)



PLAN



Note: All dimensions in mm

SECTION X-X

Fig 8

8. (a) Figure 9 shows the roof plan of a proposed hall. The roof consists of 125mm thick reinforced concrete slab support on universal beams. Check the adequacy of 533 X 165mm X 73 kg/m universal beams in grade 43 steel for the roof given the following information:

- spacing of universal beams = 2.5m centres
- roof finish together with waterproof layer of thickness 75mm is of average specific weight $20kN/m^3$
- Live load on roof finish = $0.75kN/m^2$.
- Density of reinforced concrete = $2400kg/m^3$.
- $E = 210kN/mm^2$
- $f_b = 165N/mm^2$
- $Pq = 100N/mm^2$
- Assume any other relevant information. (12 marks)

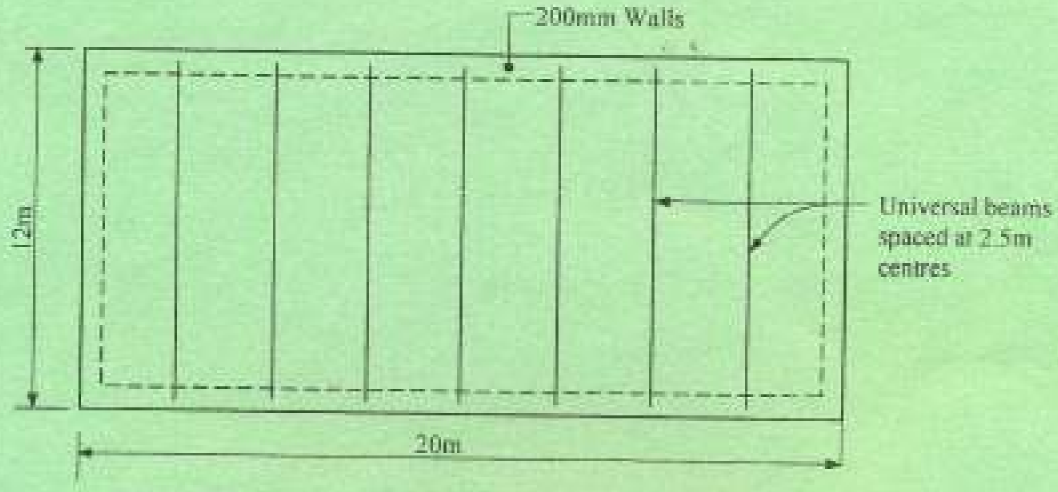


Fig 9

(b) Figure 10 shows a proposed bolted connection. Determine the safe load P. Take $f_s = 95N/mm^2$, $f_t = 155N/mm^2$ and $f_{br} = 300N/mm^2$

(8 marks)

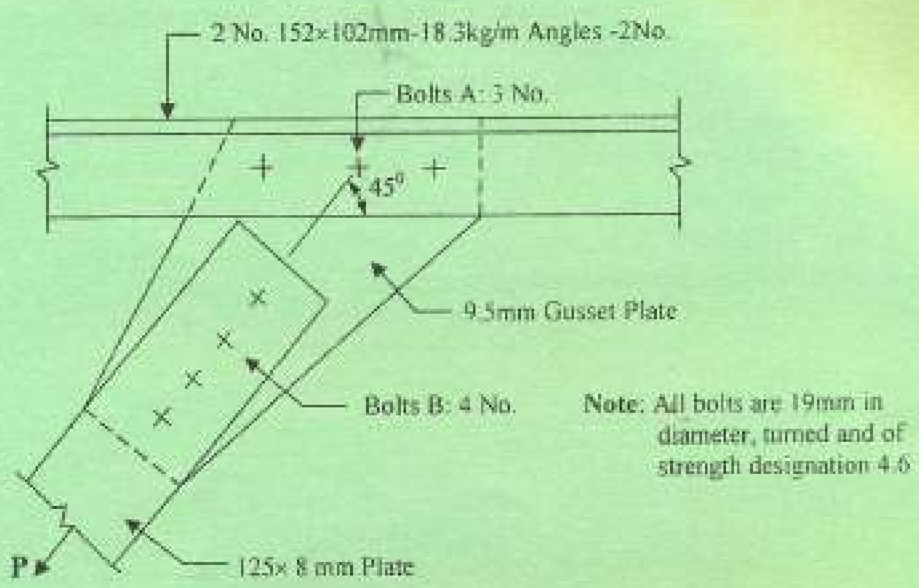


Fig 10

Duration of loading	Value of K_3
Long term	
(e.g. dead + permanent imposed)	1.00
Medium term	
(e.g. dead +snow, dead + temporary imposed)	1.25
Short term	
(e.g. dead + imposed + wind, dead + imposed + snow + wind)	1.50
Very short term	
(e.g. dead + imposed + wind)	1.75

Table 2: Depth factor, K7 (BS 5268)

1. $K_7 = 1.17$ *for solid beams having a depth* $< 72mm$

2. $K_7 = (300/h)^{0.11}$ for solid beams
   with $72mm < h < 300mm$

3. $K_7 = 0.81(h^2 + 92300)/(h^2 + 56800)$ for solid beams
   with $h < 300mm$

Table 3: Grade stresses, modulus of elasticity and density for strength class SC2 for the dry exposure condition (Table 9, BS 5268)

Strength Class	*Bending parallel to grain* (Nmm^{-2})	*Tension parallel to grain* (Nmm^{-2})	*Compression parallel to grain* (Nmm^{-2})	*Compression perpendicular to grain** (Nmm^{-2})		*Shear parallel to grain* (Nmm^{-2})	*Modulus of elasticity* (E_{mean}) (Nmm^{-2})	($E_{minimum}$) (Nmm^{-2})	*Approximate Density* (kgm^{-3})
SC1	2.8	2.2	3.5	2.1	1.2	0.46	6800	4500	540
SC2	4.1	2.5	5.3	2.1	1.6	0.66	8000	5000	540
SC3	5.3	3.2	6.8	2.2	1.7	0.67	8800	5800	540
SC4	7.5	4.5	7.9	2.4	1.9	0.71	9900	6600	590
SC5	10.0	6.0	8.7	2.8	2.4	1.00	10700	7100	590/760
SC6	12.5	7.5	12.5	3.8	2.8	1.50	14100	11800	840
SC7	15.0	9.0	14.5	4.4	3.3	1.75	16200	13600	960
SC8	17.5	10.5	16.5	5.2	3.9	2.00	18700	15600	1080
SC9	20.5	12.3	19.5	6.1	4.6	2.25	21600	18000	1200

* When the specification specifically prohibits wane at bearing areas, the higher values of compression perpendicular to the grain stress may be used; otherwise the lower values apply.

Table 4: Reinforcement-bar areas (mm^2) per metre width for various bar spacings

Bar Diameter (mm)	Bar spacing (mm)									
	75	100	125	150	175	200	225	250	275	300
6	377	283	226	189	162	142	126	113	103	94
8	671	503	402	335	287	252	223	201	183	168
10	1047	785	628	523	449	393	349	314	286	262
12	1508	1131	905	754	646	566	503	452	411	377
16	2681	2011	1608	1340	1149	1005	894	804	731	670
20	4189	3142	2513	2094	1795	1571	1396	1257	1142	1047
25	6545	4909	3927	3272	2805	2454	2182	1963	1785	1636
32	-	8042	6434	5362	4596	4021	3574	3217	2925	2681
40	-	-	10050	8378	7181	6283	5585	5027	4570	4189

Areas of group of reinforcement bars (mm^2)

Bar Diameter (mm)	Number of bars									
	1	2	3	4	5	6	7	8	9	10
6	28	57	85	113	141	170	198	226	254	283
8	50	101	151	201	251	302	352	402	452	503
10	79	157	236	314	393	471	550	628	707	785
12	113	226	339	452	565	679	792	905	1017	1131
16	201	402	603	804	1005	1206	1407	1608	1809	2011
20	314	628	942	1257	1571	1885	2199	2513	2827	3142
25	491	982	1473	1963	2454	2945	3436	3927	4418	4909
32	804	1608	2412	3216	4021	4825	5629	6433	7237	8042
40	1256	2513	3769	5026	6283	7539	8796	10050	11310	12570

UNIVERSAL BEAMS

DIMENSIONS AND PROPERTIES

Serial Size	Mass per metre	Depth of Section D	Width of Section B	Thickness Web t	Thickness Flange T	Root Radius r	Depth between Fillets d	Area of Section
mm	kg	mm	mm	mm	mm	mm	mm	cm²
914 × 419	388	920.5	420.5	21.5	36.6	24.1	791.5	493.9
	343	911.4	418.5	19.4	32.0	24.1	791.5	436.9
914 × 305	289	926.6	307.8	19.6	32.0	19.1	819.2	368.5
	253	918.5	305.5	17.3	27.9	19.1	819.2	322.5
	224	910.3	304.1	15.9	23.9	19.1	819.2	284.9
	201	903.0	303.4	15.2	20.2	19.1	819.2	256.1
838 × 292	226	850.9	293.8	16.1	26.8	17.8	756.4	288.4
	194	840.7	292.4	14.7	21.7	17.8	756.4	246.9
	176	834.9	291.6	14.0	18.8	17.8	756.4	223.9
762 × 267	197	769.6	268.0	15.6	25.4	16.5	681.2	250.6
	173	762.0	266.7	14.3	21.6	16.5	681.2	220.2
	147	753.9	265.3	12.9	17.5	16.5	681.2	187.6
686 × 254	170	692.9	255.8	14.5	23.7	15.2	610.6	216.3
	152	687.6	254.5	13.2	21.0	15.2	610.6	192.8
	140	683.5	253.7	12.4	19.0	15.2	610.6	178.4
	125	677.9	253.0	11.7	16.2	15.2	610.6	159.4
610 × 305	238	633.0	311.5	18.6	31.4	16.5	531.8	303.5
	179	617.5	307.0	14.1	23.6	16.5	531.8	227.7
	149	609.6	304.8	11.9	19.7	16.5	531.8	189.9
610 × 229	140	617.0	230.1	13.1	22.1	12.7	543.1	178.2
	125	611.9	229.0	11.9	19.6	12.7	543.1	159.4
	113	607.3	228.2	11.2	17.3	12.7	543.1	144.3
	101	602.2	227.6	10.6	14.8	12.7	543.1	129.0
610 × 178	91	602.5	178.4	10.6	15.0	12.7	547.1	115.9
	82	598.2	177.8	10.1	12.8	12.7	547.1	104.4
533 × 330	212	545.1	333.6	16.7	27.8	16.5	450.1	269.6
	189	539.5	331.7	14.9	25.0	16.5	450.1	241.2
	167	533.4	330.2	13.4	22.0	16.5	450.1	212.7
533 × 210	122	544.6	211.9	12.8	21.3	12.7	472.7	155.6
	109	539.5	210.7	11.6	18.8	12.7	472.7	138.4
	101	536.7	210.1	10.9	17.4	12.7	472.7	129.1
	92	533.1	209.3	10.2	15.6	12.7	472.7	117.6
	82	528.3	208.7	9.6	13.2	12.7	472.7	104.3
533 × 165	73	528.8	165.6	9.3	13.6	12.7	476.5	93.0
	66	524.8	165.1	8.8	11.6	12.7	476.5	83.6
457 × 191	98	467.4	192.8	11.4	19.6	10.2	404.4	125.2
	89	463.6	192.0	10.6	17.7	10.2	404.4	113.8
	82	460.2	191.3	9.9	16.0	10.2	404.4	104.4
	74	457.2	190.5	9.1	14.5	10.2	404.4	94.9
	67	453.6	189.9	8.5	12.7	10.2	404.4	85.4

UNIVERSAL BEAMS

DIMENSIONS AND PROPERTIES

Serial Size	Moment of Inertia Axis x-x Gross	Moment of Inertia Axis x-x Net	Moment of Inertia Axis y-y	Radius of Gyration Axis x-x	Radius of Gyration Axis y-y	Elastic Modulus Axis x-x	Elastic Modulus Axis y-y	Ratio D/T
mm	cm⁴	cm⁴	cm⁴	cm	cm	cm³	cm³	
914 × 419	717325	639177	42481	38.1	9.27	15586	2021	25.2
	623866	550835	36251	37.8	9.11	13691	1733	28.5
914 × 305	503781	469903	14793	37.0	6.34	10874	961.3	29.0
	435796	406504	12512	36.8	6.23	9490	819.2	32.9
	376111	350209	10425	36.3	6.05	8241	685.6	38.1
	324715	303783	8632	35.6	5.81	7192	569.1	44.7
838 × 292	339130	315153	10661	34.3	6.08	7971	725.9	31.8
	278833	259625	8384	33.6	5.83	6633	573.6	38.7
	245412	228867	7111	33.1	5.64	5879	487.8	44.4
762 × 267	239464	221138	7699	30.9	5.54	6223	574.6	30.3
	204747	189341	6376	30.5	5.38	5374	478.1	35.3
	168535	156213	5002	30.0	5.16	4471	377.1	43.1
686 × 254	169843	156106	6225	28.0	5.36	4902	486.8	29.3
	150015	137965	5391	27.8	5.28	4364	423.7	32.7
	135972	126156	4789	27.6	5.18	3979	377.5	36.0
	117700	108680	3992	27.2	5.00	3472	315.5	41.8
610 × 305	207252	192203	14973	26.1	7.02	6549	961.3	20.2
	151312	140269	10571	25.8	6.81	4901	688.6	26.2
	124341	115233	8471	25.6	6.68	4079	555.9	30.9
610 × 229	111673	101899	4253	25.0	4.88	3620	369.6	27.8
	98408	89675	3676	24.8	4.80	3217	321.1	31.2
	87260	79645	3184	24.6	4.70	2874	279.1	35.1
	75549	69132	2658	24.2	4.54	2509	233.6	40.7
610 × 178	63970	57238	1427	23.8	3.51	2124	160.0	40.2
	55779	50076	1203	23.1	3.39	1865	135.3	46.7
533 × 330	141682	121777	16064	22.9	7.72	5199	963.2	19.6
	125618	107882	14093	22.8	7.64	4657	849.6	21.6
	109109	93647	12057	22.6	7.53	4091	730.3	24.2
533 × 210	76078	68719	3208	22.1	4.54	2794	302.8	25.6
	66610	60218	2755	21.9	4.46	2469	261.5	28.7
	61530	55671	2512	21.8	4.41	2293	239.2	30.8
	55225	50040	2212	21.7	4.34	2072	211.3	34.2
	47363	43062	1826	21.3	4.18	1793	175.0	40.0
533 × 165	40414	36752	1027	20.8	3.32	1528	124.1	39.2
	35083	31144	863	20.5	3.21	1337	104.5	45.6
457 × 191	45653	40469	2216	19.1	4.21	1954	229.9	23.8
	40956	36313	1960	19.0	4.15	1767	204.2	26.2
	37039	32869	1746	18.8	4.09	1610	182.6	28.8
	33324	29570	1547	18.7	4.04	1458	162.4	31.5
	29337	26072	1328	18.5	3.99	1293	139.6	35.7