2305/303
2307/303
STRUCTURES
Oct./Nov. 2011
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

HIGHER DIPLOMA IN BUILDING
DIPLOMA IN CIVIL ENGINEERING

STRUCTURES

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:
Mathematical tables / pocket calculator;
Drawing instruments.
*Answer any **FIVE** of the following **EIGHT** questions.*
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 10 printed pages.

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

Turn over

1. Using the method of moment distribution, analyse the frame shown in **Figure 1** and plot the bending moment diagram indicating the critical values. (20 marks)

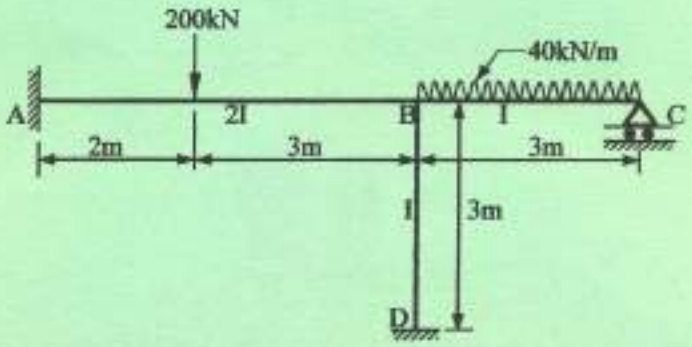


Figure 1

2. Using the three moments theorem, analyse the beam shown in **Figure 2** and plot the bending moment diagram indicating the critical values. (20 marks)

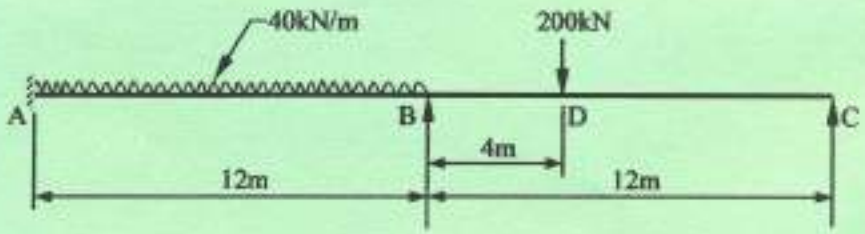


Figure 2

3. (a) (i) Explain the following reinforced concrete beams:

- Balanced section;
- Under-reinforced section;
- Over-reinforced section.

(ii) State four assumptions made in elastic theory of reinforced concrete design. (8 marks)

(b) A reinforced rectangular concrete beam is of breadth 200 mm and depth 450 mm. Determine:

(i) the moment of resistance of the beam;

(ii) the area of steel, if high yield bars are used;

(iii) the maximum uniformly distributed load that the beam may safely carry when simply supported over an effective span of 4 m.

Use the following information:

- Concrete mix: 1:1 $\frac{1}{2}$:3, of pcb = 8.5 N/mm^2 and m = 15;
- High yield bars of pst = 210 N/mm^2;
- Density of reinforced concrete = 2400 kg/m^3 .

(12 marks)

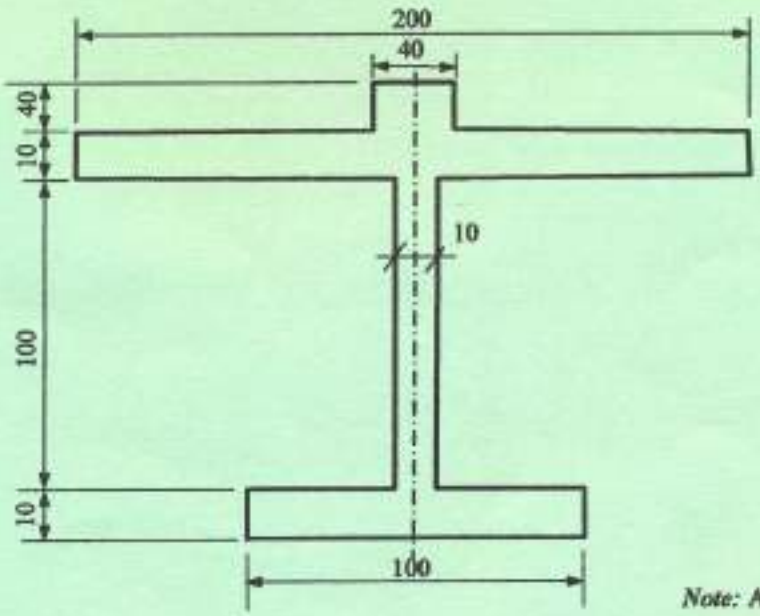
4. (a) (i) Design a reinforced concrete column given the following information:

- Axial load = 600 KN
- Effective length = 6 m
- PSC = 125 N/mm^2
- PCC = 5.3 N/mm^2
- Section = 300 x 300 mm

(ii) Detail the reinforced concrete column section designed in a (i).

(10 marks)

(b) A 1.5 m long cantilever beam carries a uniformly distributed load over the entire span. Determine the maximum intensity of the uniformly distributed load over the beam if tensile and compressive stresses are limited to 25 N/mm^2 and 75 N/mm^2 respectively, and the beam cross-section is as shown in **figure 3**. (10 marks)



Note: **All dimensions in mm**

Figure 3

5. Using the method of joint resolution, determine the magnitude and nature of forces for each member of the pin-jointed frame as shown in **figure 4**. (20 marks)

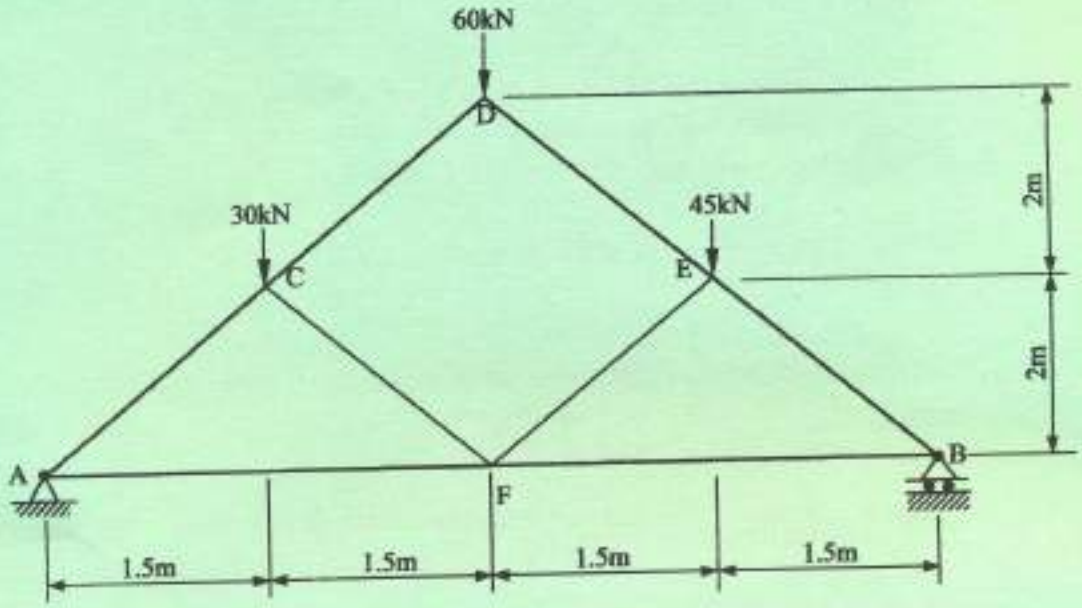
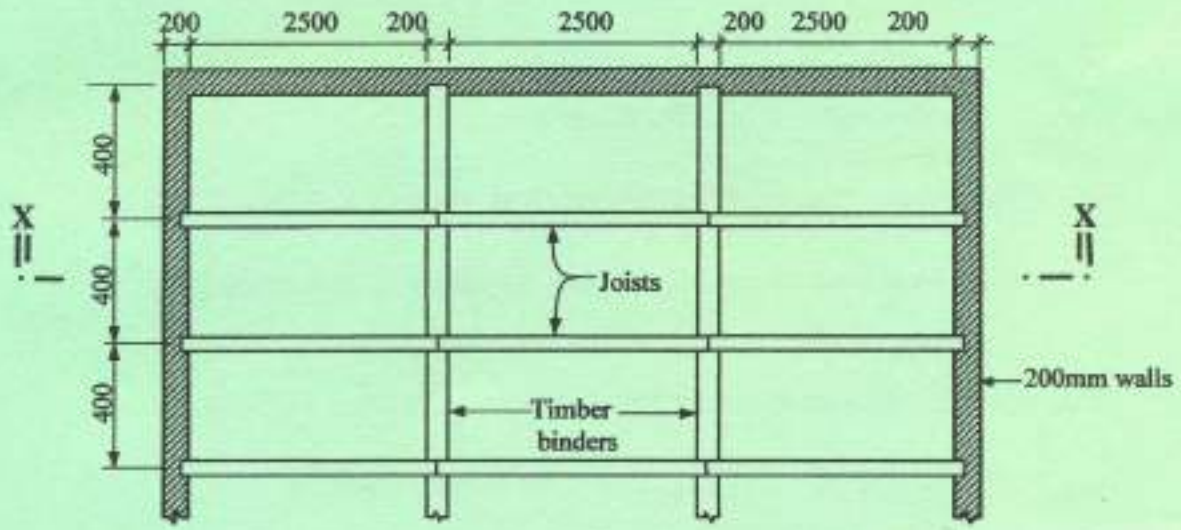


Figure 4

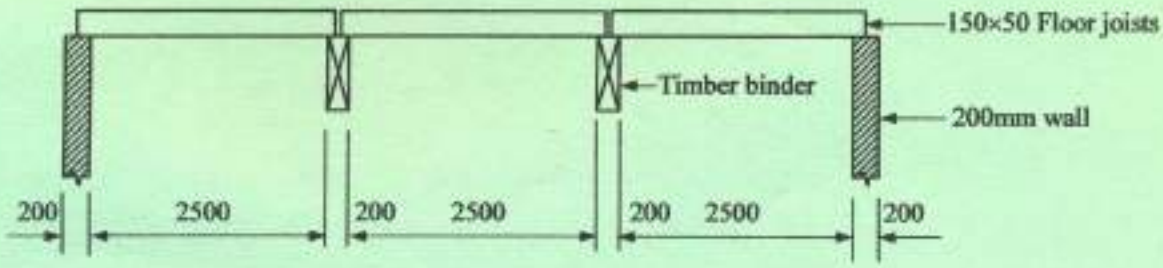
6. (a) **Figure 5** shows the plan of a proposed timber floor. Check the adequacy of 150 x 50 mm flour joints spaced at 400 mm centres, given the following information:

- Load on floor inclusive of self weight = 2.75 kN/m².
- Permissible stresses in timber:
  bending = 6.2 N/mm².
  parallel to grain = 0.6 N/mm².
  perpendicular to grain = 1.93 N/mm².
- Permissible deflection = 0.6 N/mm².
- E = 9.7 kN/mm².
- Effective span of joint = 2.75 m.

(10½ marks)



PLAN



Note: All dimensions in mm

SECTION X-X

Figure 5

(b) A flitched beam is simply supported over a span of 5 m and carries a uniformly distributed load of 2 kN/m over the entire span. If the beam cross-section is as shown in **Figure 6**, determine the maximum tensile and compressive stresses developed in both materials due to the loading. Take Es = 210 kN/mm^2 and Et = 10 kN/mm^2.

(9$\frac{1}{2}$ marks)

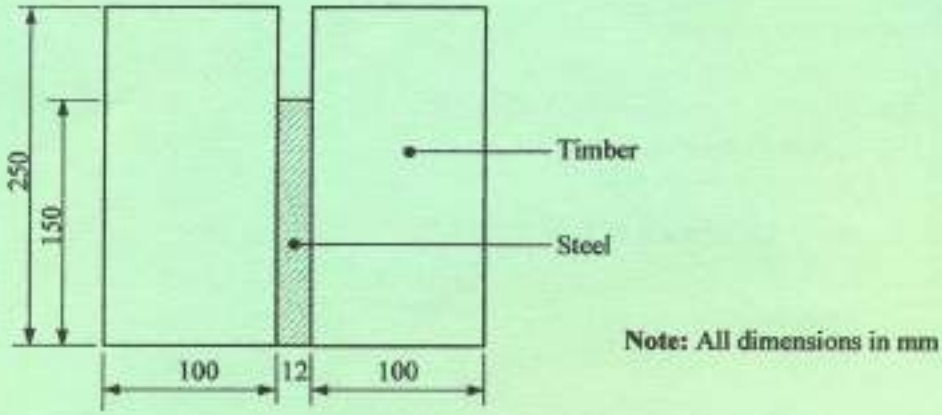


Figure 6

7. (a) (i) State **three** advantages and **three** disadvantages of welded connections.

(ii) State **four** assumptions made in the design of bolted connections.

(5 marks)

(b) Determine the safe load **P** for the bolted connection shown in **Figure 7**.

Take fs = 95 N/mm^2, ft = 155 N/mm^2 and fbr = 300 N/mm^2.

(7 marks)

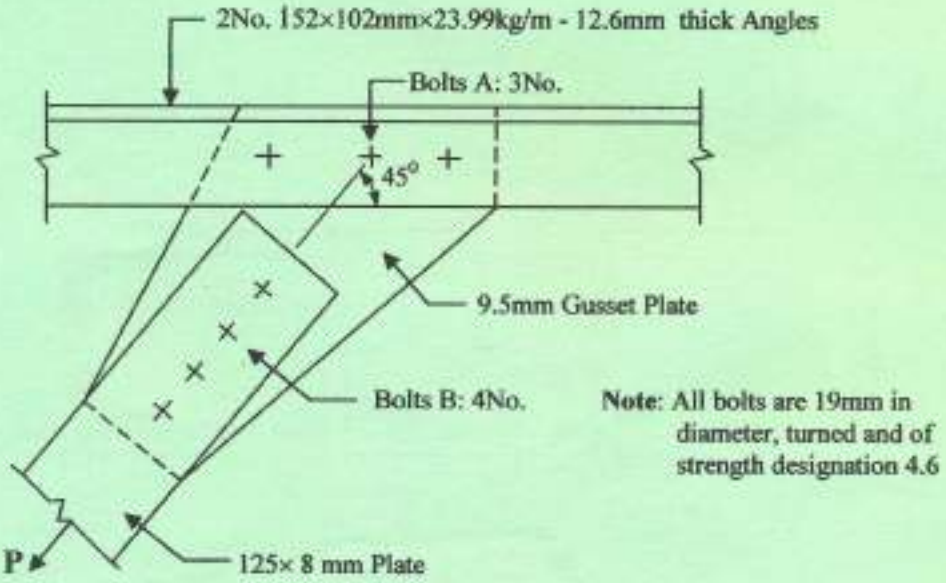


Figure 7

(c) A steel beam of 8 m effective span carries a uniformly distributed load of 20 kN/m self weight inclusive. If the flange is held against lateral displacement, design the beam in grade 43 steel given the following information:

- Allowable bending stress, pbc = 165 N/mm^2.
- Young's modulus of elasticity, E = 210 kN/mm^2.
- Allowable shear stress, fq = 100 N/mm^2.

(8 marks)

8. (a) State the objective of limit state design and mention **four** serviceability limit states.

(3 marks)

(b) A uniformly disributed loead of 5 kN/m, longer than the span, rolls over a simply suported beam of 25 m span. Using influence lines, determine the maximum shear force and bending moment at a section 10 m from the left end support.

(7 marks)

(c) **Figure 8** shows a retaining wall which supports a cohesionless soil having a density of 1900 kg/m^3 and an angle of shearing resistance of 30^0. The density of the wall material is 2400 kg/m^3. Examine the stability conditions of the wall with regard to:

(i) tension in the joints;

(ii) ground bearing pressure.

(10 marks)

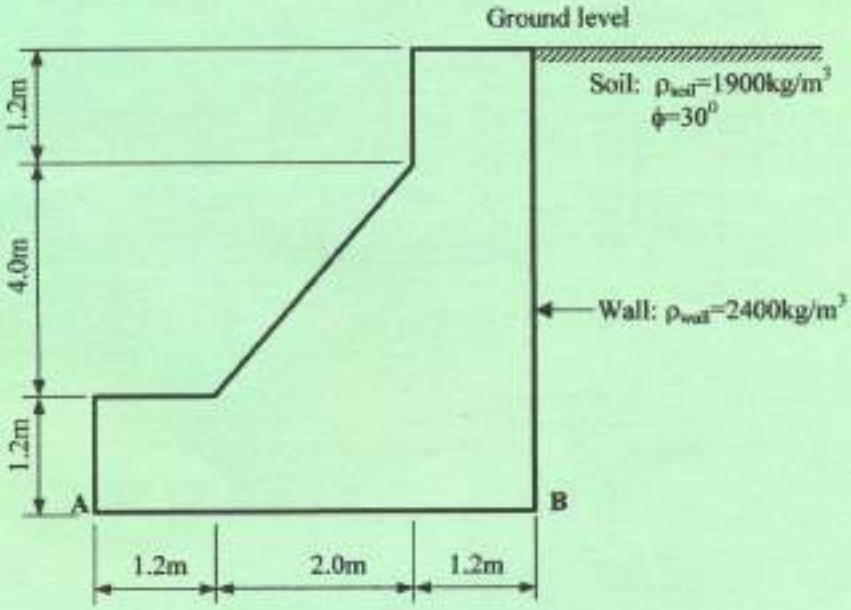


Figure 8

Table 1
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

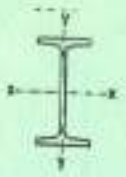
UNIVERSAL BEAMS

DIMENSIONS AND PROPERTIES

Serial Size	Mass per metre	Depth of Section D	Width of Section B	Thickness		Root Radius r	Depth between Fillets d	Area of Section
				Web t	Flange T			
mm	kg	mm	mm	mm	mm	mm	mm	cm²
914 x 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 x 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	286.0
	201	903.0	303.4	15.2	20.2	19.1	819.2	256.1
838 x 292	226	850.6	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	223.8
762 x 267	197	769.6	268.0	15.6	25.4	16.5	681.2	250.5
	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	187.8
686 x 254	170	692.9	255.8	14.5	23.7	15.2	610.6	215.3
	152	687.6	254.5	13.2	21.0	15.2	610.6	193.6
	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 x 305	238	633.0	311.5	18.6	31.4	16.5	531.6	303.5
	179	617.5	307.0	14.1	23.6	16.5	531.6	227.7
	149	609.6	304.8	11.9	19.7	16.5	531.6	189.9
610 x 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 x 178	91	602.5	178.4	10.6	16.0	12.7	547.1	115.9
	82	598.2	177.8	10.1	12.8	12.7	547.1	104.4
533 x 330	212	545.1	333.8	16.7	27.8	16.5	460.1	269.6
	189	539.5	331.7	14.8	25.0	16.5	460.1	241.2
	167	533.4	330.2	13.4	22.0	16.5	460.1	212.7
533 x 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	535.7	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 x 165	73	528.8	165.6	9.3	13.5	12.7	476.5	93.0
	66	524.8	165.1	8.9	11.6	12.7	476.5	83.6
457 x 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			Radius of Gyration		Elastic Modulus		Ratio D/T
	Axis x–x		Axis y–y	Axis x–x	Axis y–y	Axis x–x	Axis y–y	
	Gross	Net						
mm	cm⁴	cm⁴	cm⁴	cm	cm	cm³	cm³	-
914 x 419	717325	639177	42481	38.1	9.27	15586	2021	25.2
	623866	555835	36261	37.8	9.11	13681	1733	28.5
914 x 305	503781	469903	14793	37.0	5.34	10874	981.3	29.0
	438796	406504	12512	36.8	5.23	9490	819.2	32.9
	375111	346209	10412	36.3	6.05	8241	685.6	38.1
	324715	303783	8832	35.6	5.81	7157	592.1	44.7
838 x 292	339130	315153	10861	34.3	6.08	7971	726.9	31.8
	278833	259626	8394	33.6	5.83	6633	573.6	38.7
	245412	228867	7111	33.1	5.64	5879	487.6	44.4
762 x 267	239464	221138	7899	30.9	5.54	6223	574.8	30.3
	204747	189341	6376	30.6	5.38	5374	478.1	35.3
	168536	156213	5002	30.0	5.16	4471	377.1	43.1
686 x 254	169843	156106	6225	28.0	5.36	4902	486.8	29.2
	150015	137865	5391	27.8	5.28	4364	423.7	32.7
	135972	125156	4789	27.6	5.18	3979	377.5	36.0
	117700	106580	3992	27.2	5.00	3472	315.5	41.8
610 x 305	207252	192203	14973	26.1	7.02	6549	961.3	20.2
	161312	140269	10571	25.8	6.81	4901	688.6	28.2
	124341	115233	8471	25.6	6.68	4079	555.9	30.9
610 x 229	111873	101699	4253	25.0	4.88	3620	369.8	27.9
	98408	89675	3678	24.8	4.80	3217	321.1	31.2
	87280	79645	3184	24.6	4.70	2874	279.1	35.1
	76549	69132	2658	24.2	4.64	2509	233.6	40.7
610 x 178	63970	57238	1427	23.5	3.51	2124	160.0	40.2
	55779	50078	1203	23.1	3.39	1865	135.3	46.7
533 x 330	141682	121777	16054	22.9	7.72	5189	963.2	19.6
	125618	107882	14093	22.8	7.64	4657	849.6	21.6
	109109	93847	12087	22.6	7.53	4091	730.3	24.2
533 x 210	76079	68719	3208	22.1	4.54	2794	302.8	25.6
	66810	60218	2755	21.9	4.46	2459	261.5	28.7
	61530	55571	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 x 165	40414	35762	1027	20.8	3.32	1528	124.1	39.2
	36083	31144	863	20.5	3.21	1337	104.5	45.8
457 x 191	45853	40469	2216	19.1	4.21	1954	229.9	23.8
	40956	36313	1960	19.0	4.15	1767	204.2	26.2
	37039	32889	1746	18.9	4.09	1610	182.6	28.8
	33324	29570	1547	18.7	4.04	1458	162.4	31.5
	29337	26072	1328	18.5	3.95	1293	139.9	35.7

Turn over

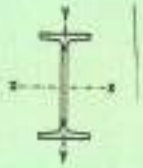
UNIVERSAL BEAMS

DIMENSIONS AND PROPERTIES

Serial Size	Mass per metre	Depth of Section D	Width of Section B	Thickness		Root Radius r	Depth between Fillets d	Area of Section
				Web t	Flange T			
mm	kg	mm	mm	mm	mm	mm	mm	cm²
457 × 152	82	465.1	153.5	10.7	18.9	10.2	404.4	104.4
	74	461.3	152.7	9.9	17.0	10.2	404.4	94.9
	67	457.2	151.9	9.1	16.0	10.2	404.4	85.3
	60	454.7	152.9	8.0	13.3	10.2	407.7	76.9
	52	449.8	152.4	7.6	10.9	10.2	407.7	66.5
406 × 178	74	412.8	179.7	9.7	16.0	10.2	357.4	94.9
	67	409.4	178.8	8.8	14.3	10.2	357.4	85.4
	60	406.4	177.8	7.8	12.8	10.2	357.4	76.1
	54	402.6	177.6	7.6	10.9	10.2	357.4	68.3
406 × 152	74	416.3	153.7	10.1	18.1	10.2	357.4	94.8
	67	412.2	152.9	9.3	16.0	10.2	357.4	85.3
	60	407.9	152.2	8.6	13.9	10.2	357.4	75.8
406 × 140	46	402.3	142.4	6.9	11.2	10.2	357.4	58.8
	39	397.3	141.8	6.3	8.6	10.2	357.4	49.3
381 × 152	67	388.6	154.3	9.7	16.3	10.2	333.2	85.4
	60	384.8	153.4	8.7	14.4	10.2	333.2	75.9
	52	381.0	152.4	7.8	12.4	10.2	333.2	66.4
356 × 171	67	364.0	173.2	9.1	15.7	10.2	309.1	85.3
	57	358.8	172.1	8.0	13.0	10.2	309.1	72.1
	51	355.6	171.5	7.3	11.5	10.2	309.1	64.8
	45	352.0	171.0	6.9	9.7	10.2	309.1	56.9
356 × 127	39	352.8	126.0	6.5	10.7	10.2	309.1	49.3
	33	348.5	125.4	5.9	8.5	10.2	309.1	41.7
305 × 165	54	310.9	166.8	7.7	13.7	8.9	262.6	68.3
	46	307.1	165.7	6.7	11.8	8.9	262.6	58.8
	40	303.8	165.1	6.1	10.2	8.9	262.6	51.4
305 × 127	48	310.4	125.2	8.9	14.0	8.9	262.6	60.8
	42	306.6	124.3	8.0	12.1	8.9	262.6	53.1
	37	303.8	123.5	7.2	10.7	8.9	262.6	47.4
305 × 102	33	312.7	102.4	6.6	10.8	7.6	275.3	41.8
	28	308.9	101.9	6.1	8.9	7.6	275.3	36.3
	25	304.8	101.6	5.8	6.8	7.6	275.3	31.4
254 × 146	43	259.6	147.3	7.3	12.7	7.6	216.2	55.0
	37	256.0	146.4	6.4	10.9	7.6	216.2	47.4
	31	251.5	146.1	6.1	8.6	7.6	216.2	39.9
254 × 102	28	260.4	102.1	6.4	10.0	7.6	224.5	36.2
	25	257.0	101.9	6.1	8.4	7.6	224.5	32.1
	22	254.0	101.6	5.8	6.8	7.6	224.5	28.4
203 × 133	30	206.8	133.8	6.3	9.6	7.6	169.9	38.0
	25	203.2	133.4	5.8	7.8	7.6	169.9	32.3

UNIVERSAL BEAMS

DIMENSIONS AND PROPERTIES



Serial Size	Moment of Inertia			Radius of Gyration		Elastic Modulus		Ratio D/T
	Axis x-x		Axis y-y	Axis x-x	Axis y-y	Axis x-x	Axis y-y	
	Gross	Net						
mm	cm⁴	cm⁴	cm⁴	cm	cm	cm³	cm³	
457 × 152	36160	32058	1093	18.8	3.24	1555	142.6	24.8
	32380	28731	963	18.5	3.16	1404	126.1	27.1
	28522	25342	829	18.3	3.12	1246	109.1	30.5
	25464	22613	794	18.3	3.23	1120	104.0	34.2
	21345	19034	646	17.9	3.11	949.0	84.61	41.3
406 × 178	27279	23981	1448	17.0	3.91	1322	161.2	25.8
	24279	21357	1269	16.9	3.85	1186	141.8	28.6
	21510	18928	1108	16.8	3.82	1059	124.7	31.8
	18576	16389	922	16.5	3.67	922.8	103.8	35.9
406 × 152	26938	23811	1047	16.9	3.32	1294	136.2	23.0
	23788	21069	908	16.7	3.26	1155	118.8	25.8
	20819	18283	768	16.5	3.18	1011	100.9	29.3
406 × 140	15603	13699	500	16.3	2.82	775.6	70.26	35.9
	12408	10963	373	15.9	2.75	624.7	52.61	46.2
381 × 152	21276	18817	947	15.8	3.33	1095	122.7	23.8
	18632	16489	814	15.7	3.27	968.4	106.2	26.7
	16046	14226	686	15.5	3.21	842.3	89.96	30.7
356 × 171	19483	17002	1278	15.1	3.87	1071	147.6	23.3
	16038	14018	1026	14.9	3.77	894.3	119.2	27.6
	14118	12349	885	14.8	3.71	794.0	103.3	30.9
	12052	10578	730	14.6	3.58	684.7	85.39	36.3
356 × 127	10054	8688	333	14.3	2.60	570.0	52.87	33.0
	8167	7099	257	14.0	2.48	468.7	40.99	41.0
305 × 165	11686	10119	988	13.1	3.80	751.9	118.5	22.7
	9924	8596	825	13.0	3.74	646.4	99.54	26.0
	8500	7368	691	12.9	3.67	559.6	83.71	29.8
305 × 127	9486	8137	438	12.5	2.68	611.1	69.94	22.2
	8124	6978	367	12.4	2.63	530.0	58.99	25.3
	7143	6142	318	12.3	2.68	470.3	51.11	28.4
305 × 102	5482	5292	189	12.6	2.13	414.6	37.00	29.0
	5415	4866	153	12.2	2.06	350.7	30.01	34.7
	4381	3959	116	11.8	1.92	287.5	22.85	44.8
254 × 146	6546	5883	833	10.9	3.38	504.3	85.97	20.4
	5544	4814	528	10.8	3.34	433.1	72.11	23.5
	4427	3859	406	10.5	3.19	352.1	55.53	29.2
254 × 102	4004	3585	174	10.5	2.19	307.5	34.13	26.0
	3404	3041	144	10.3	2.11	264.9	28.23	30.6
	2863	2572	116	10.0	2.02	225.4	22.84	37.4
203 × 133	2880	2469	354	9.71	3.05	278.5	52.85	21.5
	2348	2020	280	8.53	2.94	231.1	41.92	26.1