

2705/302
2709/302
2710/302
STRUCTURES III
June/July 2023
Time: 3 hours



THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN BUILDING TECHNOLOGY
DIPLOMA IN ARCHITECTURE

MODULE III

STRUCTURES III

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:

Answer booklet;

Mathematical tables/Scientific calculator.

This paper consists of EIGHT questions.

Answer any FIVE questions.

All questions carry equal marks.

Maximum marks for each part of a question are indicated.

Candidates should answer the questions in English.

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. Using three moment theorem, analyse the beam shown in **figure 1** and hence draw shear force and bending moment diagrams and indicate values at critical points. (20 marks)

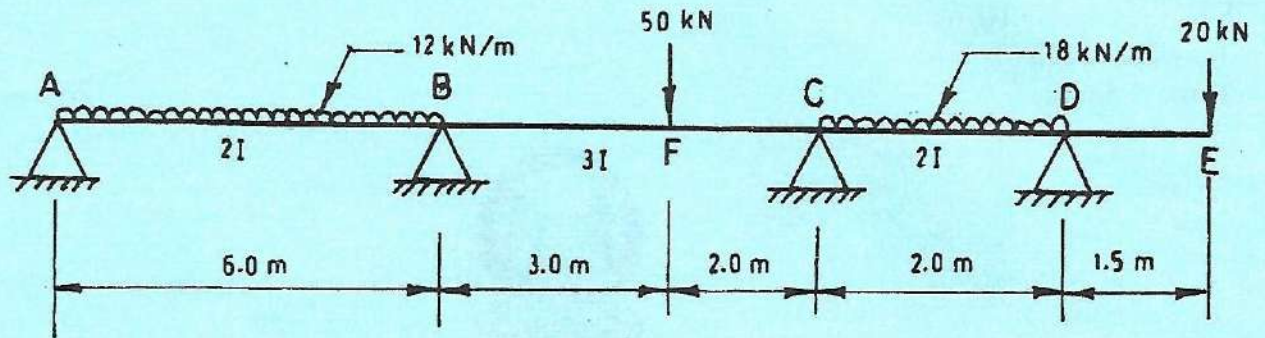


Fig.1

2. **Figure 2** shows a simply supported beam of effective span 8.0 m. It supports the loads as shown. Assuming that the beam is fully restrained laterally, select a suitable UB section in S275 steel to satisfy bending, shear and deflection using the data given and attached tables. (20 marks)

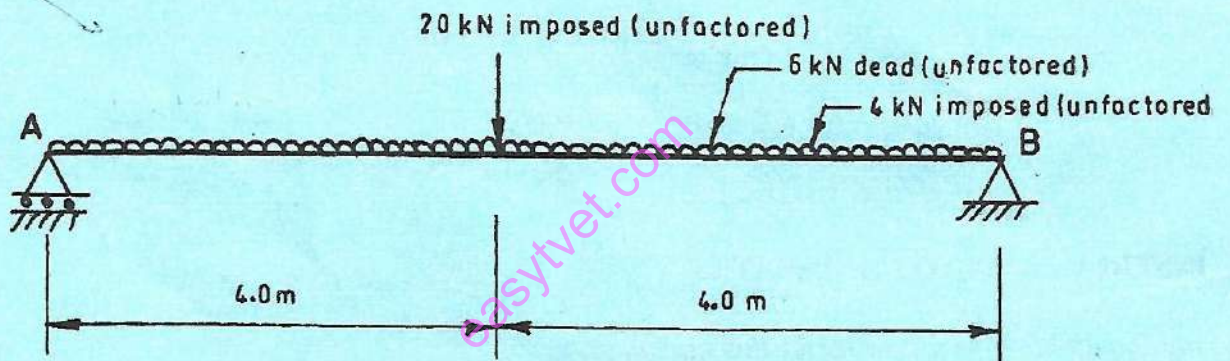


Fig.2

Data: Permissible deflection = $\frac{1}{360}$ of span

$$E = 210 \text{ kN/mm}^2.$$

3. (a) Distinguish between visual stress grading and machine grading in structural timber. (4 marks)
- (b) A timber floor is supported on joists with effective spans 4.5 m. The joists support imposed uniformly distributed loads of 4 kN/m and uniformly distributed dead loads of 1.5 kN/m. Design the joists using the data given and hence check shear, bending and deflection. (16 marks)

Data

Grade stresses

- In bending parallel to grain = 7.5 N/mm²
- In shear parallel to grain = 0.71 N/mm²
- E_{mean} = 9900 N/mm²
- depth / breadth ratio = 3
- Allowable deflection = $\frac{1}{300}$ of span

$$K_3 = 1.25; \quad K_7 = 1.03; \quad K_8 = 1.1$$

4. Using moment distribution method analyse the portal frame shown in figure 3 and hence draw the shear force and bending moment diagrams indicating values at critical points. (20 marks)

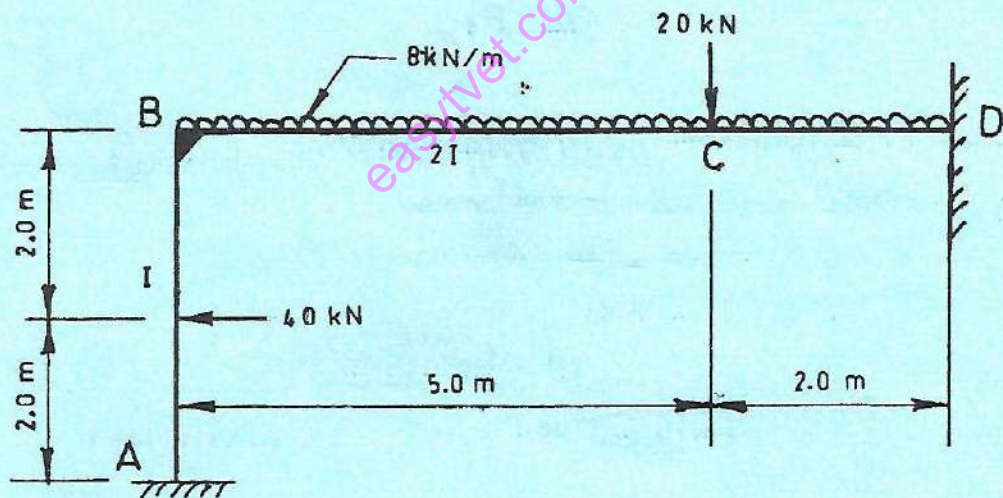


Fig. 3

5. (a) A tier bar in a truss consists of an angle section $100 \times 75 \times 10$ mm and is subjected to a load of 250 kN as shown in figure 4.

Design the joint using 8 mm fillet weld if the permissible shear stress in the weld is 220 N/mm^2 . (7 marks)

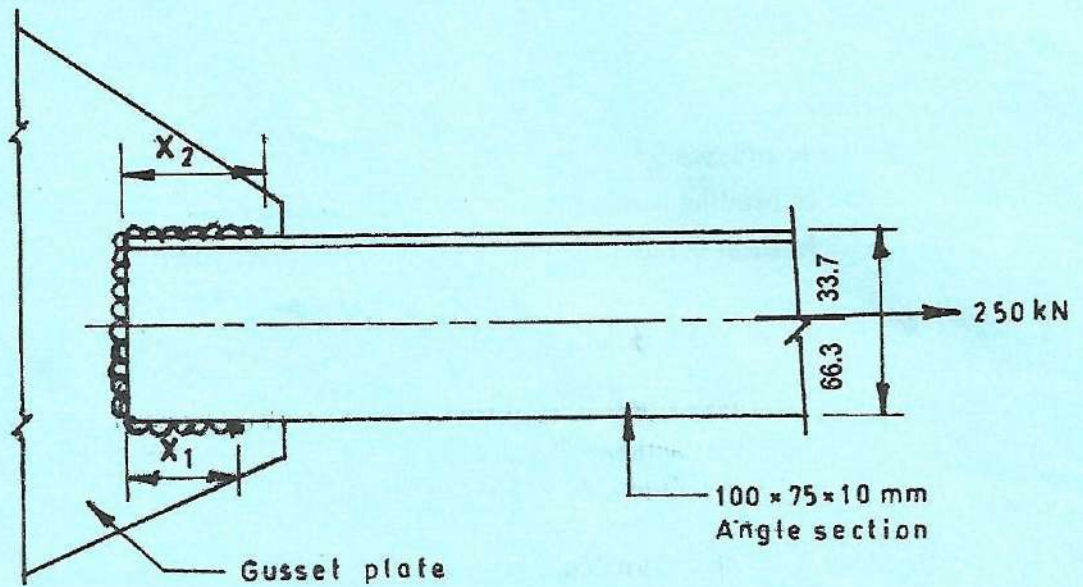


Fig. 4

- (b) Check the adequacy of a $254 \times 254 \times 167$ kg/m U.C. in grade S275 steel when subjected to the loads shown in figure 5 given that the actual height is 4.55 m and is fixed at one end and pinned on the other. (13 marks)

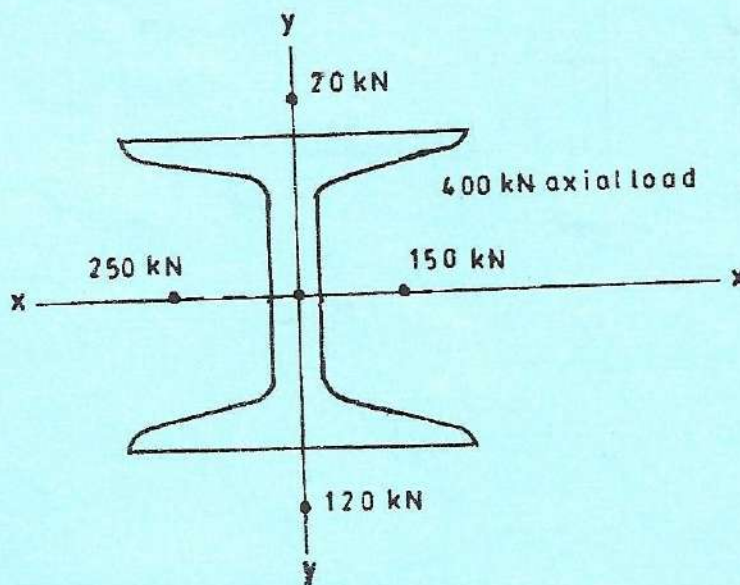


Fig. 5

6. Using the moment distribution method, analyse the beam loaded as shown in figure 6 and hence sketch the shear force and bending moment diagrams showing values at critical points. (20 marks)

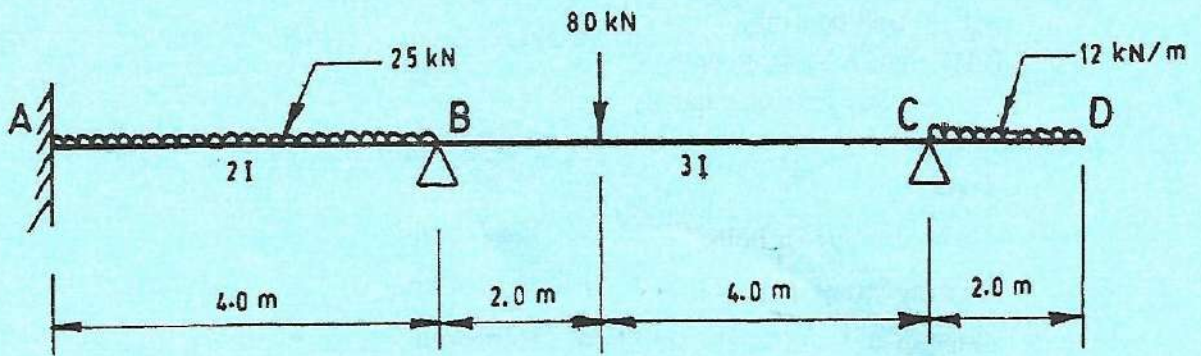


Fig. 6

7. (a) A rectangular column post of size 250 x 150 mm is subjected to an axial load of 185 kN and its actual height is 5.5 m. One end is fixed while the other is pinned. Check the adequacy of the post using SC 6 timber. (12 marks)

Modification factors: $K_3 = 1.25$; $K_8 = 1.1$

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(b) **Figure 7** shows a bolted connection. Using the data given, determine the load capacity in shear for the connection with respect to:

- (i) bolt shear;
- (ii) bolt bearing;
- (iii) plate bearing; and
- (iv) plate tension capacity.

Data

Shear strength of bolts (P_s) = 375 N/mm^2

Bearing strength (P_{bb}) = 1035 N/mm^2

Tension strength (P_t) = 560 N/mm^2

(8 marks)

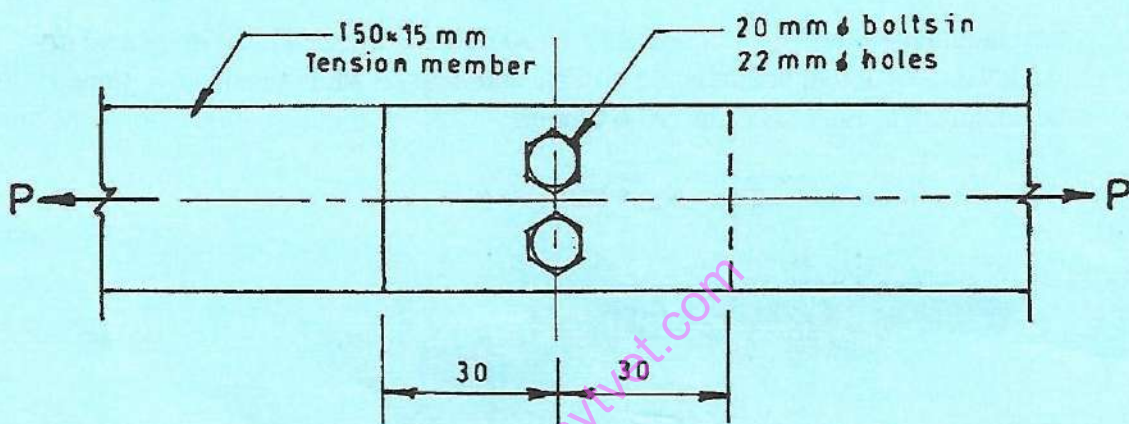


Fig. 7 (a)

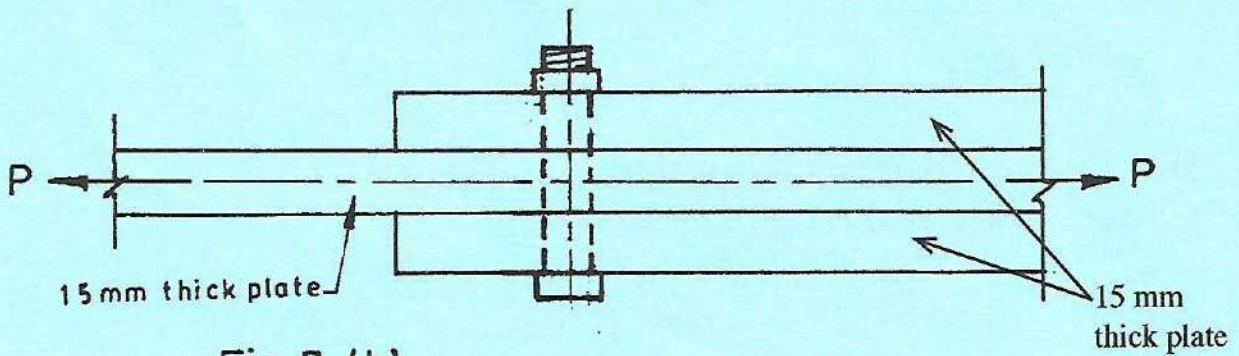


Fig. 7 (b)

8. A simply supported beam has a span of 16 m and is subjected to a U.D.L (dead load) of 5 kN/m and a U.D.L (live load) of 8 kN/m (longer than the span) as shown in figure 8.

Draw the influence line diagram for the shear force and the bending moment at a section 4 m from the left end. Use the diagrams to determine the maximum shear force and maximum bending moment at this section.

(20 marks)

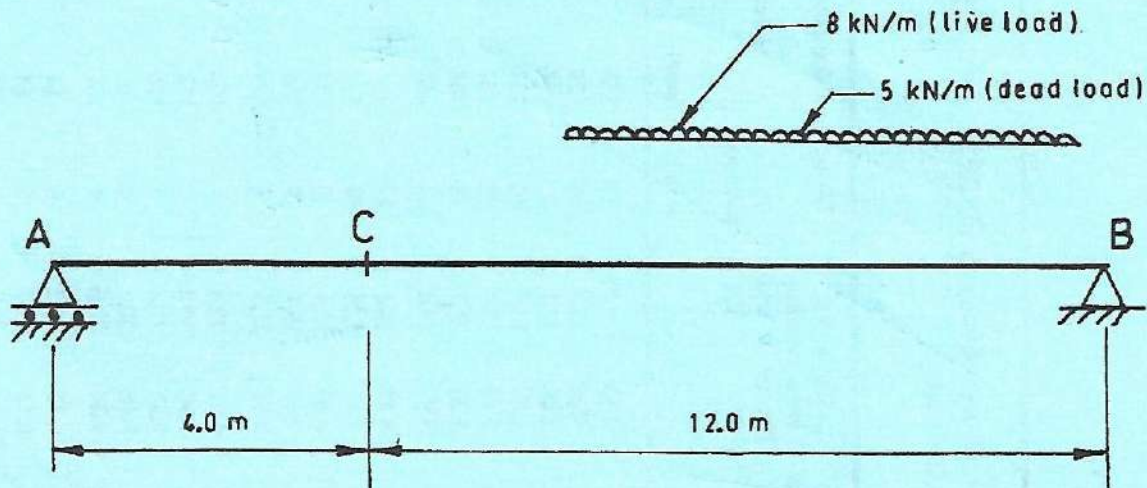


Fig. 8

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Table Universal columns (abstracted from the *Steelwork Design Guide to BS 5950: Part 1*, published by the Steel Construction Institute)

(a) Dimensions

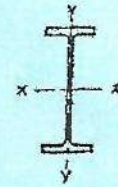
Serial size (mm)	Designation	Mass per metre (kg)	Depth of section D (mm)	Width of section B (mm)	Thickness		Root radius r (mm)	Depth between fillets d (mm)	Ratios for local buckling		Dimensions for detailing				Surface area	
					Web t (mm)	Flange T (mm)			Flange b/T	Web d/t	End clearance C (mm)	Notch N (mm)	Notch n (mm)	Per metre (m ²)	Per tonne (m ²)	
305 x 305	283	283	365.3	321.8	26.9	44.1	15.2	246.6	3.65	9.17	15	138	60	1.94	6.25	
	240	240	352.6	317.9	23.0	37.7	15.2	246.6	4.22	10.7	14	138	34	1.90	7.93	
	198	198	339.9	314.1	19.2	31.4	15.2	246.6	5.00	12.8	12	138	48	1.87	9.45	
	158	158	327.2	310.6	15.7	25.0	15.2	246.6	6.21	15.7	10	138	42	1.84	11.6	
	118	118	320.5	308.7	13.8	21.7	15.2	246.6	7.11	17.9	9	138	38	1.82	13.3	
254 x 254	167	167	314.5	306.8	11.9	18.7	15.2	246.6	8.20	20.7	8	138	34	1.81	15.3	
	132	132	307.8	304.8	9.9	15.4	15.2	246.6	9.90	24.9	7	138	32	1.79	18.4	
	107	107	289.1	264.5	19.2	31.7	12.7	200.3	4.17	10.4	12	134	46	1.58	9.44	
	89	89	276.4	261.0	15.6	25.3	12.7	200.3	5.16	12.8	10	134	40	1.54	11.7	
	73	73	266.7	258.3	13.0	20.5	12.7	200.3	6.30	15.4	9	134	34	1.52	14.2	
203 x 203	89	89	268.4	253.9	10.5	17.3	12.7	200.3	7.40	19.1	7	134	32	1.50	16.9	
	73	73	254.0	254.0	8.6	14.2	12.7	200.3	8.94	23.3	6	134	28	1.49	20.3	
	60	60	222.3	208.8	13.0	20.5	10.2	160.9	5.09	12.4	9	108	32	1.24	14.4	
	52	52	215.9	206.2	10.3	17.3	10.2	160.9	5.96	15.6	7	108	28	1.22	17.2	
	46	46	209.6	203.2	9.3	14.2	10.2	160.9	7.23	17.3	7	108	26	1.20	20.1	
152 x 152	37	37	206.2	203.9	8.9	12.5	10.2	160.9	8.16	20.1	6	108	24	1.19	23.0	
	30	30	203.2	203.2	7.3	11.0	10.2	160.9	9.24	22.0	6	108	22	1.19	25.8	
	23	23	161.8	154.4	8.1	11.5	7.6	123.5	6.71	15.2	6	84	20	0.912	24.6	
			157.5	152.9	6.6	9.4	7.6	123.5	8.13	18.7	5	84	18	0.9	30.0	
			152.4	152.4	6.1	6.8	7.6	123.5	11.2	20.2	5	84	16	0.889	38.7	

Table Universal columns continued (abstracted from the Steelwork Design Guide to BS 5950: Part 1, published by the Steel Construction Institute)

(b) Properties

Designation	Mass per metre	Second moment of area		Radius of gyration		Elastic modulus		Plastic modulus		Swickling parameter μ	Torsional index α	Warping constant (cm^6)	Torsional constant (cm^4)	Area of section A
		Axis $x-x$	Axis $y-y$	Axis $x-x$	Axis $y-y$	Axis $x-x$	Axis $y-y$	Axis $x-x$	Axis $y-y$					
Serial size (mm)	(kg)	(cm^4)	(cm^4)	(cm)	(cm)	(cm^2)	(cm^2)	(cm^3)	(cm^3)					(cm^2)
305 x 305	283	78 800	24 500	14.8	8.25	4 310	1 530	5 100	2 340	0.855	7.65	6.33	2 030	360
	240	64 200	20 200	14.5	8.14	3 640	1 270	4 250	1 950	0.854	8.75	5.01	1 770	306
	198	50 800	16 200	14.2	8.02	2 980	1 030	3 440	1 590	0.854	10.2	3.86	734	252
	158	38 700	12 500	13.9	7.89	2 370	806	2 680	1 230	0.852	12.5	2.86	379	201
	118	27 600	9 010	13.6	7.75	1 760	587	1 950	892	0.851	14.1	2.38	290	175
254 x 254	97	22 200	7 270	13.4	7.68	1 440	477	1 590	723	0.850	19.3	1.55	160	150
	167	29 900	9 800	11.9	6.79	2 070	741	2 420	1 130	0.852	8.49	1.62	625	123
	132	22 600	7 520	11.6	6.67	1 630	576	1 870	879	0.850	10.3	1.18	322	212
	107	17 300	5 900	11.3	6.57	1 310	457	1 490	695	0.848	12.4	0.894	173	169
	89	14 300	4 850	11.2	6.52	1 100	379	1 230	575	0.849	14.4	0.716	104	137
203 x 203	73	11 400	3 870	11.1	6.46	894	305	969	462	0.849	17.3	0.557	57.3	114
	86	9 460	3 120	9.27	5.32	851	299	979	456	0.85	10.2	0.317	138	92.9
	71	7 650	2 540	9.16	5.28	708	246	802	374	0.852	11.9	0.25	81.5	110
	60	6 090	2 040	8.96	5.19	581	199	652	303	0.847	14.1	0.195	46.6	91.1
	52	5 260	1 770	8.90	5.16	510	174	568	264	0.848	15.8	0.166	32.0	75.8
152 x 152	46	4 560	1 540	8.81	5.11	449	151	497	230	0.846	17.7	0.142	22.2	66.4
	37	2 220	709	6.84	3.87	274	91.8	310	140	0.848	13.3	0.04	19.5	58.8
	30	1 740	558	6.75	3.82	221	73.1	247	111	0.848	16.0	0.0306	10.5	47.4
23	1 260	403	6.51	3.68	166	52.9	184	80.9	0.837	20.4	0.0214	4.87	38.2	

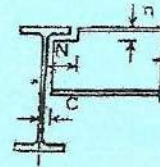
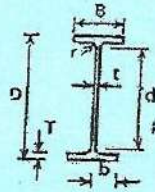
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PROPERTIES

Section Designation	Second Moment of Area		Radius of Gyration		Elastic Modulus		Plastic Modulus		Buckling Parameter u	Torsional Index x	Warping Constant H dm ⁶	Torsional Constant J cm ⁴	Area of Section A cm ²
	Axis X-X cm ⁴	Axis Y-Y cm ⁴	Axis X-X cm	Axis Y-Y cm	Axis X-X cm ³	Axis Y-Y cm ³	Axis X-X cm ³	Axis Y-Y cm ³					
457 x 191 x 98	45700	2350	19.1	4.33	1980	243	2230	379	0.882	25.7	1.18	121	125
457 x 191 x 89	41000	2090	19.0	4.29	1770	218	2010	338	0.879	28.3	1.04	90.7	114
457 x 191 x 82	37100	1870	18.8	4.23	1610	196	1830	304	0.879	30.8	0.922	69.2	104
457 x 191 x 74	33300	1670	18.8	4.20	1460	176	1650	272	0.877	33.8	0.818	51.8	94.6
457 x 191 x 67	29400	1450	18.5	4.12	1300	153	1470	237	0.872	37.9	0.705	37.1	85.5
457 x 152 x 82	36800	1190	18.7	3.37	1570	153	1810	240	0.871	27.4	0.591	99.2	105
457 x 152 x 74	32700	1050	18.6	3.33	1410	136	1630	213	0.873	30.2	0.518	85.9	94.5
457 x 152 x 67	28900	913	18.4	3.27	1260	119	1450	187	0.868	33.6	0.448	47.7	85.6
457 x 152 x 60	25500	795	18.3	3.23	1120	104	1290	163	0.868	37.5	0.387	33.8	76.2
457 x 152 x 52	21400	645	17.9	3.11	950	84.6	1100	133	0.859	43.8	0.311	21.4	66.6
406 x 178 x 74	27300	1550	17.0	4.04	1320	172	1500	267	0.882	27.8	0.608	62.8	94.5
406 x 178 x 67	24300	1370	16.9	3.99	1190	153	1350	237	0.880	30.5	0.533	46.1	85.5
406 x 178 x 60	21800	1200	16.8	3.97	1060	135	1200	209	0.880	33.8	0.466	33.3	76.5
406 x 178 x 54	18700	1020	16.5	3.85	930	115	1060	178	0.871	38.3	0.392	23.1	69.0
406 x 140 x 46	15700	538	16.4	3.03	778	75.7	888	118	0.872	39.0	0.207	19.0	58.6
406 x 140 x 39	12500	410	15.9	2.87	629	57.8	724	90.8	0.856	47.5	0.155	10.7	49.7
356 x 171 x 67	19500	1360	15.1	3.99	1070	157	1210	243	0.896	24.4	0.412	56.7	85.5
356 x 171 x 57	16000	1110	14.9	3.91	896	129	1010	199	0.892	28.8	0.330	33.4	72.6
356 x 171 x 51	14100	968	14.8	3.86	795	113	896	174	0.881	32.1	0.286	23.8	64.9
356 x 171 x 45	12100	811	14.5	3.76	687	94.8	775	147	0.874	36.8	0.237	15.8	57.3
356 x 127 x 39	10200	358	14.3	2.68	576	56.8	659	89.1	0.871	35.2	0.105	15.1	49.8
356 x 127 x 33	8250	280	14.0	2.58	473	44.7	543	70.3	0.863	42.2	0.081	8.79	42.1
305 x 165 x 54	11700	1060	13.0	3.93	754	127	846	196	0.889	23.6	0.234	34.8	63.8
305 x 165 x 46	9900	896	13.0	3.90	646	106	720	166	0.891	27.1	0.195	22.2	58.7
305 x 165 x 40	8500	764	12.8	3.86	560	92.8	623	142	0.889	31.0	0.164	14.7	51.3
305 x 127 x 48	9580	461	12.5	2.74	616	73.6	711	116	0.874	23.3	0.102	31.8	61.2
305 x 127 x 42	8200	389	12.4	2.70	534	62.6	614	98.4	0.872	26.6	0.0848	21.1	53.4
305 x 127 x 37	7170	336	12.3	2.67	471	54.5	539	85.4	0.871	29.7	0.0725	14.8	47.2
305 x 102 x 33	6500	194	12.5	2.15	416	37.9	461	60.0	0.867	31.6	0.0442	12.2	41.8
305 x 102 x 28	5370	155	12.2	2.08	348	30.5	403	48.5	0.859	37.4	0.0349	7.40	35.9
305 x 102 x 25	4460	123	11.9	1.97	292	24.2	342	38.8	0.846	43.4	0.0273	4.77	31.6
254 x 146 x 43	8540	677	10.9	3.52	504	92.0	566	141	0.890	21.2	0.103	23.9	54.8
254 x 146 x 37	5640	571	10.8	3.48	433	78.0	483	119	0.889	24.4	0.0857	15.3	47.2
254 x 146 x 31	4410	448	10.5	3.36	351	61.3	393	94.1	0.879	29.6	0.0660	8.55	39.7
254 x 102 x 29	4010	179	10.5	2.22	308	34.9	353	54.8	0.874	27.5	0.0280	9.57	36.1
254 x 102 x 25	3420	149	10.3	2.15	266	29.2	306	46.0	0.867	31.4	0.0230	6.42	32.0
254 x 102 x 22	2840	119	10.1	2.06	224	23.5	259	37.3	0.856	36.3	0.0182	4.15	28.0
203 x 133 x 30	2900	385	8.71	3.17	280	57.5	314	88.2	0.881	21.5	0.0374	10.3	36.2
203 x 133 x 25	2340	308	8.58	3.10	230	46.2	258	70.9	0.877	25.6	0.0294	5.96	32.0
203 x 102 x 23	2110	164	8.46	2.36	207	32.2	234	49.8	0.888	22.5	0.0154	7.02	29.4
178 x 102 x 19	1360	137	7.48	2.37	153	27.0	171	41.6	0.886	22.5	0.00987	4.41	24.3
152 x 89 x 16	834	89.8	6.41	2.10	109	20.2	123	31.2	0.889	19.6	0.00470	3.56	20.3
127 x 76 x 13	473	55.7	5.35	1.84	74.6	14.7	84.2	22.6	0.896	16.3	0.00199	2.85	16.5

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DIMENSIONS

Section Designation	Mass per Metre kg/m	Depth of Section D mm	Width of Section B mm	Thickness		Root Radius r mm	Depth between Fillets d mm	Ratios for Local Buckling		Dimensions for Detailing			Surface Area	
				Web t mm	Flange T mm			Flange b/T	Web d/t	End Clearance C mm	Notch		Per Metre m ²	Per Tonne m ²
											N mm	n mm		
457 x 191 x 98	98.3	467.2	192.0	11.4	19.6	10.2	407.6	4.92	35.8	8	102	30	1.67	16.9
457 x 191 x 89	89.3	463.4	191.9	10.5	17.7	10.2	407.6	5.42	38.8	7	102	28	1.66	18.5
457 x 191 x 82	82.0	460.0	191.3	9.9	16.0	10.2	407.6	5.98	41.2	7	102	28	1.65	20.1
457 x 191 x 74	74.3	457.0	190.4	9.0	14.5	10.2	407.6	6.57	45.3	7	102	26	1.64	22.1
457 x 191 x 67	67.1	453.4	189.9	8.5	12.7	10.2	407.6	7.48	48.0	6	102	24	1.63	24.3
457 x 152 x 82	82.1	465.8	155.3	10.5	18.9	10.2	407.6	4.11	38.8	7	84	30	1.51	18.4
457 x 152 x 74	74.2	462.0	154.4	9.6	17.0	10.2	407.6	4.54	42.5	7	84	28	1.50	20.3
457 x 152 x 67	67.2	458.0	153.8	9.0	15.0	10.2	407.6	5.13	45.3	7	84	26	1.50	22.3
457 x 152 x 60	59.8	454.6	152.9	8.1	13.3	10.2	407.6	5.75	50.3	6	84	24	1.49	24.9
457 x 152 x 52	52.3	449.8	152.4	7.6	10.9	10.2	407.6	6.99	53.6	6	84	22	1.48	28.2
406 x 178 x 74	74.2	412.8	179.5	9.5	16.0	10.2	360.4	5.61	37.9	7	96	28	1.51	20.3
406 x 178 x 67	67.1	409.4	178.8	8.8	14.3	10.2	360.4	6.25	41.0	6	96	26	1.50	22.3
406 x 178 x 60	60.1	406.4	177.9	7.9	12.8	10.2	360.4	6.95	45.6	6	96	24	1.49	24.8
406 x 178 x 54	54.1	402.6	177.7	7.7	10.9	10.2	360.4	8.15	46.8	6	96	22	1.48	27.4
406 x 140 x 46	46.0	403.2	142.2	6.8	11.2	10.2	360.4	6.35	53.0	5	78	22	1.34	29.2
406 x 140 x 39	39.0	396.0	141.8	6.4	8.6	10.2	360.4	8.24	56.3	5	78	20	1.33	34.2
356 x 171 x 67	67.1	363.4	173.2	9.1	15.7	10.2	311.6	5.52	34.2	7	94	26	1.36	20.6
356 x 171 x 57	57.0	358.0	172.2	8.1	13.0	10.2	311.6	6.62	38.5	6	94	24	1.37	24.1
356 x 171 x 51	51.0	355.0	171.5	7.4	11.5	10.2	311.6	7.46	42.1	6	94	22	1.36	26.7
356 x 171 x 45	45.0	351.4	171.1	7.0	9.7	10.2	311.6	8.82	44.5	6	94	20	1.36	30.1
356 x 127 x 39	39.1	353.4	128.0	6.6	10.7	10.2	311.6	5.89	47.2	5	70	22	1.18	30.2
356 x 127 x 33	33.1	349.0	125.4	6.0	8.5	10.2	311.6	7.38	51.9	5	70	20	1.17	35.4
305 x 165 x 54	54.0	310.4	166.9	7.9	13.7	8.9	265.2	6.09	33.6	6	90	24	1.26	23.0
305 x 165 x 48	48.1	306.6	165.7	6.7	11.8	8.9	265.2	7.02	39.6	5	90	22	1.25	27.1
305 x 165 x 40	40.3	303.4	165.0	6.0	10.2	8.9	265.2	8.09	44.2	5	90	20	1.24	30.8
305 x 127 x 48	48.1	311.0	125.3	9.0	14.0	8.9	265.2	4.47	29.5	7	70	24	1.09	22.7
305 x 127 x 42	41.9	307.2	124.3	8.0	12.1	8.9	265.2	5.14	33.1	6	70	22	1.08	25.8
305 x 127 x 37	37.0	304.4	123.4	7.1	10.7	8.9	265.2	5.77	37.4	6	70	20	1.07	29.0
305 x 102 x 33	32.8	312.7	102.4	6.6	10.8	7.6	275.9	4.74	41.8	5	58	20	1.01	30.8
305 x 102 x 28	28.2	308.7	101.8	6.0	8.8	7.6	275.9	5.78	46.0	5	58	18	1.00	35.4
305 x 102 x 25	24.8	305.1	101.6	5.8	7.0	7.6	275.9	7.26	47.8	5	58	16	0.992	40.0
254 x 146 x 43	43.0	259.6	147.3	7.2	12.7	7.6	219.0	5.80	30.4	6	82	22	1.08	25.1
254 x 146 x 37	37.0	256.0	146.4	6.3	10.9	7.6	219.0	6.72	34.8	5	82	20	1.07	29.0
254 x 146 x 31	31.1	251.4	146.1	6.0	8.6	7.6	219.0	8.49	36.5	5	82	18	1.06	34.2
254 x 102 x 28	28.3	260.4	102.2	6.3	10.0	7.6	225.2	5.11	35.7	5	58	18	0.904	31.9
254 x 102 x 25	25.2	257.2	101.9	6.0	8.4	7.6	225.2	6.07	37.5	5	58	16	0.897	35.8
254 x 102 x 22	22.0	254.0	101.6	5.7	6.8	7.6	225.2	7.47	39.5	5	58	16	0.890	40.5
203 x 133 x 30	30.0	206.9	133.9	6.4	9.6	7.6	172.4	6.97	26.9	5	74	18	0.923	30.8
203 x 133 x 25	25.1	203.2	133.2	5.7	7.8	7.6	172.4	8.54	30.2	5	74	16	0.915	36.4
203 x 102 x 23	23.1	203.2	101.8	5.4	9.3	7.6	169.4	5.47	31.4	5	60	18	0.790	34.2
178 x 102 x 19	19.0	177.8	101.2	4.8	7.9	7.6	146.8	6.41	30.6	4	60	16	0.738	38.8
152 x 89 x 16	16.0	152.4	88.7	4.5	7.7	7.6	121.8	5.76	27.1	4	54	16	0.638	39.8
127 x 76 x 13	13.0	127.0	75.0	4.0	7.6	7.6	96.6	5.00	24.1	4	48	16	0.537	41.3

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