To Scan

2707/302
STRUCTURES III
Oct./Nov. 2018
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN CIVIL ENGINEERING

MODULE III

STRUCTURES III

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:

Answer booklet;

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 as indicated.

Relevant design tables are attached.

Candidates should answer the questions in English.

This paper consists of 9 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 simply supported beam is loaded with factored loads as shown in **Figure 1**. Assuming that the beam is fully laterally restrained, select a suitable universal beam section in grade S 275 (grade 43) steel to satisfy bending, shear and deflection.
Given: Permissible deflection = spam/200
$E = 205\ kN/mm^2$. (20 marks)

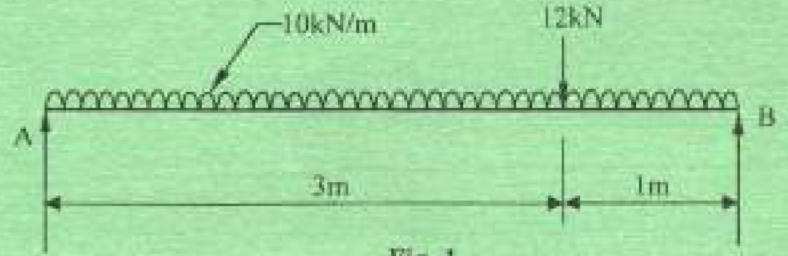


Fig. 1

2. A timber truss with pin-jointed members, carries loads as shown in **Figure 2**. Using a rectangular timber section of strength class C 16, design member AF and check for slenderness and buckling.

Take the permissible stress as $2.56\ N/mm^2$. (20 marks)

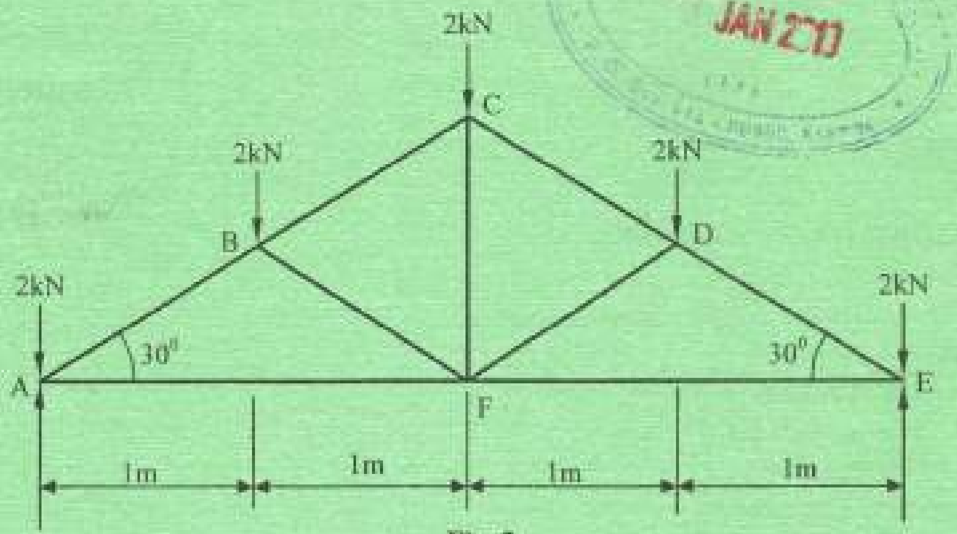


Fig. 2

3. Using the three moments theorem, analyze the beam shown in **Figure 3** and sketch the bending moment diagram, indicating the values at all critical points. (20 marks)

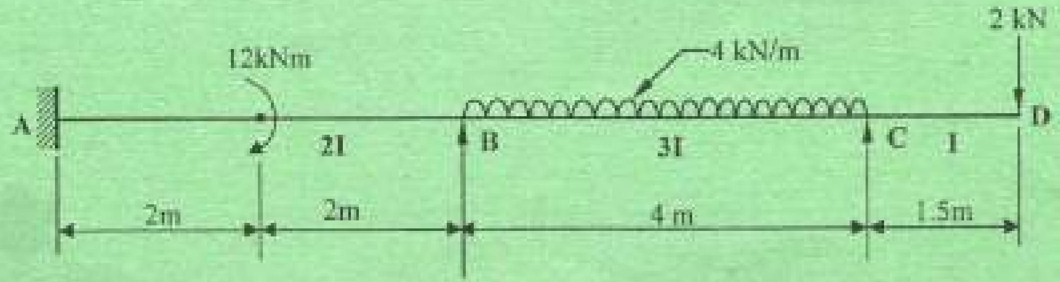


Fig. 3

4. Analyze the figure shown in **Figure 4** using the moment distribution method and hence sketch the bending moment diagram, indicating the values at all critical points. (20 marks)

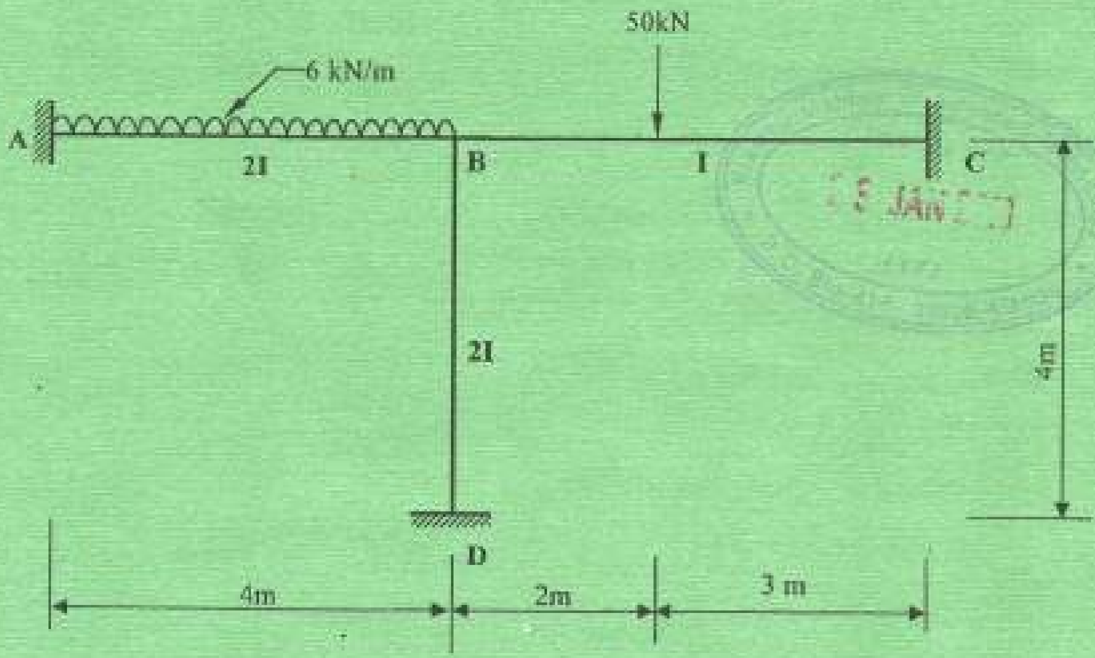


Fig. 4

5. (a) A timber strut of cross section 100 x 50 mm has an effective length of 1.5 m. Calculate the:

(i) least radius of gyration;
(ii) slenderness ratio. (6 marks)

(b) A 3 m long strut with both ends hinged, has a cross section as shown in **Figure 5**. Using Euler's formula, calculate the critical load that the strut can carry.

$E = 200\ kN/mm^2$ (14 marks)

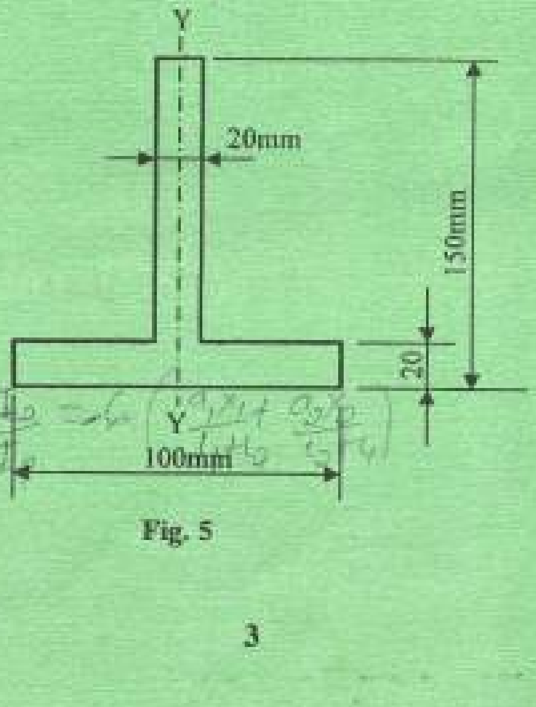


Fig. 5

6. A uniformly distributed load of 5 kN/m and length 10 m rolls across a simply supported girder of span 8 m. Sketch diagrams of the following load components, plotting the values at 2 m intervals:

   (a) maximum negative shear force;
   (b) maximum positive shear force;
   (c) maximum bending moment. (20 marks)

7. A hollow steel rectangular column of 10 mm uniform thickness carries a vertical load P of 50 kN at eccentricities of 50 mm and 30 mm about the x - x and y -y axes respectively as shown in **Figure 6**. Calculate the stresses at the following points:

   (a) external corners B and D;
   (b) internal corners 1 and 3. (20 marks)

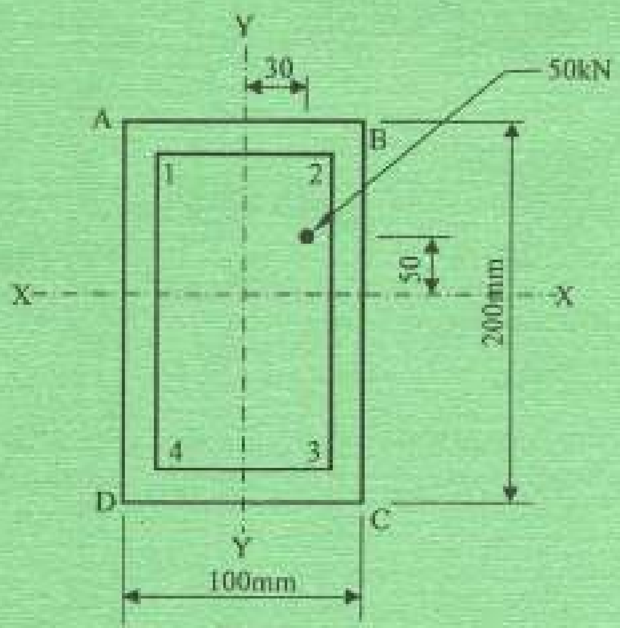


Fig. 6

8. A steel column of overall length 4 m carries unfactored imposed loads as shown in **Figure 7**. It is fixed in position and direction at both ends. Select a suitable universal column section in grade S 275 (grade 43) steel and check its adequacy. (20 marks)

Take factored load as 1.6 and assume effective length of the column as 0.7 actual length.

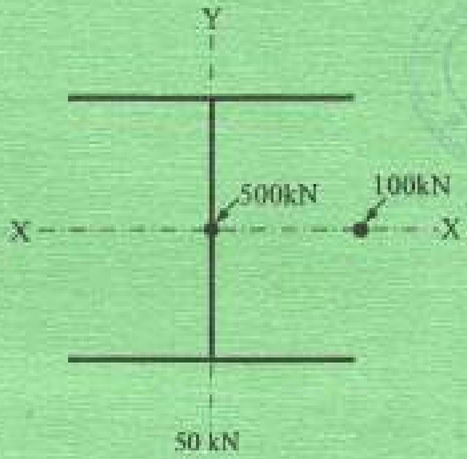
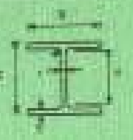
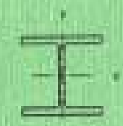


Fig. 7

UNIVERSAL COLUMNS

BS 5950-1: 2000
BS 4-1: 1993

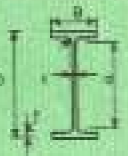




Section Designation	Mass per Metre	Depth of Section D	Width of Section B	Thickness Web t	Thickness Flange T	Root Radius r	Depth between Fillets d	Ratios for Local Buckling Flange b/T	Ratios for Local Buckling Web d/t	Second Moment of Area Axis x-x	Second Moment of Area Axis y-y	Radius of Gyration Axis x-x	Radius of Gyration Axis y-y	Elastic Modulus Axis x-x	Elastic Modulus Axis y-y	Plastic Modulus Axis x-x	Plastic Modulus Axis y-y	Buckling Parameter u	Torsional Index x	Warping Constant H	Area of Section A
	kg/m	mm	mm	mm	mm	mm	mm			cm⁴	cm⁴	cm	cm	cm³	cm³	cm³	cm³			dm⁶	cm²
356x406x634	633.9	474.6	424	47.6	77	15.2	290.2	2.75	6.1	275000	98100	18.4	11	11600	4630	14200	7110	0.843	5.46	38.8	808
356x406x551	551	455.6	418.5	42.1	67.5	15.2	290.2	3.1	6.89	227000	82700	18	10.9	9960	3950	12100	6060	0.841	6.05	31.1	702
356x406x467	467	436.6	412.2	35.8	58	15.2	290.2	3.56	8.11	183000	67800	17.5	10.7	8380	3290	10000	5030	0.839	6.86	24.3	595
356x406x393	393	419	407	30.6	49.2	15.2	290.2	4.14	9.48	147000	55400	17.1	10.5	7000	2720	8220	4150	0.837	7.86	18.9	501
356x406x340	339.9	406.4	403	26.6	42.9	15.2	290.2	4.7	10.9	123000	46800	16.8	10.4	6030	2330	7000	3540	0.836	8.85	15.5	433
356x406x287	287.1	393.6	399	22.6	36.5	15.2	290.2	5.47	12.8	99900	38700	16.5	10.3	5070	1940	5810	2950	0.835	10.2	12.3	366
356x406x235	235.1	381	394.8	18.4	30.2	15.2	290.2	6.54	15.8	79100	31000	16.3	10.2	4150	1570	4690	2380	0.834	12.1	9.54	299
356x368x202	201.9	374.6	374.7	16.5	27	15.2	290.2	6.94	17.6	66300	23700	16.1	9.6	3540	1260	3970	1920	0.844	13.4	7.16	257
356x368x177	177	368.2	372.6	14.4	23.8	15.2	290.2	7.83	20.2	57100	20500	15.9	9.54	3100	1100	3460	1670	0.844	15	6.09	226
356x368x153	152.9	362	370.5	12.3	20.7	15.2	290.2	8.95	23.6	48600	17600	15.8	9.49	2680	946	2960	1430	0.844	17	5.11	195
356x368x129	129	355.6	368.6	10.4	17.5	15.2	290.2	10.5	27.9	40200	14600	15.6	9.43	2260	793	2480	1200	0.844	19.9	4.18	164
305x305x283	282.9	365.3	322.2	26.8	44.1	15.2	246.7	3.65	9.21	78900	24600	14.8	8.27	4320	1530	5110	2340	0.855	7.65	6.35	360
305x305x240	240	352.5	318.4	23	37.7	15.2	246.7	4.22	10.7	64200	20300	14.5	8.15	3640	1280	4250	1950	0.854	8.74	5.03	306
305x305x198	198.1	339.9	314.5	19.1	31.4	15.2	246.7	5.01	12.9	50900	16300	14.2	8.04	3000	1040	3440	1580	0.854	10.2	3.88	252
305x305x158	158.1	327.1	311.2	15.8	25	15.2	246.7	6.22	15.8	38700	12600	13.9	7.9	2370	808	2680	1230	0.851	12.5	2.87	201
305x305x137	136.9	320.5	309.2	13.8	21.7	15.2	246.7	7.12	17.9	32800	10700	13.7	7.83	2050	692	2300	1050	0.851	14.2	2.39	174
305x305x118	117.9	314.5	307.4	12	18.7	15.2	246.7	8.22	20.6	27700	9060	13.6	7.77	1760	589	1960	885	0.85	16.2	1.98	150
305x305x97	96.9	307.9	305.3	9.9	15.4	15.2	246.7	9.91	24.9	22200	7310	13.4	7.69	1450	479	1590	726	0.85	19.3	1.56	123
254x254x167	167.1	289.1	265.2	19.2	31.7	12.7	200.3	4.18	10.4	30000	9870	11.9	6.81	2080	744	2420	1140	0.851	8.49	1.63	213
254x254x132	132	276.3	261.3	15.3	25.3	12.7	200.3	5.16	13.1	22500	7530	11.6	6.69	1630	576	1870	878	0.85	10.3	1.19	168
254x254x107	107.1	266.7	258.8	12.8	20.5	12.7	200.3	6.31	15.6	17500	5930	11.3	6.59	1310	458	1480	697	0.848	12.4	0.898	136
254x254x89	88.9	260.3	256.3	10.3	17.3	12.7	200.3	7.41	19.4	14300	4860	11.2	6.55	1100	379	1220	575	0.85	14.5	0.717	113
254x254x73	73.1	254.1	254.6	8.6	14.2	12.7	200.3	8.96	23.3	11400	3910	11.1	6.46	898	307	992	465	0.849	17.3	0.562	93.1
203x203x86	86.1	222.2	209.1	12.7	20.5	10.2	160.8	5.1	12.7	9450	3130	9.28	5.34	850	299	977	456	0.85	10.2	0.318	110
203x203x71	71	215.8	206.4	10	17.3	10.2	160.8	5.97	16.1	7620	2540	9.18	5.3	706	246	799	374	0.853	11.9	0.25	90.4
203x203x60	60	209.6	205.8	9.4	14.2	10.2	160.8	7.25	17.1	6120	2060	8.96	5.2	584	201	656	305	0.846	14.1	0.197	75.4
203x203x52	52	206.2	204.3	7.9	12.5	10.2	160.8	8.17	20.4	5260	1780	8.91	5.18	510	174	567	264	0.848	15.8	0.167	66.3
203x203x46	46.1	203.2	203.6	7.2	11	10.2	160.8	9.25	22.3	4570	1550	8.82	5.13	450	152	497	231	0.847	17.7	0.143	58.7
152x152x37	37	161.8	154.4	8	11.5	7.6	123.6	6.71	15.5	2210	706	6.85	3.87	273	91.5	309	140	0.848	13.3	0.04	47.1
152x152x30	30	157.6	152.9	6.5	9.4	7.6	123.6	8.13	19	1750	560	6.76	3.83	222	73.3	248	112	0.849	16	0.031	38.3
152x152x23	23	152.4	152.2	5.8	6.8	7.6	123.6	11.2	21.3	1250	400	6.54	3.7	164	52.6	182	80.1	0.84	20.7	0.021	29.2

BS 5950-1: 2000

BS 4-1: 1993



UNIVERSAL BEAMS

Section Designation	Mass per Metre kg/m	Depth of Section D mm	Width of Section B mm	Thickness Web t mm	Thickness Flange T mm	Root Radius r mm	Depth between Fillets d mm	Ratios for Local Buckling Flange b/T	Ratios for Local Buckling Web d/t	Second Moment of Area Axis x-x cm⁴	Second Moment of Area Axis y-y cm⁴	Radius of Gyration Axis x-x cm	Radius of Gyration Axis y-y cm	Elastic Modulus Axis x-x cm³	Elastic Modulus Axis y-y cm³	Plastic Modulus Axis x-x cm³	Plastic Modulus Axis y-y cm³	Buckling Parameter u	Torsional Index x	Warping Constant H dm⁶	Torsional Constant J cm⁴	Area of Section A cm²
	DIMENSIONS									PROPERTIES												
457 x 191 x 98	98.3	467.2	192.8	11.4	19.6	10.2	407.6	4.92	35.8	45700	2350	19.1	4.33	1960	243	2230	379	0.882	25.7	1.18	121	125
457 x 191 x 89	89.3	463.4	191.9	10.5	17.7	10.2	407.6	5.42	38.8	41000	2090	19.0	4.29	1770	218	2010	338	0.879	28.3	1.04	90.7	114
457 x 191 x 82	82.0	460.0	191.3	9.9	16.0	10.2	407.6	5.98	41.3	37100	1870	18.8	4.23	1610	196	1830	304	0.879	30.8	0.922	69.2	104
457 x 191 x 74	74.3	457.0	190.4	9.0	14.5	10.2	407.6	6.57	45.3	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	67.1	453.4	189.9	8.5	12.7	10.2	407.6	7.48	48.0	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	82.1	465.8	155.3	10.5	18.9	10.2	407.6	4.11	38.8	36600	1180	18.7	3.37	1570	152	1810	240	0.871	27.4	0.591	89.2	105
457 x 152 x 74	74.2	462.0	154.4	9.6	17.0	10.2	407.6	4.54	42.5	32700	1050	18.6	3.33	1410	136	1630	213	0.873	30.2	0.518	65.6	94.6
457 x 152 x 67	67.2	458.0	153.8	9.0	15.0	10.2	407.6	5.13	45.3	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	59.8	454.6	152.9	8.1	13.3	10.2	407.6	5.75	50.3	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	52.3	449.8	152.4	7.6	10.9	10.2	407.6	6.99	53.6	21400	645	17.9	3.11	950	84.6	1100	133	0.859	43.9	0.311	21.4	66.6
406 x 178 x 74	74.2	412.8	179.5	9.5	16.0	10.2	360.4	5.61	37.9	27300	1550	17.0	4.04	1320	172	1500	267	0.882	27.6	0.608	62.8	94.5
406 x 178 x 67	67.1	409.4	178.8	8.8	14.3	10.2	360.4	6.25	41.0	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	60.1	406.4	177.9	7.9	12.8	10.2	360.4	6.95	45.6	21600	1200	16.8	3.97	1060	135	1200	209	0.880	33.8	0.466	33.3	76.5
406 x 178 x 54	54.1	402.6	177.7	7.7	10.9	10.2	360.4	8.15	46.8	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	46.0	403.2	142.2	6.8	11.2	10.2	360.4	6.35	53.0	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	39.0	398.0	141.8	6.4	8.6	10.2	360.4	8.24	56.3	12500	410	15.9	2.87	629	57.8	724	90.8	0.858	47.5	0.155	10.7	49.7
356 x 171 x 67	67.1	363.4	173.2	9.1	15.7	10.2	311.6	5.52	34.2	19500	1360	15.1	3.99	1070	157	1210	243	0.886	24.4	0.412	55.7	85.5
356 x 171 x 57	57.0	358.0	172.2	8.1	13.0	10.2	311.6	6.62	38.5	16000	1110	14.9	3.91	896	129	1010	199	0.882	28.8	0.330	33.4	72.6
356 x 171 x 51	51.0	355.0	171.5	7.4	11.5	10.2	311.6	7.46	42.1	14100	968	14.8	3.86	796	113	896	174	0.881	32.1	0.286	23.8	64.9
356 x 171 x 45	45.0	351.4	171.1	7.0	9.7	10.2	311.6	8.82	44.5	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	39.1	353.4	126.0	6.6	10.7	10.2	311.6	5.89	47.2	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	33.1	349.0	125.4	6.0	8.5	10.2	311.6	7.38	51.9	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	54.0	310.4	166.9	7.9	13.7	8.9	265.2	6.09	33.6	11700	1060	13.0	3.93	754	127	846	196	0.889	23.6	0.234	34.8	68.8
305 x 165 x 46	46.1	306.6	165.7	6.7	11.8	8.9	265.2	7.02	39.6	9900	896	13.0	3.90	646	108	720	166	0.891	27.1	0.195	22.2	58.7
305 x 165 x 40	40.3	303.4	165.0	6.0	10.2	8.9	265.2	8.09	44.2	8500	764	12.9	3.86	560	92.6	623	142	0.889	31.0	0.164	14.7	51.3
305 x 127 x 48	48.1	311.0	125.3	9.0	14.0	8.9	265.2	4.47	29.5	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	41.9	307.2	124.3	8.0	12.1	8.9	265.2	5.14	33.1	8200	389	12.4	2.70	534	62.6	614	98.4	0.872	26.5	0.0846	21.1	53.4
305 x 127 x 37	37.0	304.4	123.4	7.1	10.7	8.9	265.2	5.77	37.4	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	32.8	312.7	102.4	6.6	10.8	7.6	275.9	4.74	41.8	6500	194	12.5	2.15	416	37.9	481	60.0	0.867	31.6	0.0442	12.2	41.8
305 x 102 x 28	28.2	308.7	101.8	6.0	8.8	7.6	275.9	5.78	46.0	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	24.8	305.1	101.6	5.8	7.0	7.6	275.9	7.26	47.6	4460	123	11.8	1.97	292	24.2	342	38.8	0.846	43.4	0.0273	4.77	31.6
254 x 146 x 43	43.0	259.6	147.3	7.2	12.7	7.6	219.0	5.80	30.4	6540	677	10.9	3.52	504	92.0	566	141	0.891	21.2	0.103	23.9	54.8
254 x 146 x 37	37.0	256.0	146.4	6.3	10.9	7.6	219.0	6.72	34.8	5540	571	10.8	3.48	433	78.0	483	119	0.890	24.4	0.0857	15.3	47.2
254 x 146 x 31	31.1	251.4	146.1	6.0	8.6	7.6	219.0	8.49	36.5	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 28	28.3	260.4	102.2	6.3	10.0	7.6	225.2	5.11	35.7	4010	178	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	25.2	257.2	101.9	6.0	8.4	7.6	225.2	6.07	37.5	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	22.0	254.0	101.6	5.7	6.8	7.6	225.2	7.47	39.5	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	30.0	206.8	133.9	6.4	9.6	7.6	172.4	6.97	26.9	2900	385	8.71	3.17	280	57.5	314	88.2	0.881	21.5	0.0374	10.3	38.2
203 x 133 x 25	25.1	203.2	133.2	5.7	7.8	7.6	172.4	8.54	30.2	2340	308	8.56	3.10	230	46.2	258	70.9	0.877	25.6	0.0294	5.96	32.0
203 x 102 x 23	23.1	203.2	101.8	5.4	9.3	7.6	169.4	5.47	31.4	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	19.0	177.8	101.2	4.8	7.9	7.6	146.8	6.41	30.6	1360	137	7.48	2.37	153	27.0	171	41.6	0.886	22.6	0.00987	4.41	24.3
152 x 89 x 16	16.0	152.4	88.7	4.5	7.7	7.6	121.8	5.76	27.1	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	13.0	127.0	76.0	4.0	7.6	7.6	96.6	5.00	24.1	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

Table 9: Design strengths, py, for steel

Design Grade	Thickness (mm), less than or equal to	Sections, plates and hollow sections, py (N/mm2)
43	16	275
	40	265
	63	255
	100	245
50	16	355
	40	345
	63	340
	100	325
55	16	450
	25	430
	40	425
	63	400

Table 11 — Limiting width-to-thickness ratios for sections other than CHS and RHS

Compression element			Ratio[a]	Limiting value[b]		
				Class 1 plastic	Class 2 compact	Class 3 semi-compact
Outstand element of compression flange		Rolled section	b/T	9ε	10ε	15ε
		Welded section	b/T	8ε	9ε	13ε
Internal element of compression flange		Compression due to bending	b/T	28ε	32ε	40ε
		Axial compression	b/T	Not applicable		
Web of an I-, H- or box section[c]	Neutral axis at mid-depth		d/t	80ε	100ε	120ε
	Generally[d]	If r_1 is negative:	d/t	$\frac{80\varepsilon}{1+r_1}$ but 40ε	$\frac{100\varepsilon}{1+r_1}$	$\frac{120\varepsilon}{1+2r_2}$ but 40ε
		If r_1 is positive:	d/t		$\frac{100\varepsilon}{1+1.5r_1}$ but 40ε	
	Axial compression[d]		d/t	Not applicable		

[a] Dimensions b, D, d, T and t are defined in Figure 5. For a box section b and T are flange dimensions and d and t are web dimensions, where the distinction between webs and flanges depends upon whether the box section is bent about its major axis or its minor axis, see 3.5.1.
[b] The parameter $\varepsilon = (275/p_y)^{0.5}$
[c] For the web of a hybrid section ε should be based on the design strength p_{yf} of the flanges.
[d] The stress ratios r_1 and r_2 are defined in 3.5.5.

Selected Softwood Timber Sizes (BS 5268)

Geometrical properties of sawn softwoods based on timber with a 20% moisture content

Target Sizes	Area	Section Modulus		Section Moment of Area		Radius of Gyration	
		About x-x	About y-y	About x-x	About y-y	y-y	x-x
mm	10^3mm^2	10^3mm^3	10^3mm^3	10^6mm^4	10^6mm^4	mm	mm
25x50	1.25	10.4	5.2	0.26	0.065	14.4	7.2
25x75	1.88	23.5	7.8	0.88	0.098	21.6	7.2
50x75	3.75	46.9	31.3	1.76	0.781	21.7	14.4
50x100	5.00	83.3	41.7	4.17	1.04	28.9	14.4
50x150	7.50	188	62.5	14.1	1.56	43.3	14.4
50x200	10.0	333	83.3	33.3	2.08	57.7	14.4
75x100	7.50	125	93.8	6.25	3.52	28.9	21.7
75x150	11.3	281	141	21.1	5.27	43.3	21.7
75x200	15.0	500	188	50.0	7.03	57.7	21.7
100x100	10.0	167	167	8.33	8.33	28.9	28.9
100x150	15.0	375	250	28.1	12.5	43.3	28.9
100x200	20.0	667	333	66.7	16.7	57.7	28.9
100x250	25.0	1010	417	130	20.8	72.2	28.9
100x300	30.0	1500	500	225	25.0	86.6	28.9
150x150	20.0	563	563	42.2	42.2	43.3	43.3
150x200	25.5	1000	750	100	56.3	57.7	43.3
150x300	30.0	2250	1130	338	84.4	86.6	43.3

Table 19 — Maximum depth to breadth ratios (solid and laminated members)

Degree of lateral support	Maximum depth to breadth ratio
No lateral support	2
Ends held in position	3
Ends held in position and member held in line as by purlins or tie rods at centres not more than 30 times breadth of the member	4
Ends held in position and compression edge held in line, as by direct connection of sheathing, deck or joists	5
Ends held in position and compression edge held in line, as by direct connection of sheathing, deck or joists, together with adequate bridging or blocking spaced at intervals not exceeding six times the depth	6
Ends held in position and both edges held firmly in line	7

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