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**UTHM**

Universiti Tun Hussein Onn Malaysia

**UNIVERSITI TUN HUSSEIN ONN MALAYSIA**

**FINAL EXAMINATION  
SEMESTER I  
SESSION 2019/2020**

COURSE NAME : STRUCTURAL DESIGN  
COURSE CODE : BPD 30802  
PROGRAMME CODE : BPC  
EXAMINATION DATE : DECEMBER 2019/JANUARY 2020  
DURATION : 2 HOURS  
INSTRUCTION : ANSWER ALL QUESTIONS

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THIS QUESTION PAPER CONSISTS OF TEN (10) PAGES

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**Q1** (a) Explain with the aid of sketches, the single reinforced section with rectangular stress block. (9 marks)

(b) **Figure Q1** in **APPENDIX I** shows a rectangular RC beam with the size of 250 X 500 mm (b x d). The beam has to support a design moment of 198 kNm. Given the characteristic strength of concrete,  $f_{ck} = 25 \text{ N/mm}^2$  and the characteristic strength of main reinforcement,  $f_{yk} = 500 \text{ N/mm}^2$ . Use **APPENDIX III** to **APPENDIX V** as references.

Calculate the area of reinforcement required for the beam.

(16 marks)

**Q2** (a) Explain the following topics:

- (i) Local buckling of steel structures.
- (ii) Lateral torsional buckling of steel structures.
- (iii) Stress-strain relations of steel structures.

(9 marks)

(b) A simply supported steel beam is fully restrained along its length as shown in **Figure Q2** in **APPENDIX I**. The beam supports uniformly distributed characteristic dead and imposed loads of 3.5 kN/m each, as well as a characteristic imposed point load of 15 kN at mid span. Use **APPENDIX IV** to **APPENDIX VII** as references. The given data are as follow:

Beam size = 406 x 178 x 60 kg/m UB S275  
Beam length = 8 m  
Modulus of elasticity (E) =  $205 \times 10^6 \text{ kN/m}^2$

(i) Calculate the maximum applied bending moment,  $M_c$ . (4 marks)

(ii) Sketch the shear force and bending moment diagrams. (2 marks)

(iii) Calculate the shear and moment capacity. (10 marks)

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**Q3** Figure Q3 in APPENDIX II shows a simply supported rectangular reinforced concrete slab carries a distributed permanent action of  $1.0 \text{ kN/m}^2$  (excluding selfweight) and a variable action of  $3.0 \text{ kN/m}^2$ . Given the characteristic strength of concrete,  $f_{ck} = 30 \text{ N/mm}^2$ , the characteristic strength of steel,  $f_{yk} = 500 \text{ N/mm}^2$  and unit weight of concrete  $25 \text{ kN/mm}^3$ . The nominal concrete cover is 30 mm, the slab thickness,  $h$  is 175 mm and the steel reinforcing bar is 10 mm with  $f_{ctm}$  value of 2.9. Use APPENDIX III to APPENDIX V as references.

- (a) Calculate with the aid of sketches the shear and bending moment diagrams. (6 marks)
- (b) Discuss differences between one-way spanning slab and two-way spanning slab. (4 marks)
- (c) Calculate the area of reinforcement required for the slab and perform the shear and deflection checks. (15 marks)

**Q4** (a) With aid of sketches, describe the effective length of column. (5 marks)

(b) Figure Q4 in APPENDIX II shows a cross-section of a rectangular braced column of 220 mm x 300 mm. The column is classified as short column and subjected to ultimate load of 1200 kN. Given bending moments of 55 kNm and 30 kNm about major and minor axes respectively. Use the characteristic strength of concrete,  $f_{ck} = 25 \text{ N/mm}^2$ , the characteristic strength of steel,  $f_{yk} = 500 \text{ N/mm}^2$ ,  $C_{nom} = 30 \text{ mm}$ , the effective length = 4.2 m,  $\phi_{link} = 6 \text{ mm}$  and  $\phi_{bar} = 20 \text{ mm}$ . Use APPENDIX III to APPENDIX V as references.

- (i) Calculate the value of  $M_{min}$  and  $M_{Ed}$ . (8 marks)
- (ii) Design the main reinforcement of the column. (12 marks)

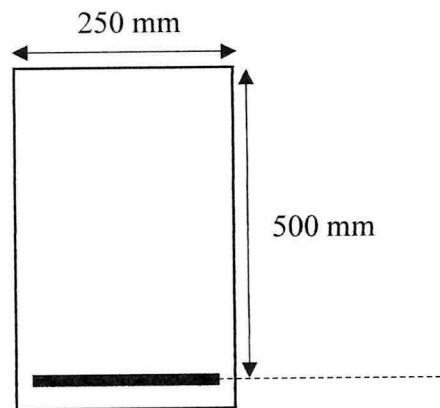
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- END OF QUESTIONS -

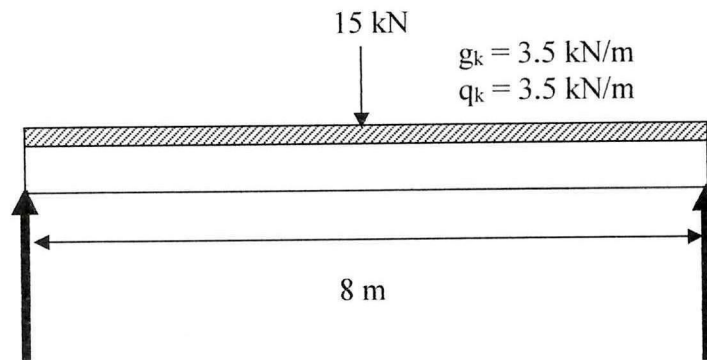
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**FIGURE Q1: Cross-section of a simply supported rectangular RC beam**



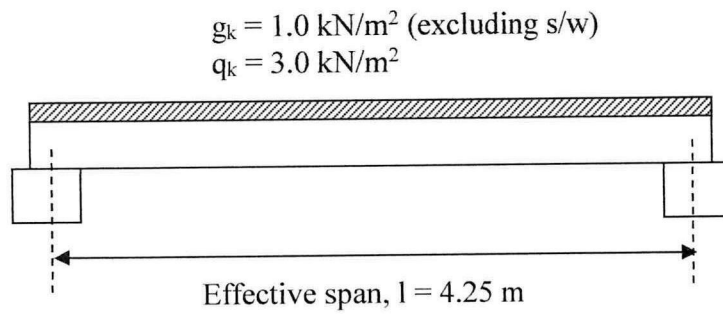
**FIGURE Q2: A simply supported steel beam**

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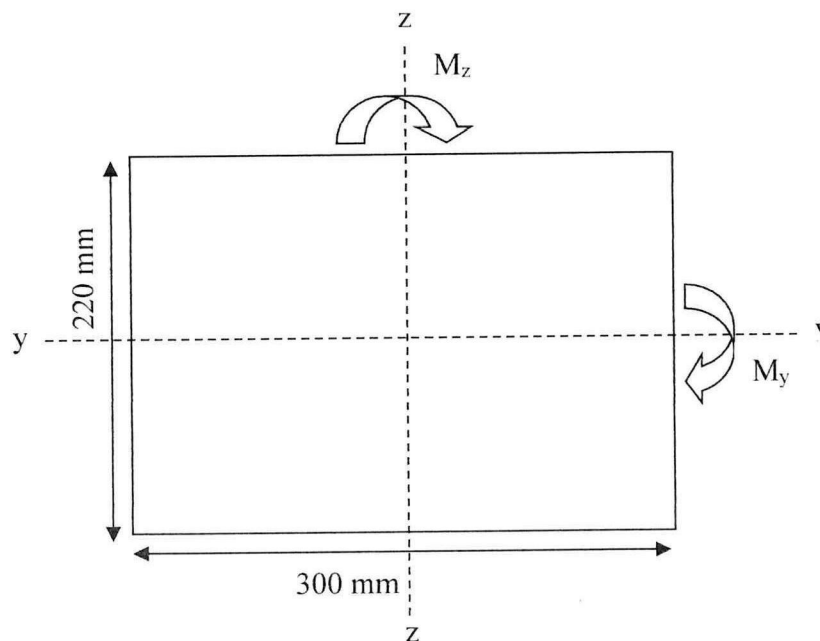
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**FIGURE Q3: A simply supported rectangular RC slab**



**FIGURE Q4: Cross-section of a rectangular braced column**

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**Cross sectional area of reinforcement**

**Table 1: Cross Sectional Area (mm<sup>2</sup>) according to Size and Numbers of Bar**

Bar Size (mm)	Number of bar								Perimeter (mm)
	1	2	3	4	5	6	7	8	
6	28.3	56.6	84.9	113	141	170	198	226	18.9
8	50.3	101	151	201	251	302	352	402	25.1
10	78.6	157	236	314	393	471	550	629	31.4
12	113	226	339	453	566	679	792	905	37.7
16	201	402	603	805	1006	1207	1408	1609	50.3
20	314	629	943	1257	1571	1886	2200	2514	62.9
25	491	982	1473	1964	2455	2946	3438	3929	78.6
32	805	1609	2414	3218	4023	4827	5632	6437	100.6
40	1257	2514	3771	5029	6286	7543	8800	10057	125.7

**Table 2: Cross Sectional Area (mm<sup>2</sup>) for every meter width at distance between bar**

Bar Size (mm)	Distance between Bar (mm)															
	50	75	100	125	150	175	200	250	300	350	400	450	500	550	600	650
6	566	377	283	226	189	162	141	113	94	1006	670	503	402	335	287	251
8	1006	670	503	402	335	287	251	201	168	1571	1048	786	629	524	449	393
10	1571	1048	786	629	524	449	393	314	262	2263	1509	1131	905	754	647	566
12	2263	1509	1131	905	754	647	566	453	377	4023	2682	2011	1609	1341	1149	1006
16	4023	2682	2011	1609	1341	1149	1006	805	670	6286	4190	3143	2514	2095	1796	1571
20	6286	4190	3143	2514	2095	1796	1571	1257	1048	9821	6548	4911	3929	3274	2806	2455
25	9821	6548	4911	3929	3274	2806	2455	1964	1637	16091	10728	8046	6437	5364	4598	4023
32	16091	10728	8046	6437	5364	4598	4023	3218	2682	25143	16762	12571	10057	8381	7184	6286
40	25143	16762	12571	10057	8381	7184	6286	5029	4190							

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Given :

1.  $M_{bal} = 0.167f_{ck}bd^2$
2.  $K = Ml / bd^2f_{ck}$
3.  $z = d\{0.5 + \sqrt{(0.25-k/1.134)}\}$
4.  $A_s = M / 0.87f_{yk}z$
5.  $C_{min} = a - \Phi\bar{b}/2$
6.  $C_{nom} = C_{min} + \Delta C_{dev}$
7.  $V = w_d L / 2$
8.  $M = w_d L^2 / 8$  (UDL)
9.  $D = h - C_{nom} - 0.5\Phi\bar{b}$
10.  $V_{ED} = 0.6F$
11.  $V_{Rd,C} = [0.12k(100\rho_l f_{ck})^{1/3}]bd$
12.  $k = 1 + (200/d)^{1/2}$
13.  $\rho_l = A_{sl} / bd$
14.  $V_{min} = [0.035k^{3/2}f_{ck}^{1/2}]bd$
15.  $\rho = A_{s,req} / bd$
16.  $\rho_o = (f_{ck})^{1/2} \times 10^{-3}$
17.  $l/d = K (11 + 1.5\sqrt{f_{ck}} \rho_o / \rho + 3.2\sqrt{f_{ck}} (\rho_o / \rho - 1)^{3/2})$
18.  $A_{s,pro} / A_{s,req}$
19.  $M_{ed} = M_{max} \{M_{02}, M_{min}\}$
20.  $M_{02} = M + N_{ED} e_i$
21.  $e_i = l_0 / 400$

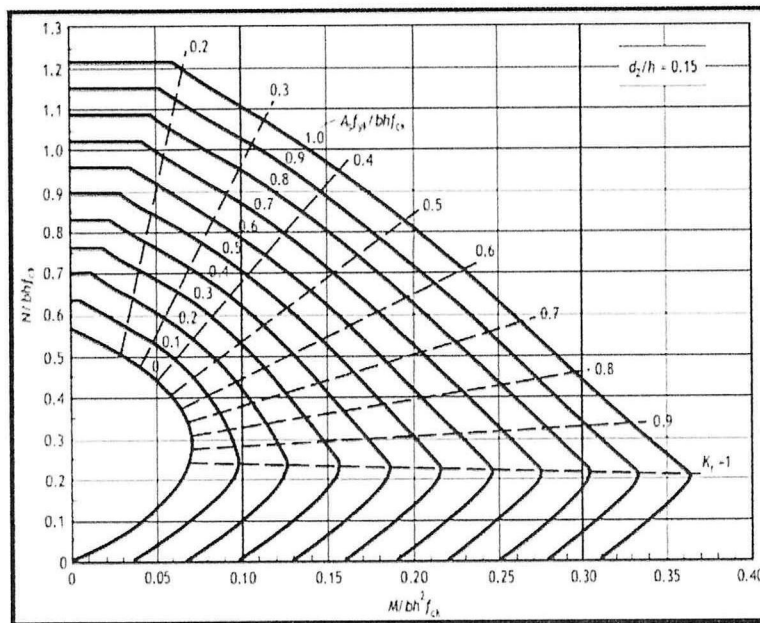
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- 22.  $M_{min} = N_{ED}.e_0$
- 23.  $e_0 = h / 30$
- 24.  $d_2 = c + \phi_{link} + (\phi_{bar} / 2)$
- 25.  $M = w_d L / 4$  (Point load)
- 26.  $N = 1.6 \times$  Point load
- 27.  $S_x = M / p_y$
- 28.  $P_v = 0.6 p_y A$
- 29.  $F_v < 0.6 P_v$
- 30.  $M_c = p_y S$
- 31.  $M_c < 1.2 p_y Z$



Column design chart



FINAL EXAMINATION

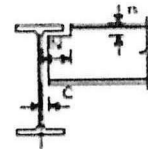
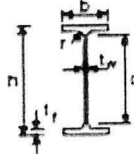
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BS EN 1993-1-1:2005  
 BS 4-1:2005

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Dimensions

Section Designation	Mass per Metre	Depth of Section h	Width of Section b	Thickness		Fillet Radius r	Depth between Fillets d	Ratio for Local Buckling		Dimensions for Detailing			Surface Area	
				t <sub>w</sub>	t <sub>f</sub>			C <sub>f</sub> /t <sub>w</sub>	C <sub>w</sub> /t <sub>w</sub>	End Clearance C	Noch		Per Metre m <sup>2</sup>	Per Tonne m <sup>2</sup>
											M	n		
533x210x138 *	138.3	549.1	213.9	14.7	23.6	12.7	476.5	3.68	32.4	9	110	38	1.90	13.7
533x210x122	122.0	544.5	211.9	12.7	21.3	12.7	476.5	4.08	27.3	8	110	34	1.89	15.5
533x210x109	109.0	530.5	210.8	11.6	18.8	12.7	476.5	4.62	41.1	8	110	32	1.88	17.2
533x210x93	101.0	526.7	210.0	10.8	17.4	12.7	476.5	4.99	44.1	7	110	32	1.87	18.5
533x210x82	92.1	533.1	209.3	10.1	15.8	12.7	476.5	5.57	47.2	7	110	30	1.86	20.2
533x210x82	82.7	528.3	208.8	9.6	13.2	12.7	476.5	6.58	49.6	7	110	28	1.85	22.5
533x165x85 *	84.8	534.9	165.5	10.3	16.5	12.7	476.5	3.96	46.3	7	90	30	1.89	18.9
533x165x75 *	74.7	529.1	165.9	9.7	13.6	12.7	476.5	4.81	49.1	7	90	28	1.88	22.5
533x165x66 *	65.7	524.7	165.1	8.9	11.4	12.7	476.5	5.74	53.5	6	90	26	1.87	25.4
457x191x101 *	101.4	492.0	199.4	10.0	22.0	10.2	407.6	2.52	22.8	11	102	44	1.73	10.7
457x191x133 *	133.3	480.6	196.1	12.3	28.3	10.2	407.6	3.06	26.6	10	102	38	1.70	12.8
457x191x106 *	105.8	468.2	194.0	12.6	20.6	10.2	407.6	3.91	32.3	8	102	32	1.67	15.8
457x191x98	98.3	467.2	192.8	11.4	19.6	10.2	407.6	4.11	35.8	8	102	30	1.67	17.0
457x191x89	89.3	463.4	191.9	10.5	17.7	10.2	407.6	4.50	38.8	7	102	28	1.66	18.6
457x191x82	82.0	460.0	191.3	9.9	16.0	10.2	407.6	5.03	41.2	7	102	28	1.65	20.1
457x191x74	74.3	457.0	190.4	9.0	14.5	10.2	407.6	5.55	45.3	7	102	26	1.64	22.1
457x191x67	67.1	453.4	189.9	8.5	12.7	10.2	407.6	6.34	48.0	6	102	24	1.63	24.3
457x152x82	82.1	465.8	152.3	10.5	18.9	10.2	407.6	3.29	38.8	7	84	30	1.51	18.4
457x152x74	74.2	462.0	154.4	9.6	17.0	10.2	407.6	3.66	42.5	7	84	28	1.50	20.2
457x152x67	67.2	458.0	153.6	9.0	15.0	10.2	407.6	4.15	45.3	7	84	26	1.50	22.3
457x152x60	59.8	454.6	152.9	8.1	13.3	10.2	407.6	4.68	50.3	6	84	24	1.49	24.9
457x152x52	52.3	449.8	152.4	7.6	10.9	10.2	407.6	5.71	53.6	6	84	22	1.48	28.3
406x178x82 *	82.3	417.5	181.9	10.9	18.2	10.2	360.4	4.14	33.1	7	96	30	1.52	17.8
406x178x74	74.2	412.8	179.5	9.5	16.0	10.2	360.4	4.68	37.9	7	96	28	1.51	20.4
406x178x67	67.1	409.4	178.6	8.8	14.3	10.2	360.4	5.23	41.0	6	96	26	1.50	22.3
406x178x60	60.1	406.4	177.9	7.9	12.8	10.2	360.4	5.84	45.6	6	96	24	1.49	24.8
406x178x54	54.1	402.6	177.7	7.7	10.9	10.2	360.4	6.86	46.8	6	96	22	1.48	27.3
406x140x83 *	83.3	406.6	143.3	7.9	12.9	10.2	360.4	4.46	45.6	6	78	24	1.35	25.3
406x140x74	74.0	403.7	142.2	6.8	11.2	10.2	360.4	5.13	53.0	5	78	22	1.34	29.1
406x140x69	69.0	398.0	141.8	6.4	8.6	10.2	360.4	6.69	56.3	5	78	20	1.33	34.1
356x171x87	87.1	363.4	173.2	9.1	15.7	10.2	311.6	4.58	34.2	7	94	28	1.38	20.6
356x171x87	87.0	358.0	172.2	8.1	13.0	10.2	311.6	5.53	38.5	6	94	24	1.37	24.1
356x171x81	81.0	355.0	171.5	7.4	11.5	10.2	311.6	6.25	42.1	6	94	22	1.36	26.7
356x171x65	65.0	351.4	171.1	7.0	9.7	10.2	311.6	7.41	44.5	6	94	20	1.36	30.2
356x127x39	39.1	353.4	126.0	6.6	10.7	10.2	311.6	4.63	47.2	5	70	22	1.18	30.2
356x127x33	33.1	349.0	125.4	6.0	8.5	10.2	311.6	5.82	51.9	5	70	20	1.17	35.4
305x165x54	54.0	310.4	166.9	7.9	13.7	8.9	265.2	5.12	33.6	6	90	24	1.25	23.2
305x165x46	46.1	306.6	165.7	6.7	11.8	8.9	265.2	5.98	39.6	5	90	22	1.25	27.1
305x165x40	40.3	303.4	165.0	6.0	10.2	8.9	265.2	6.92	44.2	5	90	20	1.24	30.8

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 \* These sections are in addition to the range of BS 4 sections.  
 FOR EXPLANATION OF TABLES SEE NOTE 2

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BS EN 1993-1-1:2005  
 BS 4 12008

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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 I <sub>w</sub> dm <sup>6</sup>	Torsional Constant I <sub>t</sub> cm <sup>4</sup>	Area of Section A cm <sup>2</sup>
	Axis Y-Y	Axis Z-Z	Axis Y-Y	Axis Z-Z	Axis Y-Y	Axis Z-Z	Axis Y-Y	Axis Z-Z					
	cm <sup>4</sup>	cm <sup>4</sup>	cm	cm	cm <sup>3</sup>	cm <sup>3</sup>	cm <sup>3</sup>	cm <sup>3</sup>					
533x210x138 *	80100	3860	22.1	4.68	3140	361	3610	568	0.874	24.9	2.67	250	176
533x210x122	76000	3390	22.1	4.67	2790	320	3200	500	0.876	27.6	2.32	176	155
533x210x109	69800	2940	21.9	4.60	2480	279	2830	436	0.875	30.9	1.99	126	139
533x210x91	61500	2690	21.9	4.57	2290	256	2610	399	0.874	33.1	1.81	101	129
533x210x82	55200	2390	21.7	4.51	2070	228	2360	355	0.873	36.4	1.60	75.7	117
533x210x62	47500	2010	21.3	4.38	1800	192	2060	300	0.863	41.2	1.33	51.5	105
483x165x85 *	48500	1270	21.2	3.44	1620	153	2100	243	0.861	35.5	0.857	73.6	106
483x165x75 *	41100	1040	20.8	3.30	1550	125	1810	200	0.853	41.1	0.691	47.9	95.2
483x165x66 *	35000	859	20.5	3.20	1340	104	1560	166	0.847	47.0	0.566	32.0	83.7
457x191x191 *	79600	4250	19.7	4.55	3240	426	3780	672	0.881	16.5	2.25	515	206
457x191x133 *	63600	3350	19.4	4.44	2660	341	3070	535	0.879	19.8	1.73	292	170
457x191x106 *	48900	2510	19.0	4.32	2080	259	2390	405	0.876	24.4	1.27	146	135
457x191x98	45700	2350	19.1	4.33	1960	243	2230	379	0.881	25.8	1.18	121	125
457x191x89	41000	2090	19.0	4.29	1770	218	2010	338	0.878	28.3	1.04	90.7	114
457x191x82	37100	1870	18.8	4.23	1610	196	1830	304	0.879	30.8	0.902	69.2	104
457x191x74	33300	1670	18.8	4.20	1460	176	1650	272	0.877	33.8	0.818	51.8	94.6
457x191x67	29400	1450	18.5	4.12	1300	153	1470	237	0.873	37.8	0.705	37.1	85.5
457x152x82	36600	1180	18.7	3.37	1570	153	1810	240	0.872	27.4	0.591	69.2	106
457x152x74	32700	1050	18.6	3.33	1410	136	1630	213	0.872	30.1	0.518	65.9	94.5
457x152x67	28900	913	18.4	3.27	1260	119	1450	187	0.868	33.6	0.448	47.7	85.6
457x152x60	25500	795	18.3	3.23	1120	104	1290	163	0.868	37.5	0.387	33.6	76.2
457x152x52	21400	645	17.9	3.11	950	84.6	1100	133	0.859	43.8	0.311	21.4	66.6
406x178x85 *	31700	1830	17.1	4.11	1520	201	1730	313	0.880	24.4	0.728	93.0	109
406x178x74	27300	1550	17.0	4.04	1320	172	1500	267	0.882	27.5	0.608	62.6	94.5
406x178x67	24300	1360	16.9	3.99	1190	153	1350	237	0.880	30.4	0.533	46.1	85.5
406x178x60	21600	1200	16.8	3.97	1060	135	1200	209	0.880	33.7	0.466	33.3	76.5
406x178x54	18700	1020	16.5	3.85	930	115	1050	178	0.871	38.3	0.392	23.1	69.0
406x140x83 *	18300	635	16.4	3.05	899	84.6	1030	139	0.870	34.1	0.346	29.0	67.9
406x140x66	15700	538	16.4	3.03	778	75.7	888	118	0.871	39.0	0.297	19.0	58.6
406x140x59	12500	410	15.9	2.87	629	57.8	724	90.8	0.858	47.4	0.155	10.7	49.7
356x171x87	19500	1360	15.1	3.99	1070	157	1210	243	0.886	24.4	0.412	50.7	85.5
356x171x67	16000	1110	14.9	3.91	896	129	1010	199	0.882	28.8	0.330	33.4	72.6
356x171x51	14100	968	14.8	3.86	796	113	896	174	0.881	32.1	0.286	23.6	64.9
356x171x45	12100	811	14.5	3.76	687	94.8	775	147	0.874	36.8	0.237	15.6	57.3
356x127x39	10200	358	14.3	2.68	576	56.8	659	89.0	0.871	35.2	0.105	15.1	49.8
356x127x33	8250	290	14.0	2.58	473	44.7	543	70.2	0.863	42.1	0.081	8.79	42.1
305x165x54	11700	1060	13.0	3.93	754	127	846	196	0.889	23.6	0.234	34.6	68.6
305x165x46	9900	896	13.0	3.90	646	108	726	166	0.890	27.1	0.195	22.2	58.7
305x165x40	8300	764	12.9	3.86	560	92.6	623	142	0.889	31.0	0.164	14.7	51.3

Advance® and UKB are trademarks of Tata Steel. A fuller description of the relationship between Universal Beams (UB) and the Advance® range of sections manufactured by Tata Steel is given in note 12.

\* These sections are in addition to the range of BS 4 sections.

FOR EXPLANATION OF TABLES SEE NOTE 3

TERBUKA