UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: July 2016

Module Number: CE5201 **Module Name**: Design of Steel Structures

[Time: Three Hours]

[Answer all questions, all questions carry ***fifteen*** marks each]

British Standard BS 5950 Part I (2000) is provided.

Q1. A heavy steel bridge truss shown in Fig. Q1(a) is made of using universal beams as top and bottom chord. The total lengths of the top and bottom chord are achieved by splicing number of individual beam lengths together. Fig. Q1(b) shows a typical splice connection used for the top and bottom chord. The structural analysis has shown that the top and bottom chords are subjected to tension and compression forces respectively with negligible bending moments. It is proposed to use 457x191x89 UB sections made of grade S275 steel for the both top and bottom chords.

a) Identify all possible failure modes at the splice joint in the bottom chord.

[2.0 Marks]

b) In terms of tension capacity of connecting members, compare the staggered and the non-staggered bolt arrangement for the given joint.

[2.0 Marks]

c) Calculate the maximum possible design tension force for bottom chord considering the tension failure of UB section.

[5.0 Marks]

d) Suppose splice joints in the top chord are positioned only at the joints connecting top chord and web members (i.e. at D, F, H and J) and the top chord is laterally bracing at above joints, identify the most critical segment/s of the top chord for compression failure. Determine the maximum possible compression force that can be applied to the critical segment? (State any assumption you made in your judgment).

[6.0 Marks]

Q2. A line diagram of a part of an idealized steel frame structure is shown in Fig. Q2. The frame includes a continuous main beam (ABCD) and secondary beams (EB-BF and GC-CH). The secondary is combined to the main beam by shear joints which transfer point load to the main beam through the web at points B and C. The estimated ultimate point loads transferred by each secondary beam is 50 kN (i.e. 2 x 50 = 100 kN at a point). In addition to these point loads, the main beam is also subjected to the uniformly distributed load due to ultimate dead and imposed loads with magnitude 10 kN/m.

A universal beam section of size 533x210x92 UB in Grade S275 is proposed to be used as the main beam.

a) Estimate the design bending moment and design shear force for main beam.

[2.0 Marks]

b) Check whether the proposed beam section is sufficient to withstand the design shear force.

[2.0 Marks]

c) Check whether the proposed beam section is sufficient to withstand the design bending moment.

[2.0 Marks]

d) Check whether the given restraining conditions are sufficient to resist the lateral torsional buckling. Assume that the secondary beams at joints B and C provide lateral restraints to the main beam.

[4.0 Marks]

e) The main beam is rested on simple supports at points A and D as shown in Fig. 2(b). Check whether the proposed beam supports are adequate to resist the design force against web bearing and web buckling failure.

[5.0 Mark]

Q3. The beam ABC shown in Fig. Q3 is subjected to axial compression, point loads at mid-span in the vertical and horizontal direction, and uniformly distributed loads also in vertical and horizontal directions. All the forces are applied concentrically. The beam ends are connected to the columns by shear connections so that they behave as pinned joints about both major and minor axes. A trail section of size 457x191x98 UB made of grade S275 steel is selected to check the suitability for this beam-column.

The applied loads to the beam are as follows:

Axial compression force	250 kN
Major axis point load	100 kN
Minor axis point load	20 kN
Major axis distributed load	10 kN/m
Minor axis distributed load	2.5 kN/m

a) Determine ultimate design bending moments and shear forces for the beam about both major and minor axes.

[2.0 Marks]

b) Check whether the cross section capacity of trial section is sufficient to withstand the combined axial compression and bending moments.

[4.0 Marks]

c) Check whether the in-plane buckling resistance of the trails section is sufficient to withstand design forces and moments.

[4.0 Marks]

d) Check whether the out-of-plane buckling resistance of the trails section under given restraining condition is sufficient to withstand the design forces and bending moments.

[5.0 Marks]

Q4. Fig. Q4(a) and Fig. Q4(b) show elevation and plan view of an idealized beam-column connection in a steel frame. The connection is made using 16 Nos. of M20 bolts of Grade 4.6 arranging symmetrically in both side of the column flanges with 10 mm

end plates. The analysis at ultimate loading conditions shows that the bending moment and shear force for entire bolt group exerted at the bolt group centroid are 35 kNm and 128 kN respectively. The column size is 457×191×98 UB and Grade of all steel is S275. The tensile area of M20 bolt is 245 mm^2.

a) Explain types of forces developed in the bolt group and derive an expression for the maximum force developed on a bolt under this loading condition.

[2.0 Marks]

b) Check whether the given connection details in Fig. Q5 is sufficient to carry the applied shear force and bending moment.
Hint: you may need to consider all possible failures modes)

[10.0 Marks]

c) Check whether the minimum and maximum spacing, end and edge distances are satisfied for the given detailing.

[3.0 Marks]

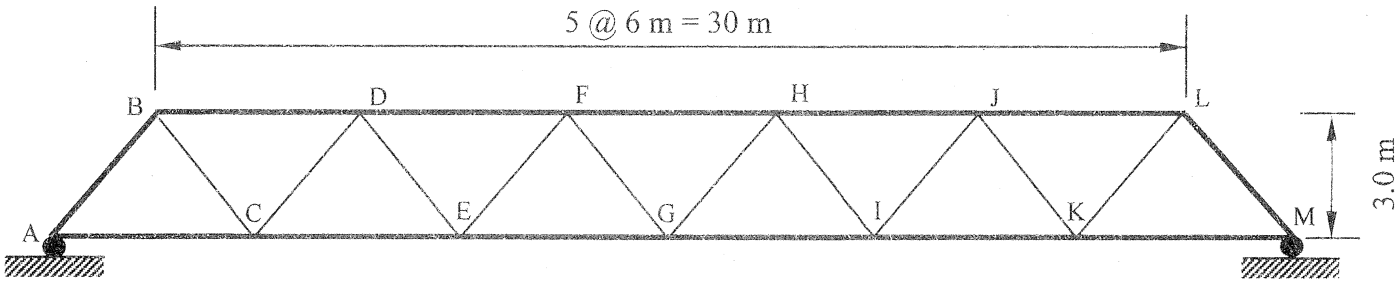
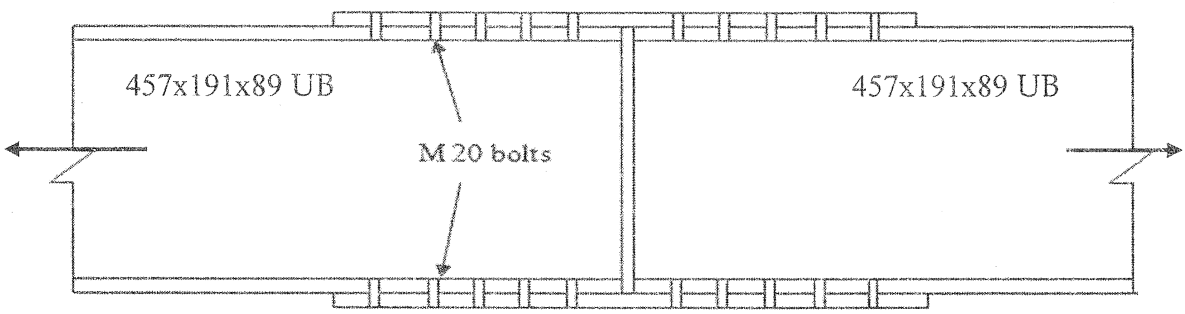
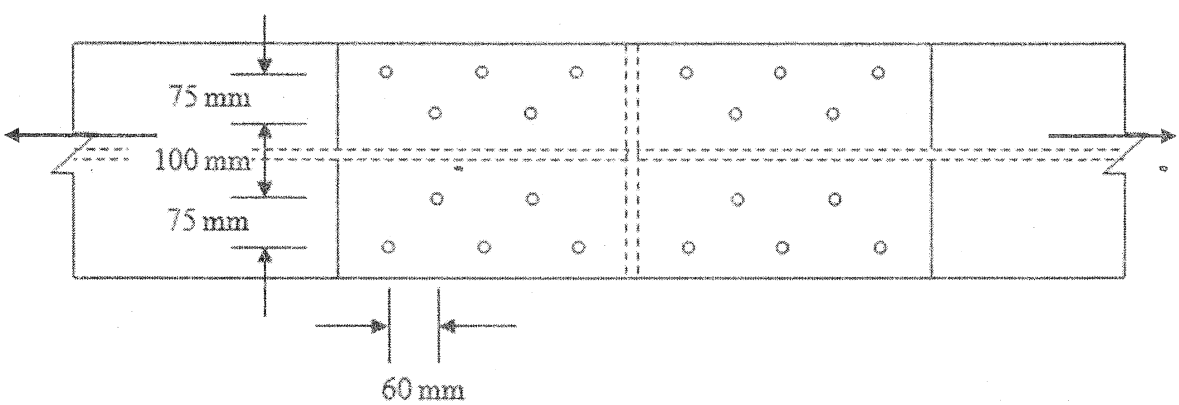


Fig.Q1 (a): Bridge truss



Elevation



Plan view

Fig.Q1 (b): Splice joint details

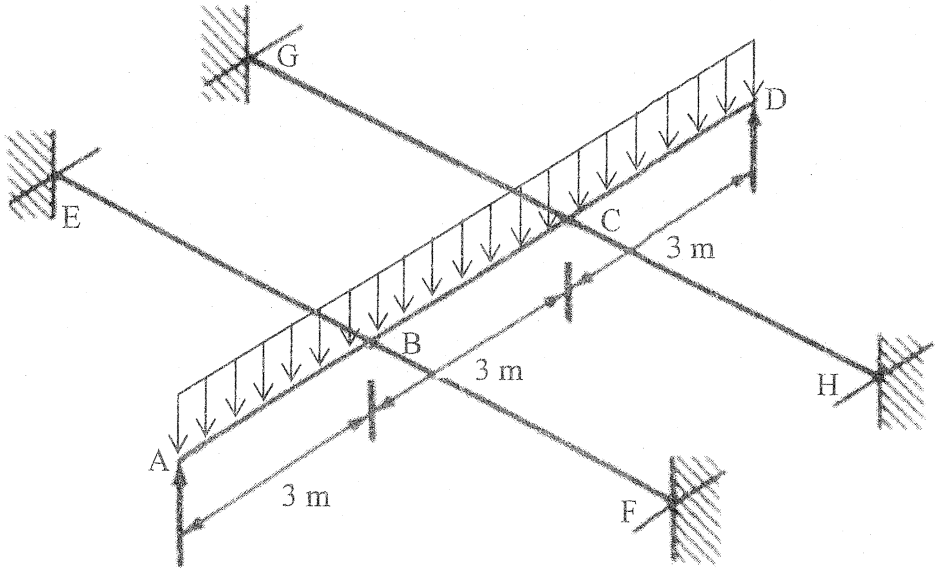


Fig.Q2(a): Steel Frame Structure

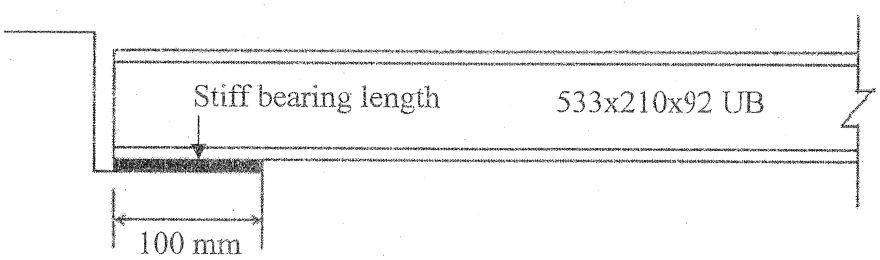


Fig. Q2(b): Support condition at point A

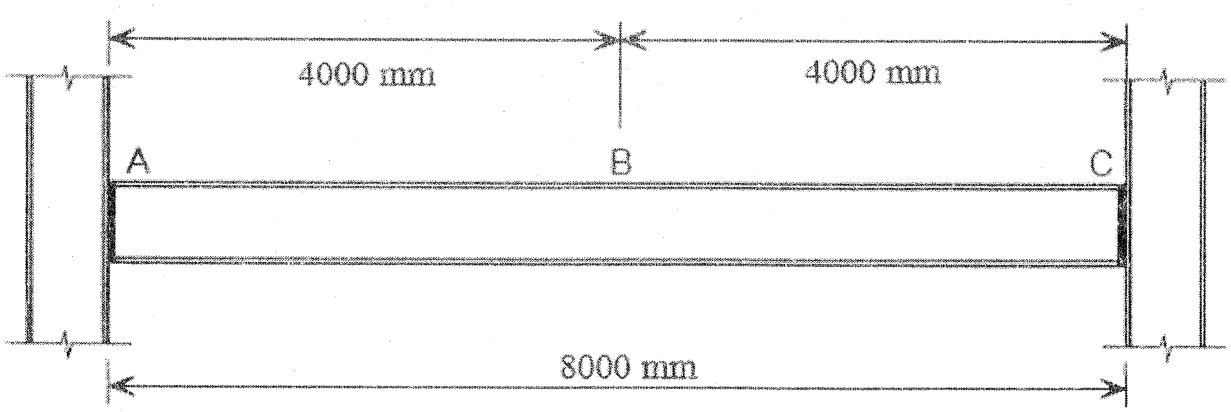


Fig.Q3

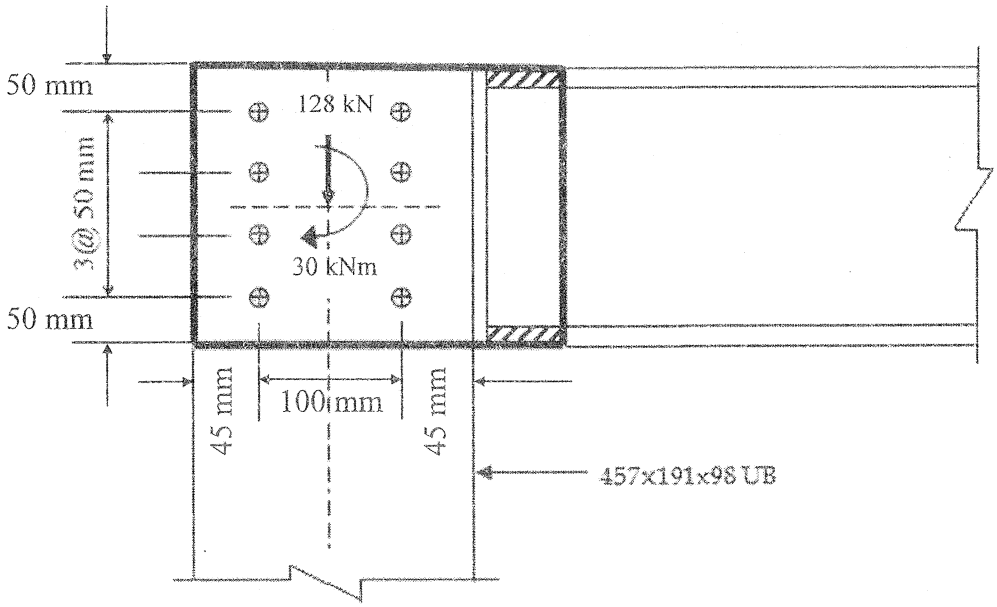


Fig. Q4(a) : Elevation

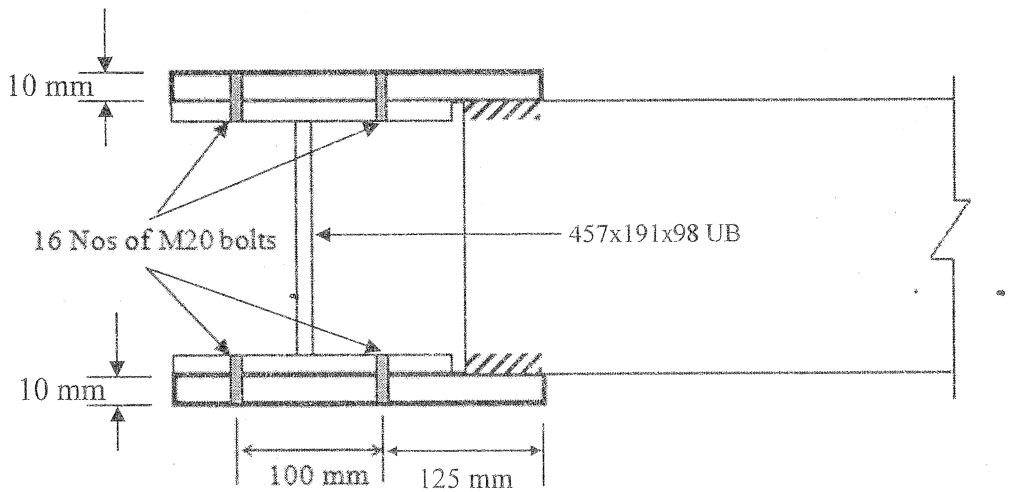


Fig. Q4(b) Plan view

BS 5950-1: 2000
BS 4-1: 2005

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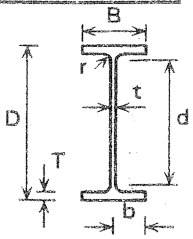

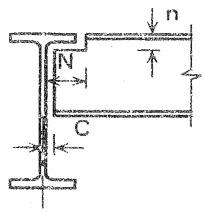

Dimensions

Section Designation	Mass per Metre	Depth of Section	Width of Section	Thickness		Root Radius	Depth between Fillets	Ratios for Local Buckling		Dimensions for Detailing			Surface Area	
				Web	Flange			Flange	Web	End Clearance	Notch		Per Metre	Per Tonne
		D	B	t	T	r	d	b/T	d/t	C	N	n		
	kg/m	mm	mm	mm	mm	mm	mm			mm	mm	mm	m^2	m^2
533x210x138 +	138.3	549.1	213.9	14.7	23.6	12.7	476.5	4.53	32.4	9	110	38	1.90	13.7
533x210x122	122.0	544.5	211.9	12.7	21.3	12.7	476.5	4.97	37.5	8	110	34	1.89	15.5
533x210x109	109.0	539.5	210.8	11.6	18.8	12.7	476.5	5.61	41.1	8	110	32	1.88	17.2
533x210x101	101.0	536.7	210.0	10.8	17.4	12.7	476.5	6.03	44.1	7	110	32	1.87	18.5
533x210x92	92.1	533.1	209.3	10.1	15.6	12.7	476.5	6.71	47.2	7	110	30	1.86	20.2
533x210x82	82.2	528.3	208.8	9.6	13.2	12.7	476.5	7.91	49.6	7	110	26	1.85	22.5
533x165x85 +	84.8	534.9	166.5	10.3	16.5	12.7	476.5	5.05	46.3	7	90	30	1.69	19.9
533x165x75 +	74.7	529.1	165.9	9.7	13.6	12.7	476.5	6.10	49.1	7	90	28	1.68	22.5
533x165x66 +	65.7	524.7	165.1	8.9	11.4	12.7	476.5	7.24	53.5	6	90	26	1.67	25.4
457x191x161 +	161.4	492.0	199.4	18.0	32.0	10.2	407.6	3.12	22.6	11	102	44	1.73	10.7
457x191x133 +	133.3	480.6	196.7	15.3	26.3	10.2	407.6	3.74	26.6	10	102	38	1.70	12.8
457x191x106 +	105.8	469.2	194.0	12.6	20.6	10.2	407.6	4.71	32.3	8	102	32	1.67	15.8
457x191x98	98.3	467.2	192.8	11.4	19.6	10.2	407.6	4.92	35.8	8	102	30	1.67	17.0
457x191x89	89.3	463.4	191.9	10.5	17.7	10.2	407.6	5.42	38.8	7	102	28	1.66	18.6
457x191x82	82.0	460.0	191.3	9.9	16.0	10.2	407.6	5.98	41.2	7	102	28	1.65	20.1
457x191x74	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
457x191x67	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
457x152x82	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
457x152x74	74.2	462.0	154.4*	9.6	17.0	10.2	407.6	4.54	42.5	7	84	28	1.50	20.2
457x152x67	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
457x152x60	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
457x152x52	52.3	449.8	152.4	7.6	10.9	10.2	407.6	6.99	53.6	6	84	22	1.48	28.3
406x178x85 +	85.3	417.2	181.9	10.9	18.2	10.2	360.4	5.00	33.1	7	96	30	1.52	17.8
406x178x74	74.2	412.8	179.5	9.5	16.0	10.2	360.4	5.61	37.9	7	96	28	1.51	20.4
406x178x67	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
406x178x60	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
406x178x54	54.1	402.6	177.7	7.7	10.9	10.2	360.4	8.15	46.8	6	96	22	1.48	27.3
406x140x53 +	53.3	406.6	143.3	7.9	12.9	10.2	360.4	5.55	45.6	6	78	24	1.35	25.3
406x140x46	46.0	403.2	142.2	6.8	11.2	10.2	360.4	6.35	53.0	5	78	22	1.34	29.1
406x140x39	39.0	398.0	141.8	6.4	8.6	10.2	360.4	8.24	56.3	5	78	20	1.33	34.1
356x171x67	67.1	363.4	173.2	9.1	15.7	10.2	311.6	5.52	34.2	7	94	26	1.38	20.6
356x171x57	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
356x171x51	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
356x171x45	45.0	351.4	171.1	7.0	9.7	10.2	311.6	8.82	44.5	6	94	20	1.36	30.2
356x127x39	39.1	353.4	126.0	6.6	10.7	10.2	311.6	5.89	47.2	5	70	22	1.18	30.2
356x127x33	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
305x165x54	54.0	310.4	166.9	7.9	13.7	8.9	265.2	6.09	33.6	6	90	24	1.26	23.3
305x165x46	46.1	306.6	165.7	6.7	11.8	8.9	265.2	7.02	39.6	5	90	22	1.25	27.1
305x165x40	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

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

FOR EXPLANATION OF TABLES SEE NOTE 2

BS 5950-1: 2000
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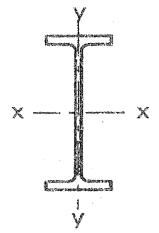

Properties

Section Designation	Second Moment of Area		Radius of Gyration		Elastic Modulus		Plastic Modulus		Buckling Parameter	Torsional Index	Warping Constant	Torsional Constant	Area of Section
	Axis x-x	Axis y-y	Axis x-x	Axis y-y	Axis x-x	Axis y-y	Axis x-x	Axis y-y	u	x	H	J	A
	cm^4	cm^4	cm	cm	cm^3	cm^3	cm^3	cm^3			dm^6	cm^4	cm^2
533x210x138 +	86100	3860	22.1	4.68	3140	361	3610	568	0.873	25.0	2.67	250	176
533x210x122	76000	3390	22.1	4.67	2790	320	3200	500	0.877	27.6	2.32	178	155
533x210x109	66800	2940	21.9	4.60	2480	279	2830	436	0.875	30.9	1.99	126	139
533x210x101	61500	2690	21.9	4.57	2290	256	2610	399	0.874	33.2	1.81	101	129
533x210x92	55200	2390	21.7	4.51	2070	228	2360	355	0.872	36.5	1.60	75.7	117
533x210x82	47500	2010	21.3	4.38	1800	192	2060	300	0.864	41.6	1.33	51.5	105
533x165x85 +	48500	1270	21.2	3.44	1820	153	2100	243	0.862	35.5	0.857	73.8	108
533x165x75 +	41100	1040	20.8	3.30	1550	125	1810	200	0.853	41.1	0.691	47.9	95.2
533x165x66 +	35000	859	20.5	3.20	1340	104	1560	166	0.847	47.0	0.566	32.0	83.7
457x191x161 +	79800	4250	19.7	4.55	3240	426	3780	672	0.882	16.4	2.25	515	206
457x191x133 +	63800	3350	19.4	4.44	2660	341	3070	535	0.880	19.6	1.73	292	170
457x191x106 +	48900	2510	19.0	4.32	2080	259	2390	405	0.877	24.4	1.27	146	135
457x191x98	45700	2350	19.1	4.33	1960	243	2230	379	0.881	25.7	1.18	121	125
457x191x89	41000	2090	19.0	4.29	1770	218	2010	338	0.880	28.3	1.04	90.7	114
457x191x82	37100	1870	18.8	4.23	1610	196	1830	304	0.877	30.9	0.922	69.2	104
457x191x74	33300	1670	18.8	4.20	1460	176	1650	272	0.877	33.9	0.818	51.8	94.6
457x191x67	29400	1450	18.5	4.12	1300	153	1470	237	0.872	37.9	0.705	37.1	85.5
457x152x82	36600	1180	18.7	3.37	1570	153	1810	240	0.873	27.4	0.591	89.2	105
457x152x74	32700	1050	18.6	3.33	1410	136	1630	213	0.873	30.1	0.518	65.9	94.5
457x152x67	28900	913	18.4	3.27	1260	119	1450	187	0.869	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	33.8	76.2
457x152x52	21400	645	17.9	3.11	950	84.6	1100	133	0.859	43.9	0.311	21.4	66.6
406x178x85 +	31700	1830	17.1	4.11	1520	201	1730	313	0.881	24.4	0.728	93.0	109
406x178x74	27300	1550	17.0	4.04	1320	172	1500	267	0.882	27.6	0.608	62.8	94.5
406x178x67	24300	1360	16.9	3.99	1190	153	1350	237	0.880	30.5	0.533	46.1	85.5
406x178x60	21600	1200	16.8	3.97	1060	135	1200	209	0.880	33.8	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
406x140x53 +	18300	635	16.4	3.06	899	88.6	1030	139	0.870	34.1	0.246	29.0	67.9
406x140x46	15700	538	16.4	3.03	778	75.7	888	118	0.871	38.9	0.207	19.0	58.6
406x140x39	12500	410	15.9	2.87	629	57.8	724	90.8	0.858	47.5	0.155	10.7	49.7
356x171x67	19500	1360	15.1	3.99	1070	157	1210	243	0.886	24.4	0.412	55.7	85.5
356x171x57	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	23.8	64.9
356x171x45	12100	811	14.5	3.76	687	94.8	775	147	0.874	36.8	0.237	15.8	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	280	14.0	2.58	473	44.7	543	70.2	0.863	42.2	0.081	8.79	42.1
305x165x54	11700	1060	13.0	3.93	754	127	846	196	0.889	23.6	0.234	34.8	68.8
305x165x46	9900	896	13.0	3.90	646	108	720	166	0.891	27.1	0.195	22.2	58.7
305x165x40	8500	764	12.9	3.86	560	92.6	623	142	0.889	31.0	0.164	14.7	51.3

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

FOR EXPLANATION OF TABLES SEE NOTE 3