THE OPEN UNIVERSITY OF SRI LANKA
Diploma In Technology (Civil) / Bachelor of Technology - Level 3
CEX 3231 - Structural Analysis & Design 1
Final Examination - 2013/2014
Time Allowed 3 hours

Date: 27th August 2014 Time 9.30p.m. - 12.30 p.m.

Answer **five** questions selecting not less than **two** questions from section A and Section B.
Please write answers clearly showing any derivations required and stating necessary assumptions

SECTION A

1. a). i). State three methods used to find the member forces in trusses (3 Marks)
ii). State three assumptions used in analyzing plane trusses. (3 Marks)

b). A structure is loaded as shown in Figure Q1 that is supported at L1 and L2. Loads of 5 kN each are applied at joints U1, U2 and L2 in the direction shown in the same figure.

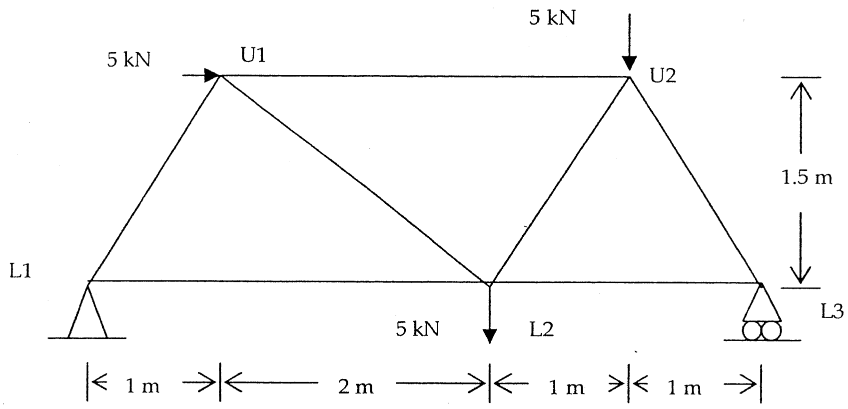


Figure Q1

i.) Analyze the truss shown on Figure Q1 with the method of joints and tabulate the member forces with their usual signs. (Sign Convention, Tension is positive) (7 Marks)

ii.) Justify your answers in part i with the Graphical metho (7 Marks)

2. a). Discuss the advantages of virtual work method over strain energy method used to determine the deflection of trusses. (4 Marks)

b). Find the defection of point L2 of the truss given in Figure Q2 (14 Marks)
(Assume the AE value for all the members)

c). Explain why strain energy method cannot be used in answering question 2.b) (2 Marks)

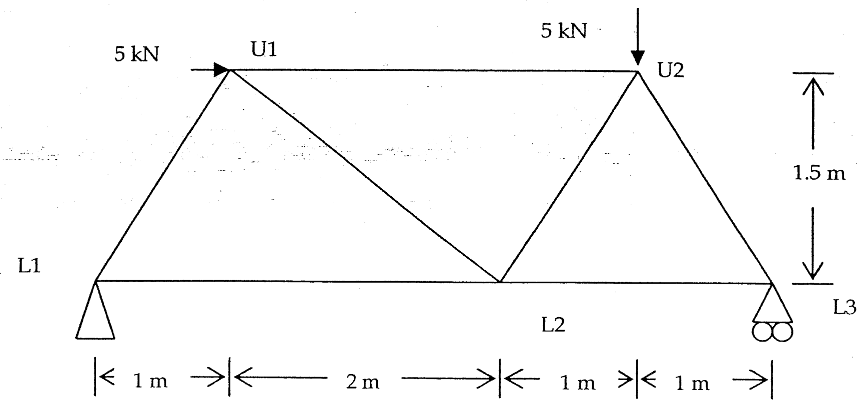


Figure Q2

3.

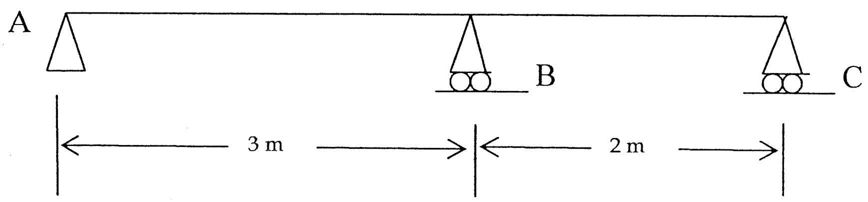


Figure Q3

a). Find the degree of statical indeterminacy of the beam given in Figure Q3
(2 Marks)

b). Assume that there is a hinge at mid span of BC and hence draw the influence lines for
i). Reaction at A
ii). Support moment at B
iii). Bending moment at mid span of AB (10 Marks)

c). Following loads (given in parts c(i) and c(ii) are moving along the beam. Find the maximum Bending Moment at mid span AB and also indicate the corresponding positions of the loadings.
i.) Uniformly distribute load of intensity 2 kN/m act length of 2 m.
ii.) Two tires of a bicycle which are 2m apart and front wheel applies 5 kN and rear wheel applies 10 kN. (Loads are moving from left to right) (8 Marks)

4.

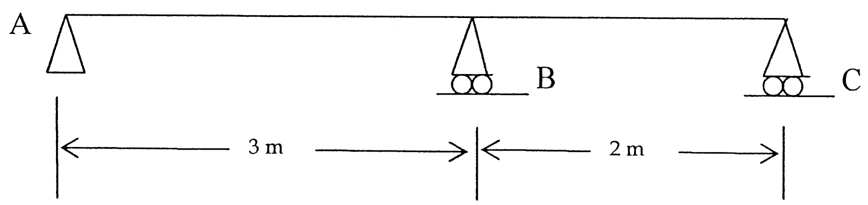


Figure Q 4

The beam given in Figure Q4 is loaded with a dead load (g_k) of 10 kN/m and imposed load (q_k) of 5 kN/m. Following loads are identified as critical load cases.

Case 1 - Maximum load at both spans.

Case 2 - Maximum load at span AB and minimum load at span BC

After introducing a hinge at mid span of BC

a). Draw the Shear Force diagram and Bending moment diagram for Load case 1 (8 Marks)

b). Draw the Shear Force diagram and Bending moment diagram for Load case 2 (8 Marks)

c). Draw the Bending moment envelope for Load case 1 and Load case 2. (4 Marks)

Maximum Load = $1.4\ G_k + 1.6\ Q_k$ and Minimum Loading = $1.0\ G_k$

SECTION B

Description for Q5 and Q6

Truss shown in Figure 1 is proposed to design with Equal Angle steel members.
The single angle members are proposed to use for web members (internal) . Back to back double angle members are proposed for chord (external) members. Bolted connections with M 18 bolts (one line parallel to axis) are proposed for all the joints. Table 1 gives the results of analysis of truss.

The results of truss analyzing is shown in Table 1

Member	Member Force (kN)	Tension or Compression
L1L2	19.5	Tension
L2L3	15.5	Tension
L1U1	15	Compression
U1U2	25	Compression
U2L2	18	Compression
U1L2	7.5	Tension
L2U2	10	Compression

Table 1

5. a).Define the two terms effective sectional area and gross sectional area of a single angle member used as a member of steel truss. Explain why effective area is used for designing tension members and gross area is used for designing compression members. (6 Marks)

b). Design member U1L2 selecting steel 50 x 50 x 7 mm equal angle member (5 Marks)

c). According the results given in Table 1 bottom chord is subjected to tension tension. Design the bottom chord using steel 50 x 50 x 7 double angle members (back to back connected) (5 Marks)

d). If perpendicular loads of 0.5 kN each applied on mid span of each member of bottom chord check the selected double angle members (part c) are adequate to resist this additional load. (4 Marks)

6. a). Define the terms effective length, radius of gyration and slenderness ratio used in steel design. Explain why members should be rejected if calculated slenderness ratio is more than allowable maximum slenderness ratio. (6 Marks)

b). Design member U2L2 selecting steel 50 x 50 x 7 equal angle member. Assume members are connected with at least two M18 bolts in both ends. (6 Marks) c). According the results given in Table 1 upper chord is subjected to compression. Design the upper chord using steel double 50 x 50 x 7 equal angle members (back to back connected). Assume members are connected with at least two M18 bolts at both ends.

The radius of gyration of double angle member is given by

r_{xx} (double) = r_{xx}

r_{yy}^2 (double)= $r_{yy}^2 + (c_y + t/2)^2$

Where r_{xx}, r_{yy} and c_y have their standard meanings and thickness of gusset plate is taken as 12 mm.

(8 Marks)

7.

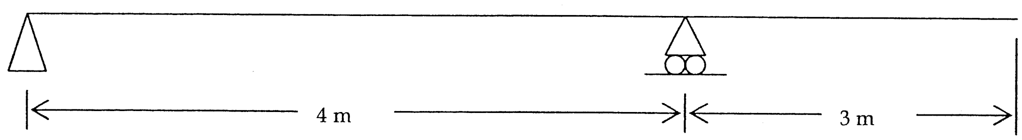


Figure Q7

The steel beam given in Figure Q7 is used to support the timber (teak) floor of 125 mm in thickness and following details are provided.

Spacing of the beams = 1.5 m
Dead load from the finishers = 1.0 kN/m^2
Density of Teak = 800 kg/m^3
Total imposed load = 2.0 kN/m^2

a). Find the design load applied on the beam. (Take the self weight of the beam as 25 % of total calculated design load). (4 Marks)

b). Design the beam selecting 100 x 200 mm T section. (Design for considering maximum sagging and hogging moments). (12 Marks)

c) Sketch the four failure modes of bolted steel connection (4 Marks)

8. a). Explain the following terms as used in wind load calculations.
   i). Post Disaster Structure
   ii). Basic wind speed
   iii). Leeward slope of the roof

(2x 3 = 6 Marks)

b). Derive the formula for Euler buckling load of strut fixed supported at both ends with first principles.

(8 Marks)

c). A strut fixed supported at both ends of effective length 4 m is used as a column and which is loaded only with axial compression load of 100 kN.

Dimension of column - 300 mm x 400 mm
Elastic modulus of column material - 6.9 x 10^8 N/m^2
Compressive strength of column material - 5 N/mm^2

Check whether the member is safe under these conditions

(6 Marks)

DATA SHEET

x a	T	M	r1	r2	A	C of G	Moment Of Inertia			Radius Of Gyration			Z
						Cx, Cy	X-X, Y-Y	U-U	V-V	X-X, Y-Y	U-U	V-V	
mm	mm	kg	mm	mm	cm^2	cm	cm^4	cm^4	cm^4	cm	cm	cm	cm^3
50 x 50	5	3.77	7,0	2,4	4.80	1.40	11.0	17.4	4.54	1.51	1.90	0.97	3.05
	6	4.47	7,0	2,4	5.69	1.45	12.8	20.4	5.33	1.50	1.89	0.97	3.61
	7	5.82	7,0	2,4	7.41	1.52	16.3	25.7	6.87	1.48	1.86	0.96	4.68
60 x 60	5	4.57	8,0	2,4	5.82	1.64	19.4	30.7	8.02	1.82	2.30	1.17	4.45
	6	5.42	8,0	2,4	6.91	1.69	22.8	36.2	9.43	1.82	2.29	1.17	5.29
	8	7.09	8,0	2,4	9.03	1.77	29.2	46.2	12.1	1.80	2.26	1.16	6..89
	10	8.69	8,0	2,4	11.1	1.85	34.9	55.1	14.8	1.78	2.23	1.16	8.41
70 x 70	6	6.38	9,0	2,4	8.13	1.93	36.9	58.5	15.2	2.13	2.68	1.37	7.27
	8	8.36	9,0	2,4	10.6	2.01	47.5	75.3	19.7	2.11	2.66	1.36	9.52
	10	10.3	9,0	2,4	13.1	2.09	57.2	90.5	23.9	2.09	2.63	1.35	11.7
80 x 80	6	7.34	10,0	4,8	9.35	2.17	55.8	88.5	23.1	2.44	3.08	1.57	9.57
	8	9.63	10,0	4,8	12.3	2.26	72.2	115	29.8	2.43	3.06	1.56	12.6
	10	11.9	10,0	4,8	15.1	2.34	87.5	139	36.3	2.41	3.03	1.55	15.4
90 x 90	6	8.3	11,0	4,8	10.6	2.41	80.3	127	33.3	2.76	3.47	1.78	12.2
	8	10.9	11,0	4,8	13.9	2.50	104	166	43.1	2.74	3.45	1.76	16.1
	10	13.4	11,0	4,8	17.1	2.58	127	201	52.6	2.72	3.42	1.76	19.8
	12	15.9	11,0	4,8	20.3	2.66	148	234	61.7	2.70	3.40	1.75	23.3
100x100	8	12.2	12,0	4,8	15.5	2.74	145	230	59.8	3.06	3.85	1.96	19.9
	12	17.8	12,0	4,8	22.7	2.90	207	328	85.7	3.02	3.80	1.94	29.1
	15	21.9	12,0	4,8	27.9	3.02	249	393	104	2.98	3.75	1.93	35.6

TABLE 19. ALLOWABLE STRESS P_t IN AXIAL TENSION

Form	Grade	Thickness	P_t
		mm	N/mm²
Sections, bars, plates, wide flats and hot rolled hollow sections	43	≤ 40	170
		over 40 but ≤ 100	155
	50	≤ 63	215
		over 63 but ≤ 100	200
	55	≤ 25	265

TENSILE STRESSES FOR ANGLES, TEES AND CHANNELS

42. *a*. Eccentric connections. When eccentricity of loading occurs in connections of angles and tees in tension, the net areas to be used in computing the mean tensile stress shall be as given by the following rules:

1. *Single angles connected through one leg, channel sections connected through the web and T-sections connected only through the flange.* To the net sectional area of the connected leg, add the sectional area of the unconnected leg multiplied by:

$$\frac{3a_1}{3a_1 + a_2}$$

where a_1 = the net sectional area of the connected leg.
a_2 = the sectional area of the unconnected leg.

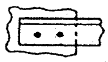
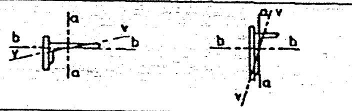
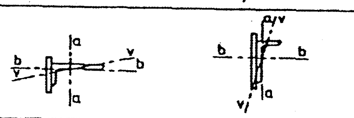
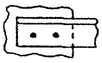
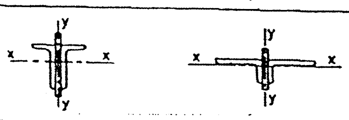
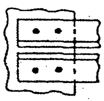
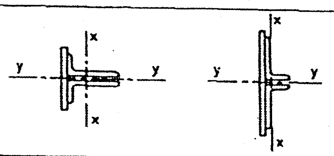
Where lug angles are used, the net sectional area of the whole of the angle member shall be taken.

2. *A pair of angles, channels or T-sections, connected together along their length*, when attached to the same side of a gusset for the equivalent by only one leg of each component:

(i) in contact or separated, by a distance not exceeding the aggregate thickness of the connected parts, with solid packing pieces.

(ii) connected by bolts or welding as specified in Subclauses 51*e* or 54*g* so that the maximum ratio of slenderness of each member between connections is not greater than 80.

TABLE 18. ANGLE STRUTS

Connection	Sections and axes	Slenderness ratios (see notes 1 and 2)
		*vv axis:* $0.85L_{vv}/r_{vv}$ but $\geq 0.7L_{vv}/r_{vv} + 15$ *aa axis:* $1.0L_{aa}/r_{aa}$ but $\geq 0.7L_{aa}/r_{aa} + 30$ *bb axis:* $0.85L_{bb}/r_{bb}$ but $\geq 0.7L_{bb}/r_{bb} + 30$
 (See note 3)		*vv axis:* $1.0L_{vv}/r_{vv}$ but $\geq 0.7L_{vv}/r_{vv} + 15$ *aa axis:* $1.0L_{aa}/r_{aa}$ but $\geq 0.7L_{aa}/r_{aa} + 30$ *bb axis:* $1.0L_{bb}/r_{bb}$ but $\geq 0.7L_{bb}/r_{bb} + 30$ (See note 3)
 (See note 4)		*xx axis:* $0.85L_{xx}/r_{xx}$ but $\geq 0.7L_{xx}/r_{xx} + 30$ *yy axis:* $1.0L_{yy}/r_{yy} + 10$
 (See note 4)		*xx axis:* $1.0L_{xx}/r_{xx}$ but $\geq 0.7L_{xx}/r_{xx} + 30$ *yy axis:* $0.85L_{yy}/r_{yy}$ but $\geq 0.7L_{yy}/r_{yy} + 10$

NOTE 1. The length L is taken between the intersections of the centroidal axes or the intersections of the setting out lines of the bolts, irrespective of whether the strut is connected to a gusset or directly to another member.

NOTE 2. Intermediate lateral restraints reduce the value of L for buckling about the relevant axes. For single angle members, L_{vv} is taken between lateral restraints perpendicular to either aa or bb.

NOTE 3. For single angles connected by one bolt, the allowable stress is also reduced to 80 per cent of that for an axially loaded member.

NOTE 4. Double angles are interconnected back-to-back to satisfy Clause 37.

TABLE 2. ALLOWABLE STRESS p_{bc} OR p_{bt} IN BENDING

(See also Clauses 19 and 20 and Tables 3 and 4)

Form	Grade	Thickness of material	p_{bc} or p_{bt}
Sections, bars, plates, wide flats and hot rolled hollow sections. Compound beams composed of rolled sections plated, with thickness of plate. Double channel sections forming a symmetrical I-section which acts as an integral unit.	43	≤ 40 >40 but ≤ 100	180 165
	50	≤ 63 >63 but ≤ 100	230 215
	55	≤ 25	280
Plate girders with single or multiple webs	43	≤ 40 >40 but ≤ 100	170 155
	50	≤ 63 >63 but ≤ 100	215 200
	55	≤ 25	265
Slab bases	All steels		185

TABLE 17*a*. ALLOWABLE STRESS p_c ON GROSS SECTION FOR AXIAL COMPRESSION

As altered Dec. 1989

l/r	p_c (N/mm²) for grade 43 steel									
	0	1	2	3	4	5	6	7	8	9
0	170	169	169	168	168	167	167	166	166	165
10	165	164	164	163	163	162	162	161	160	160
20	159	159	158	158	157	157	156	156	155	155
30	154	154	153	153	153	152	152	151	151	150
40	150	149	149	148	148	147	146	146	145	144
50	144	143	142	141	140	139	139	138	137	136
60	135	134	133	131	130	129	128	127	126	124
70	123	122	120	119	118	116	115	114	112	111
80	109	108	107	105	104	102	101	100	98	97
90	95	94	93	91	90	89	87	86	85	84
100	82	81	80	79	78	77	75	74	73	72
110	71	70	69	68	67	66	65	64	63	62
120	62	61	60	59	58	57	57	56	55	54
130	54	53	52	51	51	50	49	49	48	47
140	47	46	46	45	45	44	43	43	42	42
150	41	41	40	40	39	39	38	38	38	37
160	37	36	36	35	35	35	34	34	33	33
170	33	32	32	32	31	31	31	30	30	30
180	29	29	29	28	28	28	28	27	27	27
190	26	26	26	26	25	25	25	25	24	24
200	24	24	24	23	23	23	23	22	22	22
210	22	22	21	21	21	21	21	20	20	20
220	20	20	20	19	19	19	19	19	19	18
230	18	18	18	18	18	18	17	17	17	17
240	17	17	17	16	16	16	16	16	16	16
250	16	15	15	15	15	15	15	15	15	15
300	11	11	11	11	11	11	10	10	10	10
350	8	8	8	8	8	8	8	8	8	8

NOTE 1. Intermediate values may be obtained by linear interpolation.
NOTE 2. For material over 40 mm thick refer to subclause 30*a*.

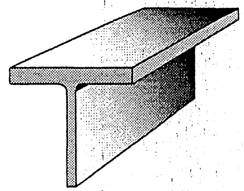
TABLE 3 *a*. ALLOWABLE STRESS p_{bc} IN BENDING (N/mm²) FOR CASE A OF CLAUSE 19*a*(2) FOR GRADE 43 STEEL

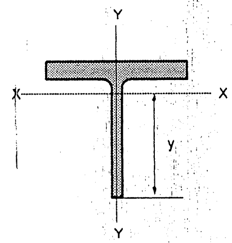
l/r_y	*D/T*									
	5	10	15	20	25	30	35	40	45	50
40	180	180	180	180	180	180	180	180	180	180
45	180	180	180	180	180	180	180	180	180	180
50	180	180	180	180	180	180	180	180	180	180
55	180	180	180	178	176	175	174	174	173	173
60	180	180	176	172	170	169	168	167	167	166
65	180	180	172	167	164	163	162	161	160	160
70	180	177	167	162	159	157	156	155	154	154
75	180	174	163	157	154	151	150	149	148	147
80	180	171	159	153	148	146	144	143	142	141
85	180	168	156	148	143	140	138	137	136	135
90	180	165	152	144	139	135	133	131	130	129
95	180	162	148	140	134	130	127	125	124	123
100	180	160	145	136	129	125	122	119	118	117
105	180	157	142	132	125	120	116	114	112	111
110	180	155	139	128	120	115	111	108	106	105
115	178	152	136	124	116	110	106	103	101	99
120	177	150	133	120	112	106	101	98	96	95
130	174	146	127	113	104	97	94	91	89	88
140	171	142	121	107	97	92	88	85	83	81
150	168	138	116	100	92	87	82	79	77	75
160	166	134	111	96	88	82	77	74	72	70
170	163	130	106	92	84	77	73	69	67	65
180	161	126	102	89	80	73	69	65	63	60
190	158	123	97	85	76	70	65	61	59	56
200	156	119	95	82	73	66	62	58	55	53
210	154	116	92	79	70	63	58	55	52	50
220	151	113	90	77	67	61	56	52	49	47
230	149	110	87	74	65	58	53	49	47	44
240	147	107	85	72	62	56	51	47	44	42
250	145	104	83	69	60	53	48	45	42	40
260	143	101	80	67	58	51	46	43	40	38
270	141	98	78	65	56	49	45	41	38	36
280	139	96	76	63	54	48	43	39	37	35
290	137	94	75	61	52	46	41	38	35	33
300	135	93	73	60	51	44	40	36	34	32

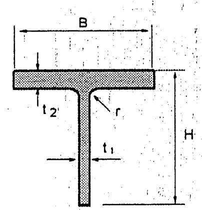
T-Beam

Metric Size | JIS 3192

Sectional Index	Standard Sectional Dimension					Sectional Area	Unit Weight	Informative Reference							Remarks
	Depth of Section	Width of Section	Thickness		Corner Radius			Center of Gravity	Geometrical Moment of Inertia		Radius of Gyration of Area		Modulus of Section		
			Web	Flange											
	HB	H	t_1	t_2	r	A		y	I_x	I_y	i_x	i_y	Z_x	Z_y	
mm	mm	mm	mm	mm	mm	cm^2	kg/m	mm	cm^4	cm^4	cm	cm	cm^3	cm^3	
T 50 x 100	50	100	6	8	10	10.95	8.6	40	16	67	1.2	2.47	4	13.4	
T 62.5 x 125	62.5	125	6.5	9	10	15.16	11.9	50.6	35	147	1.51	3.11	6.9	23.5	
T 75 x 75	75	75	5	7	8	8.93	7	57	42	25	2.18	1.67	7.4	6.6	
T 75 x 150	75	150	7	10	11	20.07	15.75	61.3	66	282	1.81	3.75	10.8	37.6	
T 100 x 100	100	100	5.5	8	11	13.58	10.65	71.7	114	67	2.9	2.22	14.8	13.4	
T 99 x 100	99	100	4.5	7	11	11.59	9.1	78.1	94	58	2.84	2.25	12	11.7	
T 87.5 x 175	87.5	175	7.5	11	12	25.61	20.1	72	114	492	2.11	4.38	15.8	56.2	
T 100 x 200	100	200	8	12	13	31.77	24.95	82.7	184	801	2.41	5.02	22.2	80.1	
T 125 x 125	125	125	6	9	12	18.83	14.8	97.2	248	147	3.63	2.79	25.5	23.5	
T 124 x 124	124	124	5	8	12	16.34	12.85	97.7	207	127	3.56	2.79	21.2	20.5	
T 125 x 250	125	250	9	14	16	46.09	36.2	104.2	411	1825	2.98	6.29	39.4	146	
T 150 x 150	150	150	6.5	9	13	23.39	18.35	115.9	463	254	4.45	3.29	39.9	33.8	
T 149 x 149	149	149	5.5	8	13	20.4	16	116.4	393	221	4.39	3.29	33.7	29.6	
T 150 x 300	150	300	10	15	18	59.9	47	125.3	796	3378	3.64	7.51	63.5	225.2	
T 175 x 175	175	175	7	11	14	31.57	24.8	137.5	814	492	5.08	3.95	59.2	56.3	
T 173 x 174	173	174	6	9	14	26.34	20.7	136	678	396	5.07	3.88	49.9	45.5	
T 175 x 350	175	350	12	19	20	86.95	68.85	146.4	1515	6794	4.17	8.84	103.5	388.2	
T 200 x 200	200	200	8	13	16	42.06	33	157.7	1395	868	5.76	4.54	88.5	86.8	
T 198 x 199	198	199	7	11	16	36.08	28.3	156.3	1193	723	5.75	4.48	76.3	72.7	
T 200 x 400	200	400	13	21	22	109.35	86	167.9	2470	11207	4.75	10.12	147.1	560.4	
T 225 x 200	225	200	9	14	18	48.38	38	173.5	2155	936	6.67	4.4	124.2	93.6	
T 250 x 200	250	200	10	16	20	57.1	44.8	190.5	3210	1071	7.5	4.33	168.5	107.1	
T 300 x 200	300	200	11	17	22	67.2	53	221.6	5786	1139	9.29	4.12	261.9	113.9	
T 294 x 300	294	300	12	20	28	96.25	75.5	233.2	6695	4509	8.34	6.84	295.3	300.6	
T 350 x 300	350	300	13	24	28	117.75	92.5	274.5	12015	5412	10.1	6.78	447.3	360.8	
T 400 x 300	400	300	14	26	28	133.7	105	308.3	18787	5866	11.85	6.62	609.5	391.1	







NOTE :
- Material specification refer to Wide Flange (IWF)
- Tolerance H= ±2mm
- Non standard sizes are available upon request and subject to minimum quantity