00196

THE OPEN UNIVERSITY OF SRI LANKA
Diploma In Technology (Civil) / Bachelor of Technology – Level 3
CEX 3231 – Structural Analysis & Design 1
Final Examination – 2011/2012
Time Allowed 3 hours

Date: 14th March 2012 Time 2.00 p.m. – 5.00 p.m.

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

SECTION A

1. A Symmetrical structure is loaded as shown in Figure Q1.

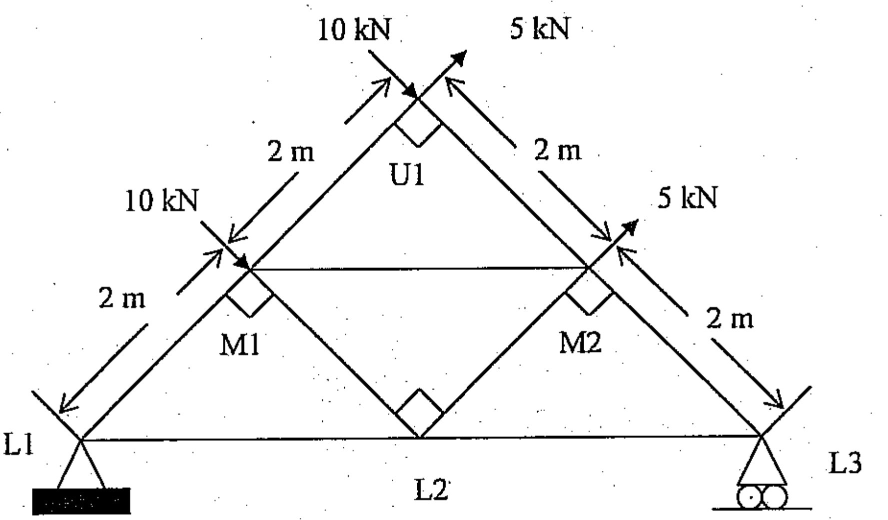


Figure Q1

i) The structure is proposed to be designed as a truss. What are the assumptions and idealizations required to analyses the structure as a truss. By considering the given structure, discus the validity of your assumptions. (5 marks)

ii) Find the member forces of the given truss using method of joints and indicate whether the members are in tension or compression. (10 Marks)

iii) Re check your values of member forces of members L1M1, M1L2, M1M2 using the method of sections. (5 marks)

2. i) Deflections of the joints of trusses are very important design criteria of truss analysis/design. List three methods use in calculating the deflections of trusses and discuss their applications and limitations. (4 Marks)

ii) As shown in Figure Q2, the truss is loaded.
   a) Find the vertical deflection of joint U1 (6 marks)

b) Find the horizontal deflection of joint U1 (6 marks)

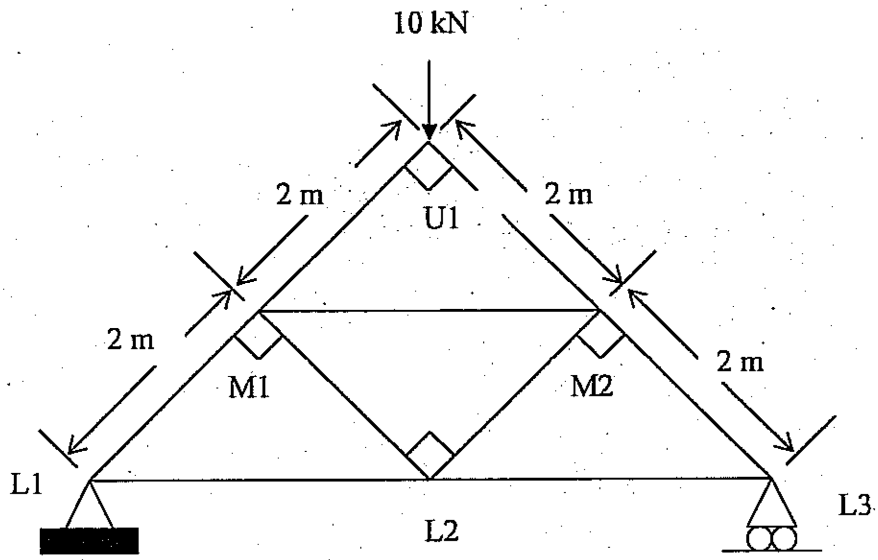


Figure Q2

c). If the allowable deflection is 0.003 x L, where L – maximum member length of the truss, Check the deflection of joint U1. (4 Marks)

Area of the section = 736 mm^2
Elastic Modulus of Steel =205 GPa (1 Pa = 1 N/m^2)

3. i) State what you understand by the term "Influence Line" of mid span moment of the simply supported beam. (3 Marks)

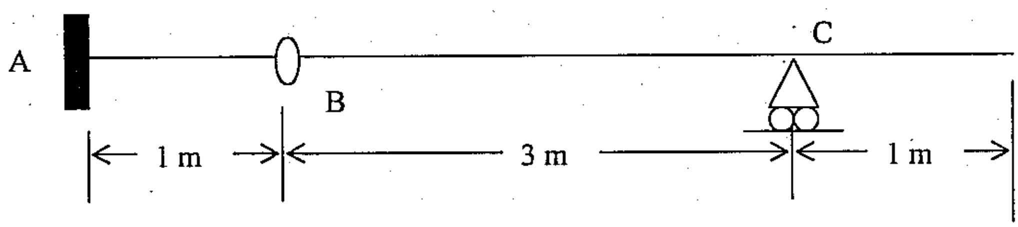


Figure Q3

ii). Figure Q3 shows a propped cantilever and a hinge introduced at point B.
Draw the Influence lines of following actions
i). Reaction at A
ii). Reaction at C
iii). Moment at A
iv). Bending moment at mid span of AC (3x4 = 12 Marks)

iii). Find the maximum Bending Moment at mid span AC if following loads are traveling along the beam. Also indicate the corresponding positions of the loadings.

a). Uniformly distribute load of intensity 5 kN/m of a length 2 m. (2 Marks)
b). Two tires of a bicycle which are 2m apart and front wheel applies 5 kN and rear wheel applies 10 kN. (3 Marks)

4.

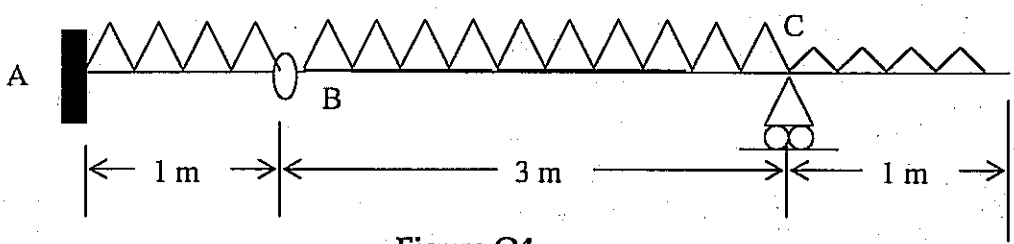


Figure Q4

The beam shown in figure 4 is loaded with dead load, 5 kN/m and imposed load 3 kN/m.

i). Find the maximum and minimum loads applied to the beam. (4 Marks)
ii). If the beam is loaded as shown in the figure 4 draw the Shear Force diagram and Bending moment diagram of the beam for given load condition. (12 Marks)
iii). State what do you understand by "Bending Moment Envelope" (4 marks)

SECTION B

Description for Q5 and Q6

Truss shown in Figure 1 is proposed to design with 50 x 50 x 8 mm EA members.
The single angle members are proposed to use for web members and double angle members are proposed for Chord members. Bolted connections with M 16 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	8.9	Tension
L1M1	2.5	Tension
L3M2	12.5	Compression
M1U1	5	Tension
M2U1	10	Compression
L2M1	7.5	Compression
L2M2	7.5	Tension

M1M2	3.55	Compression

Table 1

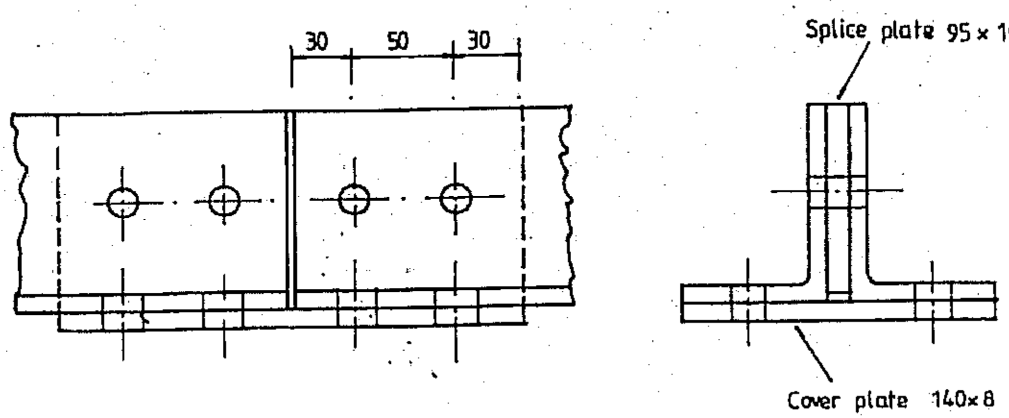
5. i). Design the web members subjected to tension. (8 marks)
   ii). Design the chord members subjected to Tension (6 Marks)
   iii). If bottom chord members are subjected to 1.5 kNm of bending moment other than axial load, check the suitability of selected section. (6 Marks)

6. i). Define following terms used in design of compression members.
   i). Effective length
   ii). Radius of gyration
   iii). Slenderness Ratio (2x3 = 6 marks)
   ii). Design the web members subjected to compression. Assume at least two bolts per each connection (If selected section is not satisfied select a suitable section from Section table of Equal angles). (8 Marks)
   iii). Design the chord members subjected to compression. (6 marks)
   Radius of gyration of double angle members can be calculated from

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

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

7.



2 No. 100x65x8 ⅃L
Bolts - 20mm dia. ordinary bolts
Holes - 22mm dia.

Figure Q7

The connection shown in the figure 7 is designed with M20 bolts.

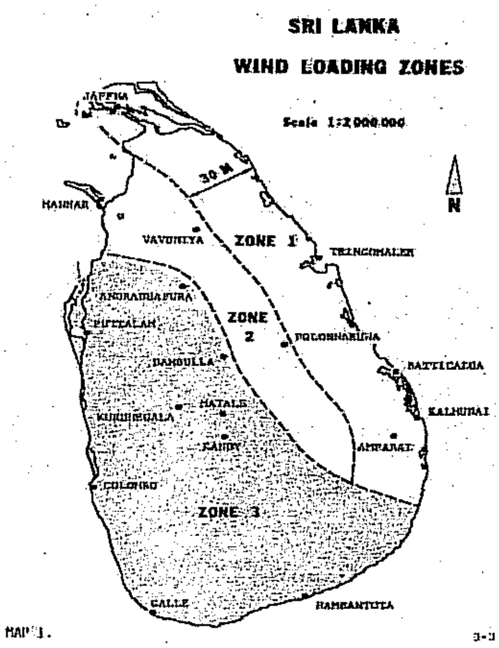
i). Find the capacity of M20 bolt in single shear connection. (6 Marks)
ii). Find the capacity of M20 bolt in double shear connection. (6 Marks)
iii). Using the capacities found in i), ii), calculate the capacity of the connection. (8 Marks)

8. i). Explain following terms used in wind load calculation.
   i). Basic wind speed
   ii). Design wind speed
   iii). Post Disaster Structures
   iv). Wind Zones in Sri Lanka
   v). Windward slope and Leeward slope (2x 5 = 10 Marks)

ii). The truss shown in Figure Q1 is proposed to use as a roof truss. Considering following details find the total wind load applied on Joint M1, if L1U1 is windward slope. (10 Marks)

<u>Details for wind load calculation</u>

Wind Angle = 0^0
Location of the Building = Matara
Building is proposed to use as a Police Station
$S_1 = 1.0$, $S_2 = 0.85$, $S_3 = 1.0$
Cpi = - 0.1
Spacing of truss = 2.5 m
Total height of the building = 3 m

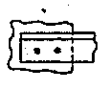
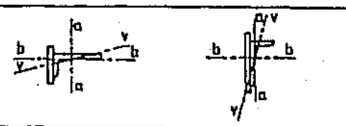
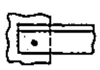
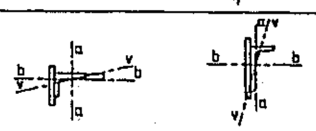
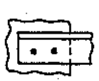
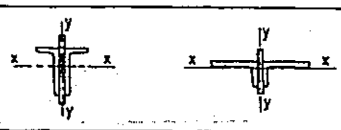
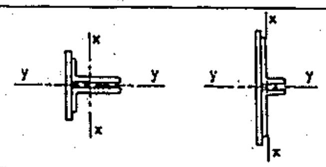


Zone	Basic wind speed V in m/s	
	Post-disaster structures	Normal structures
1	53.5	49.0
2	47.0	42.5
3	38.0	33.5

Design Charts

xa	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 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.

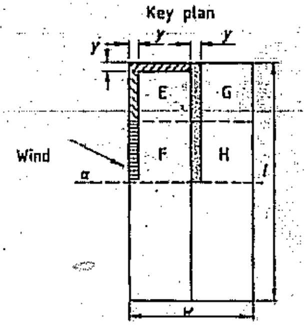
NOTE 4. Double angles are interconnected back-to-back to satisfy Clause 37.

Table 8. Pressure coefficients C_{pe} for pitch roofs of rectangular clad buildings

Building height ratio	Roof angle	Wind angle α 0° EF	Wind angle α 0° GH	Wind angle α 90° EG	Wind angle α 90° FH	Local coefficients			
	degrees								
$\frac{h}{w} \leq \frac{1}{2}$	0	−0.8	−0.4	−0.8	−0.4	−2.0	−2.0	−2.0	—
	5	−0.9	−0.4	−0.8	−0.4	−1.4	−1.2	−1.2	−1.0
	10	−1.2	−0.4	−0.8	−0.6	−1.4	−1.4		−1.2
	20	−0.4	−0.4	−0.7	−0.6	+1.0			−1.2
	30	0	−0.4	−0.7	−0.6	−0.8			−1.1
	45	+0.3	−0.5	−0.7	−0.6				−1.1
	60	+0.7	−0.6	−0.7	−0.6				−1.1
$\frac{1}{2} < \frac{h}{w} \leq \frac{3}{2}$	0	−0.8	−0.6	−1.0	−0.6	−2.0	−2.0	−2.0	—
	5	−0.9	−0.6	−0.9	−0.6	−2.0	−2.0	−1.5	−1.0
	10	−1.1	−0.6	−0.8	−0.6	−2.0	−2.0	−1.5	−1.2
	20	−0.7	−0.5	−0.8	−0.6	−1.5	−1.5	−1.5	−1.0
	30	−0.2	−0.5	−0.8	−0.8	−1.0			−1.0
	45	+0.2	−0.5	−0.8	−0.8				
	60	+0.6	−0.5	−0.8	−0.8				
$\frac{3}{2} < \frac{h}{w} < 6$	0	−0.7	−0.6	−0.9	−0.7	−2.0	−2.0	−2.0	—
	5	−0.7	−0.6	−0.8	−0.8	−2.0	−2.0	−1.5	−1.0
	10	−0.7	−0.6	−0.8	−0.8	−2.0	−2.0	−1.5	−1.2
	20	−0.8	−0.6	−0.8	−0.8	−1.5	−1.5	−1.5	−1.2
	30	−1.0	−0.5	−0.8	−0.7	−1.5			
	40	−0.2	−0.5	−0.8	−0.7	−1.0			
	50	+0.2	−0.5	−0.8	−0.7				
	60	+0.5	−0.5	−0.8	−0.7				

NOTE 1. h is the height to eaves or parapet and w is the lesser horizontal dimension of a building.
NOTE 2. The pressure coefficient on the underside of any roof overhang should be taken as that on the adjoining wall surface.
Where no local coefficients are given the overall coefficients apply.
NOTE 3. For hipped roofs the local coefficient for the hip ridge may be conservatively taken as the appropriate ridge value.

Key plan



$y = h$ or $0.15w$, whichever is the lesser.

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

As altered Dec. 1989

l/r	p_c (N/mm^2) 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 30a.

BS 449: Part2: 1969 Tables & Clause

from BS 449 Table 10: Allowable maximum shear stress p_q

Allowable maximum shear stress p_q for sections, bars, plates, wide flats and hot rolled sections of grade 43 steel:
For thickness ≤ 40 mm: 125 N/mm²
For 40 < thickness ≤ 100 mm: 115 N/mm²

BS 449 Table 20: Allowable stresses in Rivets and Bolts (N/mm²)

Description of fasteners	Axial tension	Shear	Bearing
Power-driven rivets	100	100	300
Hand-driven rivets	80	80	250
Close tolerance and turned bolts	120	100	300
Bolts in clearance holes	120	80	250

BS 449 Table 20A : Allowable Bearing stresses on connected parts (N/mm²)

Description of fasteners	Material of connected part		
	Grade 43	Grade 50	Grade 55
Power-driven rivets Close tolerance and turned bolts	300	420	480
Hand-driven rivets Bolts in clearance holes	250	350	400

BS 449 Table 21: Edge distance of Holes

Diameter of hole	Distance to sheared or hand flame cut edge	Distance to rolled, machine flame cut, sawn or planed edge
mm	mm	mm
39	68	62
36	62	56
33	56	50
30	50	44
26	42	36
24	38	32
22	34	30
20	30	28
18	28	26
16	26	24
14	24	22