THE OPEN UNIVERSITY OF SRI LANKA
Diploma In Technology (Civil) / Bachelor of Technology - Level 3
CEX 3231 – Structural Analysis & Design 1
Final Examination – 2012/2013
Time Allowed 3 hours

Date: 14th August 2013 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). Sketch the supports used in structures and mark their appropriate reactions. (3 Marks)

b). A structure is loaded as shown in Figure Q1 that is supported with a pin support at U1.

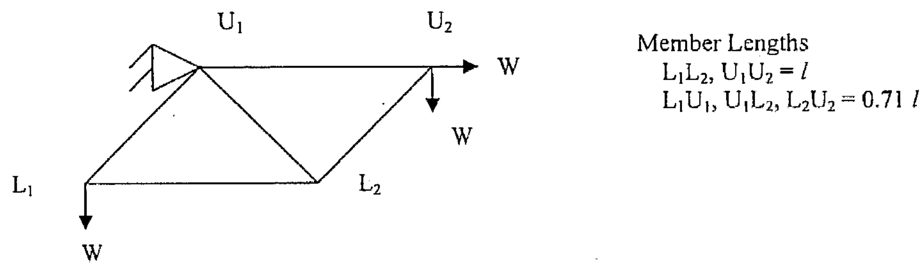


Figure Q1

i. Show that the structure given in Figure Q1 is not in equilibrium (2 Marks)

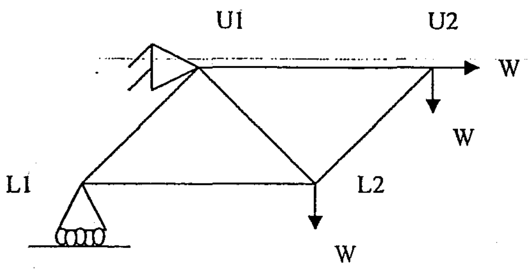
ii. The truss shown in Figure Q1 is now supported at L_2 with a roller support (restricted on Vertical direction). Show that the new structure is statically determinate. (2 Marks)

iii. Analyze the truss shown on figure Q1 after the modification mentioned in part ii using an analytical method and give the member forces in terms of W. Also mention whether member forces are tension or compression. (7 Marks)

iv. Justify your answers in part iii with Graphical method. (6 Marks)

2. a). List down three methods used to determine the deflection of trusses. Discuss their limitations. (4 Marks)

b). Find the defection of point U_2 of the truss given in Figure Q2, in terms of W, A, E. (14 Marks)
(Assume AE value is same for all the members)



Member Lengths
L_1L_2, $U_1U_2 = l$
L_1U_1, U_1L_2 $L_2U_2 = 0.71\ l$

Figure Q2

c). Explain why strain energy method cannot be used to find deflection of point L_2.

(2 Marks)

3.

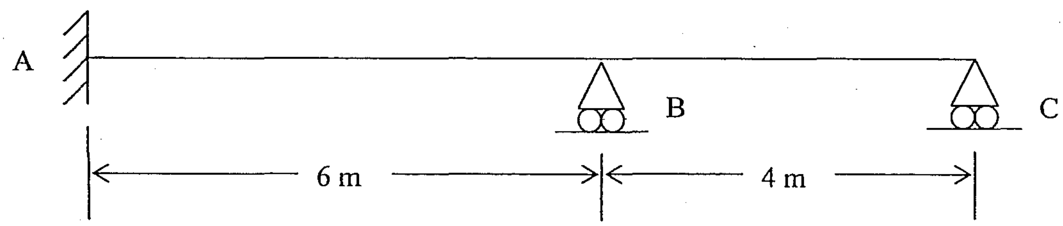


Figure Q3

a). Show that statically indeterminacy of the beam given in Figure Q3 is 2. (2 Marks)

b). Assume there are two hinges at mid spans of each span AB and BC and draw influence lines for
   a). Reaction at B
   b). End moment at A
   c). Bending moment at B (10 Marks)

c). Following loads (given in parts i and ii) are moving along the beam. Find the maximum Bending Moment at support A and also indicate the corresponding positions of the loadings.
   i. Uniformly distribute load of intensity 5 kN/m of a length more than 10 m.
   ii. Two tires of a bicycle which are 2m apart and front wheel applies 5 kN and rear wheel applies 10 kN.
(8 Marks)

4.

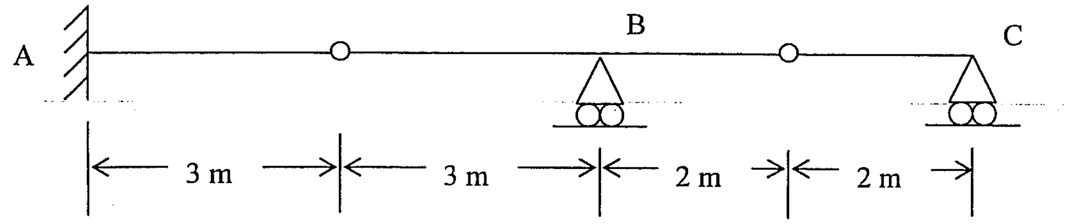


Figure Q 4

The beam given in Figure Q4 is loaded with dead load (G_k) of 10 kN/m and imposed load (Q_k) 5 kN/m. Following load cases 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

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

b). Draw the 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

Data – For Q5 and Q6

Properties	50 x 50 x 7 EA	70 x 70 x 8 EA
Area of Section	7.41 cm^2	10.6 cm^2
Distance to centre of gravity	1.52 cm	2.01 cm
Second moment of area	16.3 cm^4 xx and yy axes	47.5 cm^4 xx and yy axes
Radius of gyration xx axis , yy axis vv axis	 1.48 cm 0.96 cm	 2.11 cm 1.36 cm

5. a).Define the two terms effective sectional area and gross sectional area of a single angle member used as a member of steel roof truss (4 Marks)

b). Check the suitability of a 70 x 70 x 8 equal angle member which is subjected to 75 kN tension load. Assume that the member is connected with 20 mm bolts at both ends. (8 Marks)

c). If 4 kNm sagging bending moment is applied to the member other than the applied tensile force check the suitability of the given member for this loading condition. (8 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). A compression member of length 2.5 m is proposed to design with
   i). Single angle member 70 x 70 x 8 EA
   ii). Back to back double angle member of 50 x 50 x 7 EA,

both the members are connected with two M20 bolts in both ends.

Find the capacity of each selection.

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

(14 Marks)

7. A simply supported beam of effective span 4m is used to support the concrete slab of 150 mm in thickness and following details are provided.

Spacing of the beams = 1.0 m
Dead load from the finishers = 1.0 kN/m^2
Density of Concrete = 24 kN/m^3
Imposed load from the people = 1.5 kN/m^2
Imposed load from the furniture = 0.5 kN/m^2

a). Find out the design load applied on the beam. (Take the self weight of the beam as 15 % of total calculated design load).

(4 Marks)

b). If a T beam 100 x 200 is selected for this simply supported beam, check the suitability of the selection.

(8 Marks)

From the tabulated properties of 100 x 200 T beam

Depth of Section, D = 100 mm, Width of the section B = 200 mm
Flange Thickness, T = 12 mm, web thickness, t = 8 mm
Radius of gyration, r_x = 14.6 cm and r_y = 3.77 cm
Sectional Area = 31.77 cm^2
Distance to the center of gravity Cy = 82.7 mm
Elastic Modulus, Z_{xx} = 80.1 cm^3, Z_{yy} = 22.2 cm^3

c) The beam is connected to a plate through its flange with two symmetrical lines of M 20 bolts.
   i. Calculate the number of bolts required for the joint.
   ii. Draw the arrangement of bolts considering spacing and edge/end distances.

(8 Marks)

The allowable strengths are:
the allowable stress in bolts in clearance holes, in shear = 80 N/mm^2
the allowable stress in bolts in clearance holes, in bearing = 250 N/mm^2
the allowable stress in bolts in clearance holes, in axial tension = 120 N/mm^2
the edge distance of 22 mm diameter holes = 30 mm
minimum spacing between center of bolts = 2.5 x Nominal Diameter

8. a). Explain following terms used in wind load calculation.
i). Design wind speed
ii). Post Disaster Structures
iii). Windward slope and Leeward slope (2x 3 = 6 Marks)

b). Derive the formula for Euler buckling load of cantilever strut with first principles. (10 Marks)

c). A cantilever strut of effective length 4 m is used as a column and which is loaded only with axial compression load.
Dimension of column – 300 mm x 400 mm
Elastic modulus of column material – 6.9×10^8 N/m^2
Compressive strength of column material – 5 N/mm^2

Check whether the member is safe under these conditions

(4 Marks)

DATA SHEETS

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.

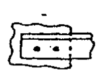
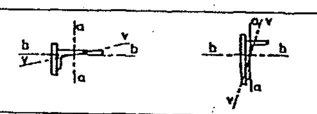
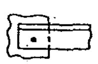
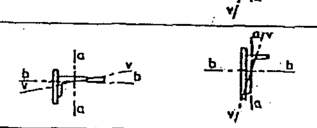
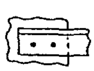
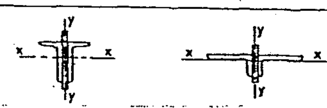
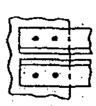
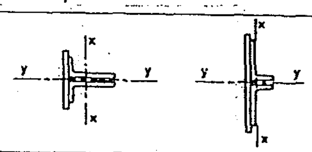
Where lug angles are used, the net sectional area of the whole of the angle member shall be taken.

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 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*.

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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 3 *a*. ALLOWABLE STRESS p_{bc} IN BENDING (N/mm^2) 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