THE OPEN UNIVERSITY OF SRI LANKA
Diploma In Technology (Civil) / Bachelor of Technology – Level 3
CEX 3231 – Structural Analysis & Design 1
Final Examination – 2007/2008
Time Allowed 3 hours

Date 6th of May 2008   Time – 9.30 – 12.30 hrs

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
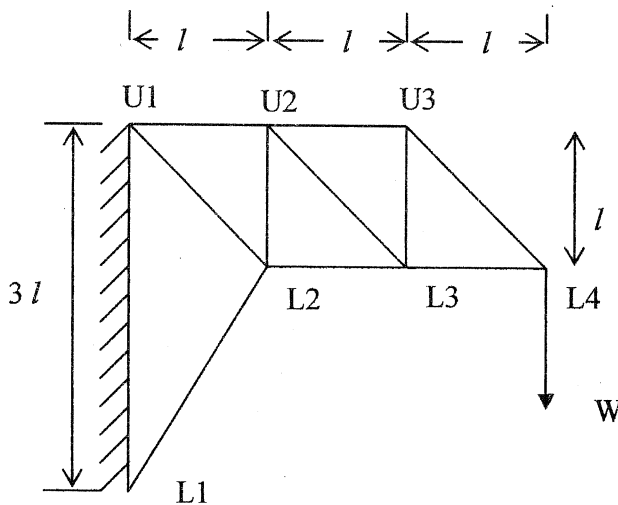
1). Figure 1 shows the body diagram of a cantilever truss.

FIGURE 1

a)   State the difference between statically determinant structures and statically indeterminant structures.

(4 Marks)

b)   Find out the member forces of each member of the truss shown in Figure 1 using the method of Joints in terms of W. Indicate the sign of each member force. (Use sign convention Tension – positive)

(10 Marks)

c)   Find out the member forces of the members U2U3, U2L3 and U3L3 using the method of Section.

(6 Marks)

2). a). Discuss the drawbacks of the Strain energy method of displacement calculation with respect to the Virtual work method of displacement calculation.

(4 Marks)

b). Find out the vertical displacement of point L4 of truss given in Figure 1 in the terms of W, l, AE. (Assume AE is constant for all the members)

c). Find out the horizontal and vertical displacements of point L2.

3) Figure 2 shows a simple beam with an overhang

Figure 2

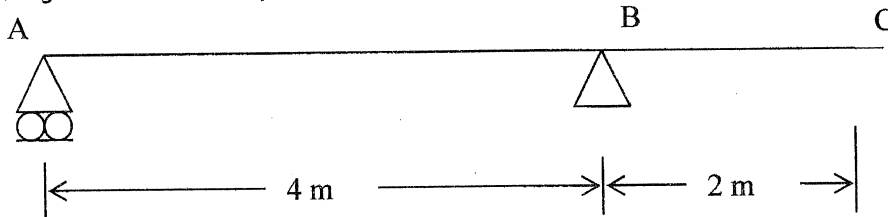a). Draw the Influence lines for the following
    i). Reaction at A
    ii). Bending moment at mid span of the AB
    iii). Moment of Support B
    iv). Shear force at B

(8 Marks)

b). If following loads are moving on the beam, find out the maximum Bending Moment at mid span of the AB and respective load positions.
    i). Two concentrated loads of 5 kN each and 2 m apart.
    ii). A Uniformly distributed load of 2 kN /m and 10 m in length.
    iii). A Uniformly distributed load of 5 kN /m and 2 m in length.

(12 Marks)

SECTION B

Data sheets are available and should be returned please, before you leave the examination hall

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

(5 Marks)

b). Check the suitability of a 70 x 70 x 8 equal angle member which is subjected to the 50 kN tension load. Assume that the member is connected with 18 mm bolts at both ends.

(8 Marks)

c). If 5 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.

(7 Marks)

the properties of a 70 x 70 x 8 equal angle as follows
Area of Section = 10.7 cm^2, distance to center of gravity c = 2.02 cm,
Second moment of area
relative to xx-axis , y-y axis =58.0 cm^4
Radius of gyration
relative to x-x axis and y-y axis = 2.12 cm and vv-axis =1.37 cm

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 bearing stresses on connected parts   = 250 N/mm^2
the edge distance of 20 mm diameter holes   = 30 mm

5 a). Define the term slenderness ratio used in steel design and explain its requirements

(4 Marks)

b). A back to back double angle member of 70 x 70 x 8 used in roof truss is 2.5 m long and which is connected by two 18 mm bolts. Determine its compressive strength.

(10 marks)

The radius of gyration of double angle member is given by

$$r_{yy} = \sqrt{\left(r_{yy}^2 + \left(c_y + \frac{12}{2} \right)^2 \right)}$$

Where all the terms have their standard meanings and thickness of gusset plate is taken as 12 mm.

c). If the member is subjected to 30 kN axial compression load, check whether two bolts used for connection are enough.

(6 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 bearing stresses on connected parts   = 250 N/mm^2
the edge distance of 18 mm diameter holes   = 30 mm

6). Figure 3 shows the body diagram of Cantilever span of the steel beam.
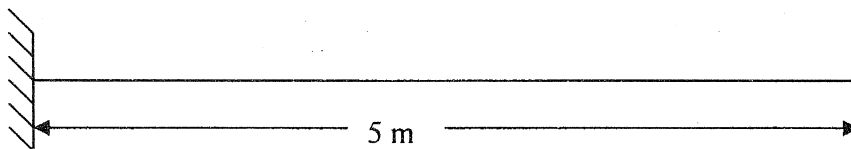

Figure 3

The beam supports the concrete slab of 150 mm in thickness and following details are provided.

Spacing of the beams = 1.0 m
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
Dead load from the finishers = 1.0 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). Draw the Shear Force diagram and the Bending Moment diagram for the given beam by taking effective span as 5 m. Find the design Bending moment and Shear force.

(8 Marks)

c). If a universal beam (UB) 356 x 171 x 45 is selected for this cantilever beam check the suitability of the selected UB.

(8 Marks)

From the tabulated properties of 356 x 171 x 45 (UB)
Elastic Modulus Z_{xx} = 686 x 10^3 mm^3
Depth of Section, D = 352 mm
Flange Thickness, T = 15.7 mm
Radius of gyration, r_x = 14.6 cm and r_y = 3.77 cm

7). a). State and describe the factors used in finding out of the Design Wind speed of the steel roof truss.

(6 Marks)

b). Discuss why the Police station of a particular area is considered as a post disaster structure in wind load calculation.

(3 Marks)

c). Describe how the structures can fail due to the lateral buckling.

(3 Marks)

d). Derive a formula for Euler buckling load of a pinned strut.

(8 Marks)

TABLE 19. ALLOWABLE STRESS P_t IN AXIAL TENSION

Form	Grade	Thickness	P_t
		mm	N/mm^2
Sections, bars, plates,	43	≤ 40	170
wide flats and hot		over 40 but ≤ 100	155
rolled hollow sections	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 51e or 54g so that the maximum ratio of slenderness of each member between connections is not greater than 80.

To the net sectional area of the connect part, add the sectional area of the unconnected part multiplied by:

$$\frac{5a_1}{5a_1 + a_2}$$

where a_1 = the net sectional area of the connected part.

    a_2 = the sectional area of the unconnected part.

Where the components are widely spaced, this rule does not apply, and the member shall be specially designed.

    b. Double angles, tees or channels placed back-to-back and connected to each side of a gusset or to each side of part of a rolled section. For computing the mean tensile stress the net sectional area of the pair shall be taken, provided the members are connected together along their length as specified in Subclause 51 e or 54g.

NOTE. The area of the leg of an angle shall be taken as the product of the thickness by the length from the outer corner minus half the thickness, and the area of the leg of a tee as the product of the thickness by the depth minus the thickness of the table.

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.

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c. **Angles as struts.** (i) For single-angle struts connected to gussets or to a section either by riveting or bolting by not less than two rivets or bolts in line along the angle at each end, or by their equivalent in welding, the eccentricity of the connection with respect to the centroid of the strut may be ignored and the strut designed as an axially-loaded member provided that the calculated average stress does not exceed the allowable stresses given in Table 17, in which l/r is taken as the greatest of:

1. $0.85L_{vv}/r_{vv}$ but $\geq 0.7L_{vv}/r_{vv} + 15$

2. $1.0L_{aa}/r_{aa}$ but $\geq 0.7L_{aa}/r_{aa} + 30$

3. $0.85L_{bb}/r_{bb}$ but $\geq 0.7L_{bb}/r_{bb} + 30$

The length of L shall be taken as the distance between the intersections of centroidal axes or the intersections of the setting out lines of the rivets or bolts and r is the radius of gyration about the relevant axis. Axes are defined in Table 18. Intermediate lateral restraints shall be allowed for in determining the length L for buckling about the relevant axis.

Single angle struts with single-bolted or riveted connections shall be treated similarly, but the ratio of slenderness l/r shall not exceed 180. The calculated stress for such single angle struts shall not exceed 80 per cent of the values given in table 17 and l/r shall be taken as the greatest of:

1. $1.0L_{vv}/r_{vv}$ but $\geq 0.7L_{vv}/r_{vv} + 15$

2. $1.0L_{aa}/r_{aa}$ but $\geq 0.7L_{aa}/r_{aa} + 30$

3. $1.0L_{bb}/r_{bb}$ but $\geq 0.7L_{bb}/r_{bb} + 30$

contd.

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

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 30a

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/mm²) FOR CASE A OF CLAUSE 19a(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

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