2705/302
2709/302
2710/302
STRUCTURES III
Oct. / Nov. 2017
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN BUILDING TECHNOLOGY
DIPLOMA IN ARCHITECTURE
MODULE III

STRUCTURES III

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:
answer booklet;
scientific calculator.
*This paper consists of **EIGHT** questions.*
*Answer any **FIVE** questions in the answer booklet provided.*
All questions carry equal marks.
Maximum marks for each part of a question are indicated.
Relevant design tables are attached.
Candidates should answer the questions in English.

This paper consists of 8 printed pages.

Candidates should check the question paper to ascertain that all the pages are printed as indicated and that no questions are missing.

1. A simply supported beam is loaded with unfactored dead loads as shown in **figure 1**.

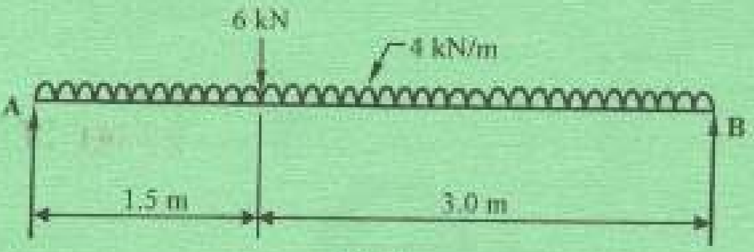


Fig. 1

Assuming that the beam is fully laterally restrained, select a suitable universal beam section in grade 5275 steel (grade 43) to satisfy bending, shear and deflection.
$E = 205\ kN/mm^2$ (20 marks)

2. A simply supported timber beam of effective span 2.4 carries a uniformly distributed load of 2 kN/m inclusive of self weight and a concentrated load of 2 kN at mid-span. The ends of the beam are held in position. Select a suitable rectangular section for the beam using timber of strength class C_{16}. (SC 3) Check for bending, shear, deflection and lateral buckling. Assume all modification factors are equal to 1.0. (20 marks)

3. Using the three moments theorem, analyse the beam shown in **figure 2** and sketch the bending moment and shear force diagrams, indicating the values at all critical points. (20 marks)

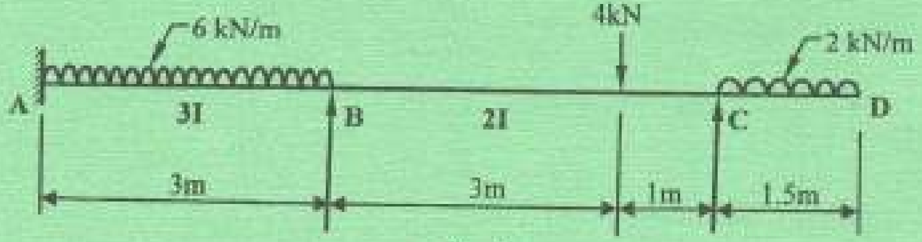


Fig. 2

4. Using the moment distribution method, analyse the frame shown in **figure 3** and hence sketch the bending moment diagram, indicating the values at all critical points. (20 marks)

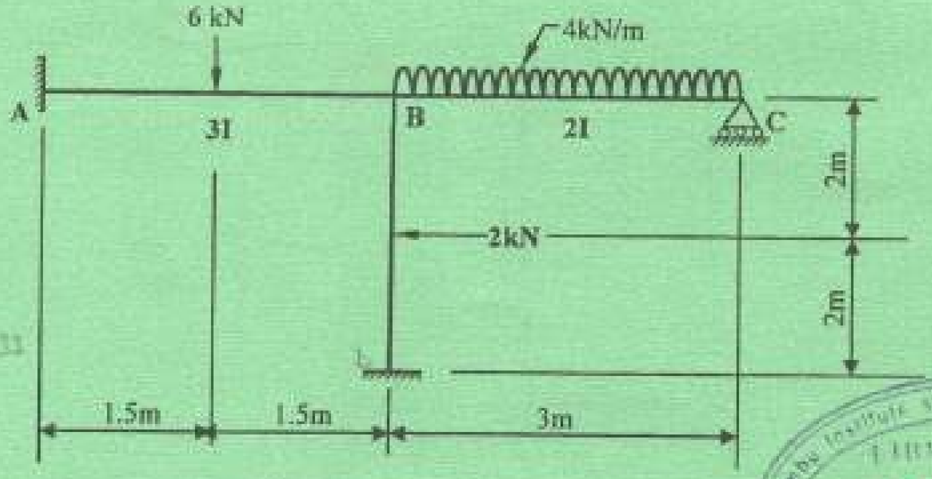


Fig. 3

5. **Figure 4** shows a simply supported beam.

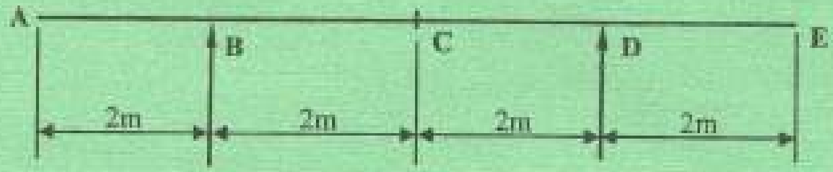


Fig. 4

Using equilibrium conditions, sketch the influence line diagrams for the following load components:

(a) reaction at point D;
(b) shear at point C;
(c) bending moment at point C.

Plot the values at every 1 m interval. (20 marks)

6. A cased 254 x 254 x 107 universal column of grade 5275 (grade 43) steel had an effective length of 3.6 m and supports factored loads as shown in **figure 5**.

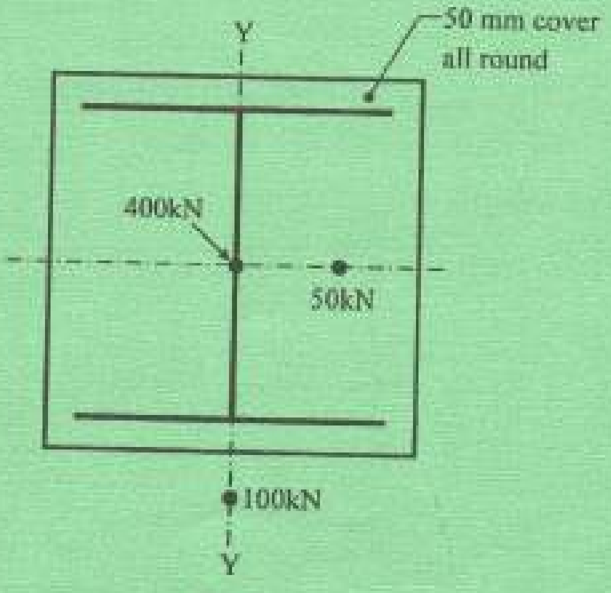


Fig. 5

Check the adequacy of the cased section.
$f_{cu} = 25\ N/mm^2$; $P_c = 212\ N/mm^2$ (20 marks)

7. **Figure 6** shows a loaded timber truss.

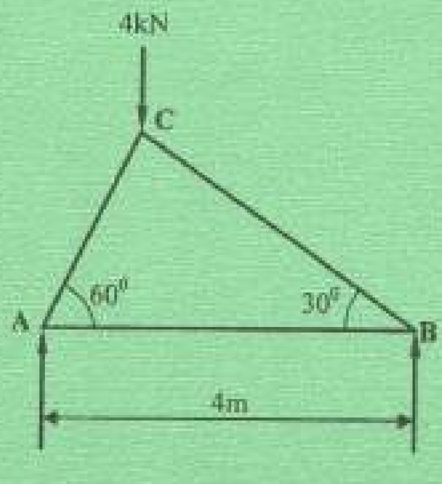


Fig. 6

Assuming that all members are pin-jointed, design members AB and AC using rectangular timber sections of strength class C_{16} (SC 3).

permissible tensile stress = $2.56\ N/mm^2$

permissible compressive stress = $4.08\ N/mm^2$

(20 marks)

8. Using the moment distribution method, analyse the frame shown in **figure** 7 and hence sketch the bending moment diagram, indicating the values at all critical points.
Make **six** distributions. (20 marks)

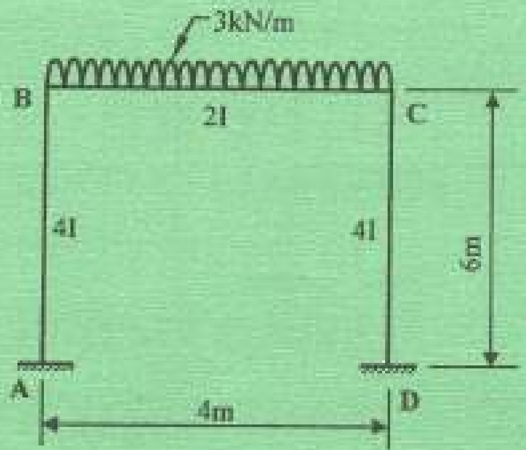
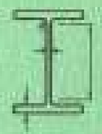


Fig. 7



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

UNIVERSAL COLUMNS

Section Designation	Mass per Metre	Depth of Section	Width of Section	Thickness		Root Radius	Depth between Fillets	Ratios for Local Buckling		Second Moment of Area		Radius of Gyration		Elastic Modulus		Plastic Modulus		Buckling Parameter	Torsional Index	Warping Constant	Area of Section
				Web	Flange			Flange	Web	Axis x-x	Axis y-y	Axis x-x	Axis y-y	Axis x-x	Axis y-y	Axis x-x	Axis y-y				
		D	B	t	T	r	d	b/T	d/t									u	x	H	A
	kg/m	mm	mm	mm	mm	mm	mm			cm^4	cm^4	cm	cm	cm^3	cm^3	cm^3	cm^3			dm^6	cm^2
356x406x634	633.9	474.6	424	47.6	77	15.2	290.2	2.75	6.1	275000	98100	18.4	11	11600	4630	14200	7110	0.843	5.46	38.8	808
356x406x551	551	455.6	418.5	42.1	67.5	15.2	290.2	3.1	6.89	227000	82700	18	10.9	9960	3950	12100	6060	0.841	6.05	31.1	702
356x406x467	467	436.6	412.2	35.8	58	15.2	290.2	3.55	8.11	183000	67800	17.5	10.7	8380	3290	10000	5030	0.839	6.86	24.3	595
356x406x393	393	419	407	30.6	49.2	15.2	290.2	4.14	9.48	147000	55400	17.1	10.5	7000	2720	8220	4150	0.837	7.86	18.9	501
356x406x340	339.9	406.4	403	26.6	42.9	15.2	290.2	4.7	10.9	123000	46900	16.8	10.4	6030	2330	7000	3540	0.836	8.85	15.5	433
356x406x287	287.1	393.6	399	22.6	36.5	15.2	290.2	5.47	12.8	99900	38700	16.5	10.3	5070	1940	5810	2950	0.835	10.2	12.3	366
356x406x235	235.1	381	394.8	18.4	30.2	15.2	290.2	6.54	15.8	79100	31000	16.3	10.2	4150	1570	4690	2380	0.834	12.1	9.54	299
356x368x202	201.9	374.6	374.7	16.5	27	15.2	290.2	6.94	17.6	66300	23700	16.1	9.6	3540	1260	3970	1920	0.844	13.4	7.16	257
356x368x177	177	368.2	372.6	14.4	23.8	15.2	290.2	7.83	20.2	57100	20500	15.9	9.54	3100	1100	3460	1670	0.844	15	6.09	226
356x368x153	152.9	362	370.5	12.3	20.7	15.2	290.2	8.95	23.6	48600	17600	15.8	9.49	2680	948	2960	1430	0.844	17	5.11	195
356x368x129	129	355.6	368.6	10.4	17.5	15.2	290.2	10.5	27.9	40200	14600	15.6	9.43	2260	793	2480	1200	0.844	19.9	4.18	164
305x305x283	282.9	365.3	322.2	26.8	44.1	15.2	246.7	3.65	9.21	78900	24600	14.8	8.27	4320	1530	5110	2340	0.855	7.65	6.35	360
305x305x240	240	352.5	318.4	23	37.7	15.2	246.7	4.22	10.7	64200	20300	14.5	8.15	3640	1280	4250	1950	0.854	8.74	5.03	306
305x305x198	198.1	339.9	314.5	19.1	31.4	15.2	246.7	5.01	12.9	50900	16300	14.2	8.04	3000	1040	3440	1580	0.854	10.2	3.88	252
305x305x158	158.1	327.1	311.2	15.8	25	15.2	246.7	6.22	15.6	38700	12600	13.9	7.9	2370	808	2680	1230	0.851	12.5	2.87	201
305x305x137	136.9	320.5	309.2	13.8	21.7	15.2	246.7	7.12	17.9	32800	10700	13.7	7.83	2050	692	2300	1050	0.851	14.2	2.39	174
305x305x118	117.9	314.5	307.4	12	18.7	15.2	246.7	8.22	20.6	27700	9060	13.6	7.77	1760	589	1960	895	0.85	16.2	1.98	150
305x305x97	96.9	307.9	305.3	9.9	15.4	15.2	246.7	9.91	24.9	22200	7310	13.4	7.69	1450	479	1590	726	0.85	19.3	1.56	123
254x254x167	167.1	289.1	265.2	19.2	31.7	12.7	200.3	4.18	10.4	30000	9870	11.9	6.81	2080	744	2420	1140	0.851	8.49	1.63	213
254x254x132	132	276.3	261.3	15.3	25.3	12.7	200.3	5.16	13.1	22500	7530	11.6	6.69	1630	576	1870	878	0.85	10.3	1.19	168
254x254x107	107.1	266.7	258.8	12.8	20.5	12.7	200.3	6.31	15.6	17500	5930	11.3	6.59	1310	458	1480	697	0.848	12.4	0.898	136
254x254x89	88.9	260.3	256.3	10.3	17.3	12.7	200.3	7.41	19.4	14300	4860	11.2	6.55	1100	379	1220	575	0.85	14.5	0.717	113
254x254x73	73.1	254.1	254.6	8.6	14.2	12.7	200.3	8.96	23.3	11400	3910	11.1	6.48	898	307	992	465	0.849	17.3	0.562	
203x203x86	86.1	222.2	209.1	12.7	20.5	10.2	160.8	5.1	12.7	9450	3130	9.28	5.34	850	299	977	456	0.85	10.2	0.318	
203x203x71	71	215.8	206.4	10	17.3	10.2	160.8	5.97	16.1	7620	2540	9.18	5.3	706	246	799	374	0.853	11.9	0.25	
203x203x60	60	209.6	205.8	9.4	14.2	10.2	160.8	7.25	17.1	6120	2060	8.96	5.2	584	201	656	305	0.846	14.1	0.197	
203x203x52	52	206.2	204.3	7.9	12.5	10.2	160.8	8.17	20.4	5260	1780	8.91	5.18	510	174	567	264	0.848	15.8	0.167	
203x203x46	46.1	203.2	203.6	7.2	11	10.2	160.8	9.25	22.3	4570	1550	8.82	5.13	450	152	497	231	0.847	17.7	0.143	
152x152x37	37	161.8	154.4	8	11.5	7.6	123.6	6.71	15.5	2210	706	6.85	3.87	273	91.5	309	140	0.848	13.3	0.04	
152x152x30	30	157.6	152.9	6.5	9.4	7.6	123.6	8.13	19	1750	560	6.76	3.83	222	73.3	248	112	0.849	16	0.031	
152x152x23	23	152.4	152.2	5.8	6.8	7.6	123.6	11.2	21.3	1250	400	6.54	3.7	164	52.6	182	80.1	0.84	20.7	0.021	

Grade stresses and moduli of elasticity for various strength classes: for service classes 1 and 2

Strength class	Bending parallel to grain N/mm²	Tension parallel to grain N/mm²	Compression parallel to grain N/mm²	Compression perpendicular to grain [a] N/mm²		Shear parallel to grain N/mm²	Modulus of elasticity		Characteristic density, ρ_k [b] kg/m³	Average density, ρ_{mean} [b] kg/m³
							Mean N/mm²	Minimum N/mm²		
C14	4.1	2.5	5.2	2.1	1.6	0.60	6 800	4 600	290	350
C16	5.3	3.2	6.8	2.2	1.7	0.67	8 800	5 800	310	370
C18	5.8	3.5	7.1	2.2	1.7	0.67	9 100	6 000	320	380
C22	6.8	4.1	7.5	2.3	1.7	0.71	9 700	6 500	340	410
C24	7.5	4.5	7.9	2.4	1.9	0.71	10 800	7 200	350	420

NOTE Strength classes C14 to C40 are for softwoods and D30 to D70 are for hardwoods

[a] When the specification specifically prohibits wane at bearing areas, the higher values of compression perpendicular to grain stress may be used, otherwise the lower values apply.

[b] The values of characteristic density given above are for use when designing joints. For the calculation of dead load, the average density should be used.

Maximum depth to breadth ratios (solid and laminated members)

Degree of lateral support	Maximum depth to breadth ratio
No lateral support	2
Ends held in position	3
Ends held in position and member held in line as by purlins or tie rods at centres not more than 30 times breadth of the member	4
Ends held in position and compression edge held in line, as by direct connection of sheathing, deck or joists	5
Ends held in position and compression edge held in line, as by direct connection of sheathing, deck or joists, together with adequate bridging or blocking spaced at intervals not exceeding six times the depth	6
Ends held in position and both edges held firmly in line	7

Limiting width-to-thickness ratios for sections other than CHS and RHS

Compression element			Ratio[a]	Limiting value[b]		
				Class 1 plastic	Class 2 compact	Class 3 semi-compact
Outstand element of compression flange	Rolled section		b/T	9E	10E	15E
	Welded section		b/T	8E	9E	13E
Internal element of compression flange	Compression due to bending		b/T	28E	32E	40E
	Axial compression		b/T	Not applicable		
Web of an I-, H- or box section[c]	Neutral axis at mid-depth		d/t	80E	100E	120E
	Generally[d]	If r_1 is negative:	d/t	$\frac{80E}{1+r_1}$ but 40E	$\frac{100E}{1+r_1}$	$\frac{120E}{1+2r_2}$ but 40E
		If r_1 is positive:	d/t		$\frac{100E}{1+1.5r_1}$ but 40E	
	Axial compression[d]		d/t	Not applicable		

[a] Dimensions b, D, d, T and t are defined in Figure 5. For a box section b and T are flange dimensions and d and t are web dimensions, where the distinction between webs and flanges depends upon whether the box section is bent about its major axis or its minor axis, see 3.5.1.
[b] The parameter $E = (275/p_y)^{0.5}$.
[c] For the web of a hybrid section E should be based on the design strength p_{yf} of the flanges.
[d] The stress ratios r_1 and r_2 are defined in 3.5.5.

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