Name: ____________________ Index No.: __________/____

2705/302 2710/302
2709/302
STRUCTURES III
Oct./Nov. 2015
Time: 3 hours

Candidate's Signature: __________

Date: __________

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN BUILDING TECHNOLOGY
DIPLOMA IN ARCHITECTURE
MODULE III

STRUCTURES III

3 hours

INSTRUCTIONS TO CANDIDATES

Write your name and index number in the spaces provided above.
Sign and write the date of the examination in the spaces provided above.
You should have Mathematical tables/Scientific calculator and drawing instruments for this examination.
*This paper consists of **EIGHT** questions.*
*Answer any **FIVE** of the **EIGHT** questions in the spaces provided in this question paper.*
All questions carry equal marks.
Maximum marks for each part of a question are as indicated.
Relevant design tables are attached.
*Do **NOT** remove any pages from this booklet.*
Candidates should answer the questions in English.

For Examiner's Use Only

Question	1	2	3	4	5	6	7	8	TOTAL SCORE
Candidate's Score									

This paper consists of 20 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) State **three** advantages of the following connections:

(i) Bolted connections;

(ii) Welded connections. (6 marks)

(b) Figure 1 shows a bolted connection required to transmit a tensile force of 250 KN. Check the adequacy of the joint in terms of:

(i) Tensile stress in plates;

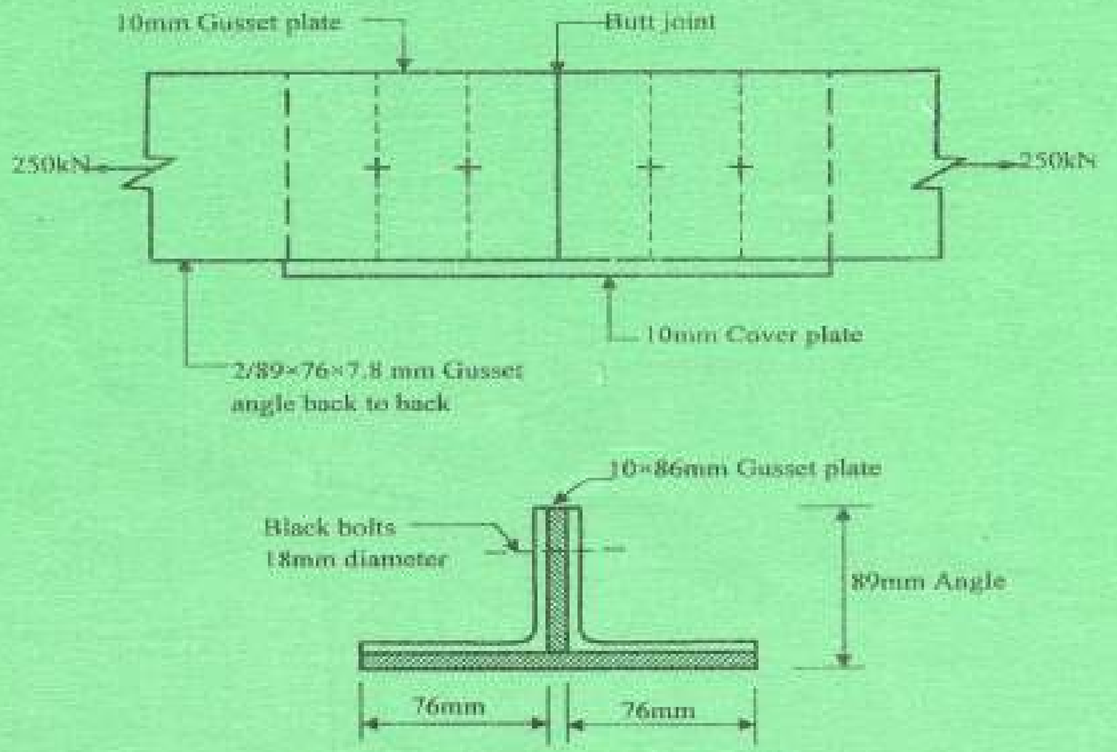
(ii) Tensile stress in angles;

(iii) hear stress in bolts;

(iv) Bearing stress in angles. (14 marks)

Take the area of an 89 x 76 x 7.8 mm angle to be 12.35 cm^2.

Permissible tensile stress = 155 N/mm^2
Permissible shear stress = 80 N/mm^2
Permissible bearing stress = 250 N/mm^2



SECTION THROUGH SPLICE JOINT

Fig. 1

2. (a) State **four** advantages of casing a steel section. (4 marks)

(b) A universal column used as an edge stanchion in a multi-storey building has an actual length of 3.6 m centre to centre of floor beam. The loading in the bean is as shown in figure 2. Design the stanchion as an encased column in Grade 43 steel, using the tables provided. (16 marks)

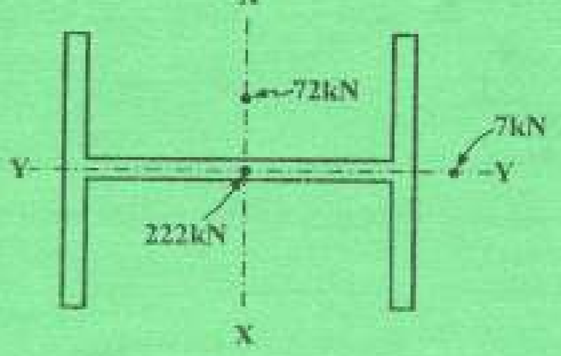


Fig. 2

3. (a) Define the following terms as used to structure timber:

(i) Basic stress;

(ii) Green stress;

(iii) Grade stress. (3 marks)

(b) A solid timber column of 200 mm x 150 mm and of strength of class 50 s is 4 m long. It is restrained in position and direction at both ends and is required to carry an axial load of 85 KN. Check the adequacy of the column.

- Table 9 BS 5268
- Grade stress parallel to grain = 8.7 N/mm^2
- Eminimum = 7.1 KN/mm^2
- $K_1 = 1.25$, K_8 = 1.0, for medium duration.

(17 marks)

4. Using the moment distribution method, analyse the beam in figure 3 and sketch the bending moment diagram, indicating all critical values. (20 marks)

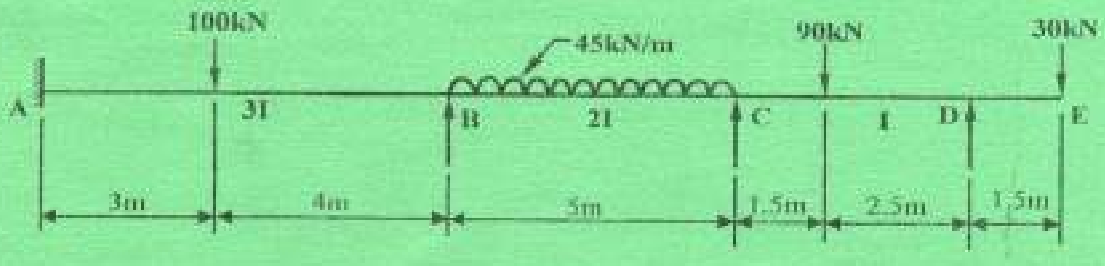


Fig. 3

5. Using the three moment theorem, analyse the bean shown in figure 4 and hence sketch the shear force and bending moment diagrams, indicating values at all critical points. (20 marks)

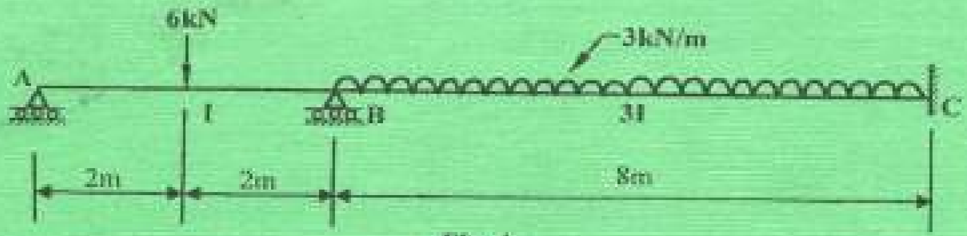


Fig. 4

6. Analyse the frame in figure 5 using moment of distribution method and then plot bending moment diagram, showing the values at all critical points. (20 marks)

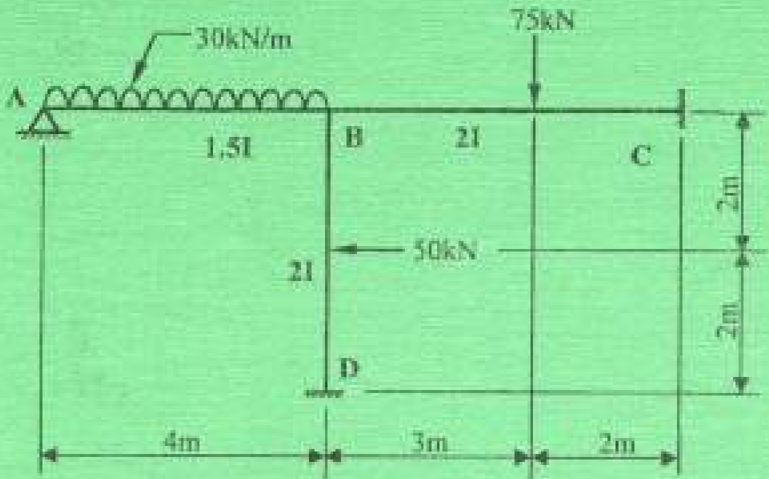


Fig. 5

7. (a) Figure 6 is a simply supported universal beam loaded as shown. Using the data provided below, check if a 533 x 165 x 73 kg/m UB will be satisfactory and hence check for shear and deflection.

Data

- Live loads = 75% of point load
- Compression flanges fully restrained

P_q = 100 N/mm²

E = 210 KN/mm²

(9 marks)

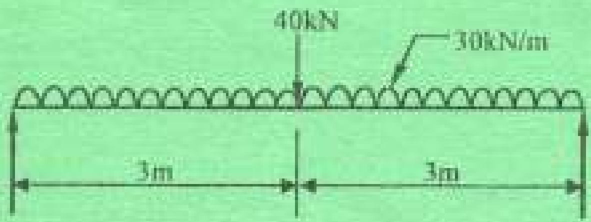


Fig. 6

(b) (i) Sketch any **two** butt welds.

(ii) Design the connection in figure 7 shown using balanced weld design.

(11 marks)

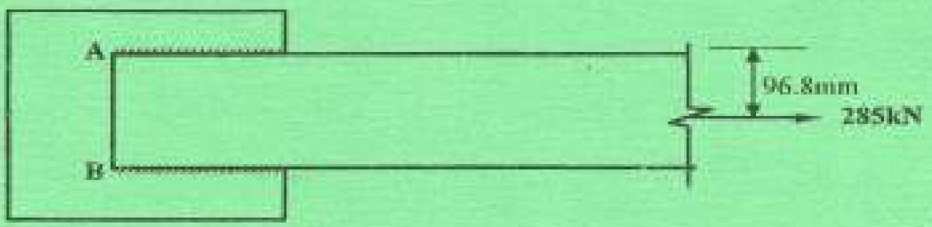


Fig. 7

8. (a) State **five** properties of structural timber as a construction material. (5 marks)

(b) A timber having a clear span of 6.0 m is suspended on 250 mm bearing at each end. The beam carries a uniformly distributed load of 15 KN/m over the entire span.

Design the beam using the following information:

- Permissible deflection = span/300
- Permissible shear stress = 1.2 N/mm²
- Depth of section is twice the breadth
- Young's modulus of elasticity, E = 8 KN/mm²

(15 marks)

TABLE 1

UNIVERSAL COLUMNS

Parallel Flanges

DIMENSIONS AND PROPERTIES

Serial Size	Mass per metre	Depth of Section D	Width of Section B	Thickness Web t	Thickness Flange T	Root Radius r	Depth between Fillets d	Area of Section
mm	kg	mm	mm	mm	mm	mm	mm	cm^2
356 × 406	634	474.7	424.1	47.6	77.0	15.2	290.1	808.1
	551	455.7	418.5	42.0	67.5	15.2	290.1	701.8
	467	436.6	412.4	35.9	58.0	15.2	290.1	595.5
	393	419.1	407.0	30.6	49.2	15.2	290.1	500.9
	340	406.4	403.0	26.5	42.9	15.2	290.1	432.7
	287	393.7	399.0	22.6	36.5	15.2	290.1	366.0
	235	381.0	395.0	18.5	30.2	15.2	290.1	299.8
Column Core	477	427.0	424.4	48.0	53.2	15.2	290.1	607.2
356 × 368	202	374.7	374.4	16.8	27.0	15.2	290.1	257.9
	177	368.3	372.1	14.5	23.8	15.2	290.1	225.7
	153	362.0	370.2	12.6	20.7	15.2	290.1	195.2
	129	355.6	368.3	10.7	17.5	15.2	290.1	164.9
305 × 305	283	365.3	321.8	26.9	44.1	15.2	246.5	360.4
	240	352.6	317.9	23.0	37.7	15.2	246.6	305.6
	198	339.9	314.1	19.2	31.4	15.2	246.6	252.3
	158	327.2	310.6	15.7	25.0	15.2	246.6	201.2
	137	320.5	308.7	13.8	21.7	15.2	246.6	174.6
	118	314.5	306.8	11.9	18.7	15.2	246.6	149.8
	97	307.8	304.8	9.9	15.4	15.2	246.6	123.3
254 × 254	167	289.1	264.5	19.2	31.7	12.7	200.2	212.4
	132	276.4	261.0	15.6	25.1	12.7	200.2	167.7
	107	266.7	258.3	13.0	20.5	12.7	200.2	136.6
	89	260.4	255.9	10.5	17.3	12.7	200.2	114.0
	73	254.0	254.0	8.6	14.2	12.7	200.2	92.9
203 × 203	86	222.3	208.8	13.0	20.5	10.2	160.8	110.1
	71	215.9	206.2	10.3	17.3	10.2	160.8	91.1
	60	209.6	205.2	9.3	14.2	10.2	160.8	75.8
	52	206.2	203.9	8.0	12.5	10.2	160.8	66.4
	46	203.2	203.2	7.3	11.0	10.2	160.8	58.8
152 × 152	37	161.8	154.4	8.1	11.5	7.6	123.4	47.4
	30	157.5	152.9	6.6	9.4	7.6	123.4	38.2
	23	152.4	152.4	6.1	6.8	7.6	123.4	29.8

UNIVERSAL COLUMNS

Parallel Flanges

DIMENSIONS AND PROPERTIES

Serial Size	Moment of Inertia Axis x–x Gross	Moment of Inertia Axis x–x Net	Moment of Inertia Axis y–y	Radius of Gyration Axis x–x	Radius of Gyration Axis y–y	Elastic Modulus Axis x–x	Elastic Modulus Axis y–y	Ratio D/T
mm	cm^4	cm^4	cm^4	cm	cm	cm^3	cm^3	
356 × 406	275140	243076	98211	18.5	11.0	11592	4632	6.2
	227023	200312	82665	18.0	10.9	9964	3951	6.8
	183118	161331	67905	17.5	10.7	8388	3293	7.5
	146765	129159	55410	17.1	10.5	7004	2723	8.5
	122474	107657	46816	16.8	10.4	6027	2324	9.5
	99994	87849	38714	16.5	10.3	5080	1940	10.8
	79110	69424	31008	16.3	10.2	4153	1570	12.6
Column Core	172391	152836	68056	16.8	10.6	8075	3207	8.0
356 × 368	66307	57908	23632	16.0	9.57	3540	1262	13.9
	57153	49758	20470	15.9	9.52	3104	1100	15.6
	48525	42150	17470	15.8	9.46	2681	943.8	17.5
	40246	35040	14555	15.6	9.39	2264	790.4	20.3
305 × 305	78777	72827	24545	14.8	8.25	4314	1525	8.3
	64177	59298	20239	14.5	8.14	3641	1273	9.4
	50832	46835	16230	14.2	8.02	2991	1034	10.8
	38740	35786	12524	13.9	7.89	2368	806.3	13.1
	32838	30314	10672	13.7	7.82	2049	691.4	14.8
	27601	25472	9006	13.6	7.75	1755	587.0	16.8
	22202	20498	7268	13.4	7.68	1442	476.9	20.0
254 × 254	29914	27171	9796	11.9	6.79	2070	740.6	9.1
	22416	20350	7444	11.6	6.66	1622	570.4	11.0
	17510	15890	5901	11.3	6.57	1313	456.9	13.0
	14307	12976	4849	11.2	6.52	1099	378.9	15.1
	11360	10297	3873	11.1	6.46	894.5	305.0	17.9
203 × 203	9462	8374	3119	9.27	5.32	851.5	298.7	10.8
	7647	6758	2536	9.16	5.28	708.4	246.0	12.5
	6088	5383	2041	8.96	5.19	581.1	199.0	14.8
	5263	4653	1770	8.90	5.16	510.4	173.6	16.5
	4564	4035	1539	8.81	5.11	449.2	151.5	18.5
152 × 152	2218	1932	709	6.84	3.87	274.2	91.78	14.1
	1742	1515	558	6.75	3.82	221.2	73.06	16.8
	1263	1104	403	6.51	3.68	165.7	52.95	22.4

Note: One hole is deducted from each flange under 300mm wide (serial size) and two holes from each flange 300mm and over (serial size), in calculating the Net Moment of Inertia about x–x.

TABLE 2

UNIVERSAL BEAMS

DIMENSIONS AND PROPERTIES

Serial Size	Mass per metre	Depth of Section D	Width of Section B	Thickness Web t	Thickness Flange T	Root Radius r	Depth between Fillets d	Area of Section
mm	kg	mm	mm	mm	mm	mm	mm	cm²
914 × 419	388	920.5	420.5	21.5	36.6	24.1	791.5	493.8
	343	911.4	418.5	19.4	32.0	24.1	791.5	436.9
914 × 305	289	926.6	307.8	19.6	32.0	19.1	819.2	368.8
	253	918.5	305.5	17.3	27.9	19.1	819.2	322.8
	224	910.3	304.1	15.9	23.9	19.1	819.2	284.8
	201	903.0	303.4	15.2	20.2	19.1	819.2	256.1
838 × 292	226	850.9	293.8	16.1	26.8	17.8	756.4	288.4
	194	840.7	292.4	14.7	21.7	17.8	756.4	246.9
	176	834.9	291.6	14.0	18.8	17.8	756.4	223.9
762 × 267	197	769.6	268.0	15.6	25.4	16.5	681.2	250.8
	173	762.0	266.7	14.3	21.6	16.5	681.2	220.2
	147	753.9	265.3	12.9	17.5	16.5	681.2	187.8
686 × 254	170	692.9	255.8	14.5	23.7	15.2	610.6	219.3
	152	687.6	254.5	13.2	21.0	15.2	610.6	193.8
	140	683.5	253.7	12.4	19.0	15.2	610.6	178.4
	125	677.9	253.0	11.7	16.2	15.2	610.6	159.4
610 × 305	238	633.0	311.5	18.6	31.4	16.5	537.6	303.5
	179	617.5	307.0	14.1	23.6	16.5	537.6	227.7
	149	609.6	304.8	11.9	19.7	16.5	537.5	189.3
610 × 229	140	617.0	230.1	13.1	22.1	12.7	543.1	179.2
	125	611.9	229.0	11.9	19.6	12.7	543.1	159.4
	113	607.3	228.2	11.2	17.3	12.7	543.1	144.2
	101	602.2	227.6	10.6	14.8	12.7	543.1	129.0
610 × 178	91	602.5	178.4	10.6	15.0	12.7	547.1	115.9
	82	598.2	177.8	10.1	12.8	12.7	547.1	104.4
533 × 330	212	545.1	333.6	16.7	27.8	16.5	480.1	269.6
	189	539.5	331.7	14.9	25.0	16.5	480.1	241.2
	167	533.4	330.2	13.4	22.0	16.5	480.1	212.7
533 × 210	122	544.6	211.9	12.8	21.3	12.7	472.7	155.8
	109	539.5	210.7	11.6	18.8	12.7	472.7	138.4
	101	536.7	210.1	10.9	17.4	12.7	472.7	129.1
	92	533.1	209.3	10.2	15.6	12.7	472.7	117.8
	82	528.3	208.7	9.6	13.2	12.7	472.7	104.3
533 × 165	73	528.8	165.6	9.3	13.5	12.7	476.5	93.0
	66	524.8	165.1	8.8	11.5	12.7	476.5	83.6
457 × 191	98	467.4	192.8	11.4	19.6	10.2	404.4	125.3
	89	463.6	192.0	10.6	17.7	10.2	404.4	113.8
	82	460.2	191.3	9.9	16.0	10.2	404.4	104.4
	74	457.2	190.5	9.1	14.5	10.2	404.4	94.9
	67	453.6	189.9	8.5	12.7	10.2	404.4	85.4

UNIVERSAL BEAMS

DIMENSIONS AND PROPERTIES

Serial Size	Moment of Inertia Axis x–x Gross	Moment of Inertia Axis x–x Net	Moment of Inertia Axis y–y	Radius of Gyration Axis x–x	Radius of Gyration Axis y–y	Elastic Modulus Axis x–x	Elastic Modulus Axis y–y	Ratio D/T
mm	cm⁴	cm⁴	cm⁴	cm	cm	cm³	cm³	
914 × 419	717320	639177	42481	38.1	9.27	15586	2021	25.2
	623866	553826	36251	37.8	9.11	13691	1733	28.5
914 × 305	503781	469902	14793	37.0	6.34	10874	961.3	29.0
	435796	405504	12512	36.8	6.23	9490	819.2	32.9
	376111	350209	10425	36.3	6.05	8241	685.6	38.1
	324715	303783	9422	35.6	5.81	[illegible]	[illegible]	44.7
838 × 292	339130	315153	10661	34.3	6.08	7971	725.9	31.8
	278833	258635	8384	33.6	5.83	6633	573.6	38.7
	245412	228867	7111	33.1	5.64	5879	487.8	44.4
762 × 267	239464	221138	7699	30.9	5.54	6223	574.6	30.3
	204747	189341	6376	30.5	5.38	5374	478.1	35.3
	168535	156213	5002	30.0	5.16	4471	377.1	43.1
686 × 254	169843	156106	6225	28.0	5.36	4902	486.8	29.2
	150015	137965	5391	27.8	5.28	4364	423.7	32.7
	135972	125156	4789	27.6	5.18	3979	377.5	36.0
	117700	108580	3992	27.2	5.00	3472	315.5	41.8
610 × 305	207252	192203	14973	26.1	7.02	6549	961.3	20.2
	151312	140269	10571	25.8	6.81	4901	688.6	26.2
	124341	115223	8471	25.6	6.68	4079	555.9	30.9
610 × 229	111673	101888	4253	25.0	4.88	3620	369.6	27.9
	98408	89675	3676	24.8	4.80	3217	321.1	31.2
	87260	79645	3184	24.6	4.70	2874	279.1	35.1
	75549	69132	2658	24.2	4.54	2508	233.6	40.7
610 × 178	63970	57238	1427	23.5	3.51	2124	160.0	40.2
	55779	50076	1203	23.1	3.39	1865	135.3	46.7
533 × 330	141682	121777	16064	22.9	7.72	5185	963.2	19.6
	125618	107882	14093	22.8	7.64	4657	849.6	21.6
	109109	93647	12057	22.6	7.53	4091	730.2	24.2
533 × 210	76078	68715	3208	22.1	4.54	2794	302.8	25.6
	66610	60218	2755	21.9	4.46	2469	261.5	28.7
	61530	55671	2512	21.8	4.41	2293	239.2	30.8
	55225	50040	2212	21.7	4.34	2072	211.3	34.2
	47363	43062	1826	21.3	4.18	1793	175.0	40.0
533 × 165	40414	35763	1027	20.8	3.32	1528	124.1	39.2
	35083	31144	863	20.5	3.21	1337	104.5	45.6
457 × 191	45653	40469	2216	19.1	4.21	1954	229.9	23.8
	40956	36313	1960	19.0	4.15	1767	204.2	26.2
	37039	32865	1746	18.8	4.09	1610	182.6	28.8
	33324	29570	1547	18.7	4.04	1458	162.4	31.5
	29337	26072	1328	18.5	3.95	1293	139.9	35.7

TABLE 3:

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	155	155	154	154	153	153	153	152	152	151
10	151	151	150	150	149	149	148	148	148	147
20	147	146	146	146	145	145	144	144	144	143
30	143	142	142	142	141	141	141	140	140	139
40	139	138	138	137	137	136	136	136	135	134
50	134	133	132	131	130	130	129	128	127	126
60	126	125	124	123	122	121	120	119	118	117
70	115	114	113	112	111	110	108	107	106	105
80	104	102	101	100	99	97	96	95	94	92
90	91	90	89	87	86	85	84	83	81	80
100	79	78	77	76	75	74	73	72	71	70
110	69	68	67	66	65	64	63	62	61	61
120	60	59	58	57	56	56	55	54	53	53
130	52	51	51	50	49	49	48	48	47	46
140	46	45	45	44	43	43	42	42	41	41
150	40	40	39	39	38	38	38	37	37	36
160	36	35	35	35	34	34	33	33	33	32
170	32	32	31	31	31	30	30	30	29	29
180	29	28	28	28	28	27	27	27	26	26
190	26	26	25	25	25	25	24	24	24	24
200	24	23	23	23	23	22	22	22	22	22
210	21	21	21	21	21	20	20	20	20	20
220	20	19	19	19	19	19	19	18	18	18
230	18	18	18	18	17	17	17	17	17	17
240	17	16	16	16	16	16	16	16	16	15
250	15									
300	11									
350	8									

Intermediate values may be obtained by linear interpolation.

NOTE. For material over 40 mm thick, other than rolled I-beams or channels, and for Universal columns of thicknesses exceeding 40 mm, the limiting stress is 140 N/mm².

TABLE 4

Modification factor K_{12} for compression members

$E/\sigma_{c,\parallel}$	Value of K_{12}																			
	Values of slenderness ratio λ (= L_e/i)																			
	< 5	5	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	220	240	250
	Equivalent L_e/b (for rectangular sections)																			
	< 1.4	1.4	2.9	5.8	8.7	11.6	14.5	17.3	20.2	23.1	26.0	28.9	34.7	40.5	46.2	52.0	57.8	63.6	69.4	72.3
400	1.000	0.975	0.951	0.896	0.827	0.735	0.621	0.506	0.408	0.330	0.271	0.225	0.162	0.121	0.094	0.075	0.061	0.051	0.043	0.040
500	1.000	0.975	0.951	0.899	0.837	0.759	0.654	0.562	0.468	0.385	0.320	0.269	0.195	0.148	0.115	0.092	0.076	0.063	0.053	0.048
600	1.000	0.975	0.951	0.901	0.843	0.774	0.692	0.601	0.511	0.430	0.363	0.307	0.226	0.172	0.135	0.109	0.089	0.074	0.063	0.058
700	1.000	0.975	0.951	0.902	0.848	0.784	0.711	0.629	0.545	0.467	0.399	0.341	0.254	0.195	0.154	0.124	0.102	0.085	0.072	0.067
800	1.000	0.975	0.952	0.903	0.851	0.792	0.724	0.649	0.572	0.497	0.430	0.371	0.280	0.217	0.172	0.139	0.115	0.096	0.082	0.076
900	1.000	0.976	0.952	0.904	0.853	0.797	0.734	0.665	0.593	0.522	0.456	0.397	0.304	0.237	0.188	0.153	0.127	0.106	0.091	0.084
1000	1.000	0.976	0.952	0.904	0.855	0.801	0.742	0.677	0.609	0.542	0.478	0.420	0.325	0.255	0.204	0.167	0.138	0.116	0.099	0.092
1100	1.000	0.976	0.952	0.905	0.856	0.804	0.748	0.687	0.623	0.559	0.497	0.440	0.344	0.272	0.219	0.179	0.149	0.126	0.107	0.100
1200	1.000	0.976	0.952	0.905	0.857	0.807	0.753	0.695	0.634	0.573	0.513	0.457	0.362	0.288	0.233	0.192	0.160	0.135	0.116	0.107
1300	1.000	0.976	0.952	0.905	0.858	0.809	0.757	0.701	0.643	0.584	0.527	0.472	0.378	0.303	0.247	0.203	0.170	0.144	0.123	0.115
1400	1.000	0.976	0.952	0.906	0.859	0.811	0.760	0.707	0.651	0.595	0.539	0.486	0.392	0.317	0.259	0.214	0.180	0.153	0.131	0.122
1500	1.000	0.976	0.952	0.906	0.860	0.813	0.763	0.712	0.668	0.603	0.550	0.498	0.405	0.330	0.271	0.226	0.189	0.161	0.138	0.129
1600	1.000	0.976	0.952	0.906	0.861	0.814	0.766	0.716	0.664	0.611	0.559	0.508	0.417	0.342	0.282	0.235	0.198	0.169	0.145	0.135
1700	1.000	0.976	0.952	0.906	0.861	0.815	0.768	0.719	0.669	0.618	0.567	0.518	0.428	0.353	0.292	0.245	0.207	0.177	0.152	0.142
1800	1.000	0.976	0.952	0.906	0.862	0.816	0.770	0.722	0.673	0.624	0.574	0.526	0.438	0.363	0.302	0.254	0.215	0.184	0.159	0.148
1900	1.000	0.976	0.952	0.907	0.862	0.817	0.772	0.725	0.677	0.629	0.581	0.534	0.447	0.373	0.312	0.262	0.223	0.191	0.165	0.154
2000	1.000	0.976	0.952	0.907	0.863	0.818	0.773	0.728	0.681	0.634	0.587	0.541	0.466	0.392	0.320	0.271	0.230	0.198	0.172	0.160

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