2705/302
2709/302
2710/302
STRUCTURES III
June/July 2016
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;
A Scientific calculator.
*Answer any **FIVE** of the following **EIGHT** questions.*
All questions carry equal marks.
Maximum marks for each part of a question are as indicated.
Relevant design tables for this examination are included.
Candidates should answer the questions in English.

This paper consists of 9 printed pages.

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

Turn over

1. Use the three moments theorem to analyse the loaded beam in figure 1 below; and hence draw the bending moment diagram, indicating values at the critical points. (20 marks)

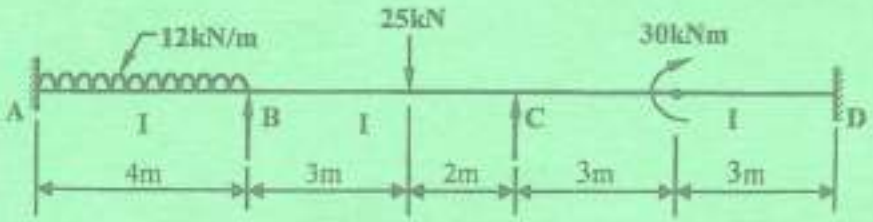

Fig. 1

2. Use moment distribution method to analyse the beam in figure 2 below by making four distributions, and hence draw the bending moment diagram, indicating values at critical points. (20 marks)

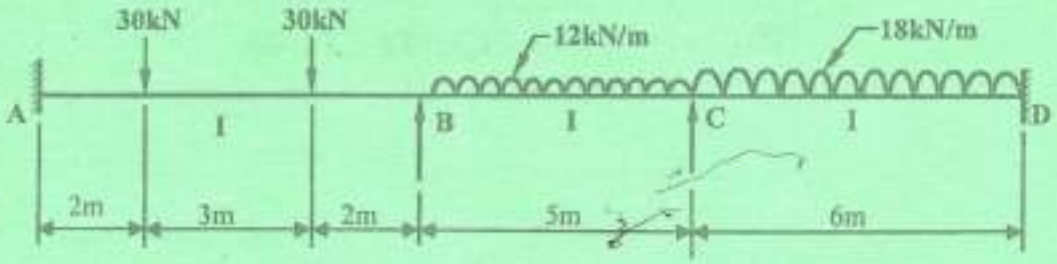

Fig. 2

3. Figure 3 shows a beam with a rolling load moving across it from A to B. Calculate:

(a) The maximum shear force and corresponding bending moment at point C due to the moving load.

(b) The maximum bending moment at point C due to the moving load.

(20 marks)

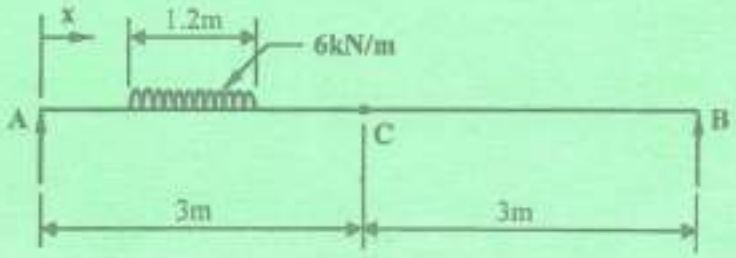

Fig. 3

4. (a) Analyse the beam in figure 4 below, using the three moment theorem and hence draw the bending moment diagram indicating values at critical points.

(b) Calculate the reactions at supports A, B and C in the figure analysed in (a) above.

(20 marks)

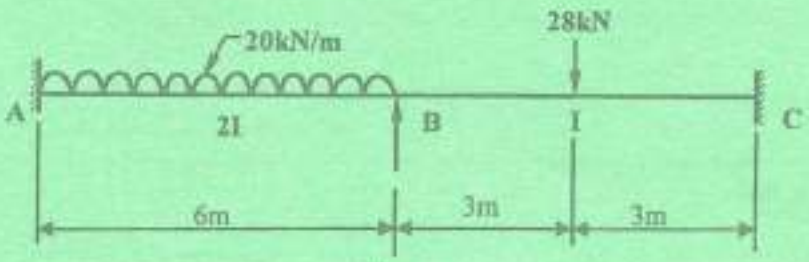

Fig. 4

5. A beam of effective span 6 m is fully restrained laterally and is loaded as described below. Assuming grade 43 steel, check if a 457 x 152 x 67 kg/m universal beam, will be adequate in:

(a) bending ULS;
(b) shear ULS;
(c) deflection SLS.

Data:

- distributed dead load inclusive of self weight = 10 kN/m
- point load at mid-span = 20 kN

Imposed loads:

- distributed load = 14 kN/m
- point load at mid span = 16 kN

(20 marks)

6. (a) Sketch a section of a universal column and indicate the following:
Flange, web, D, d, T, t. (4 marks)

(b) A universal column 4 metres in length between supports, is required to support an axial load of 1100 kN. The ends of the column are restrained in position but not in direction. Check whether a 203 x 203 x 71 kg/m, grade 43 universal column will be adequate.

(16 marks)

7. Use the data provided below to check the adequacy of the joint connection in figure 5 below.

Data:

- 16 mm diameter black bolts grade 4.6 in 18 mm diameter holes
- Take tensile area of bolt as 157 mm^2 and Py = 250 N/mm^2.

(20 marks)

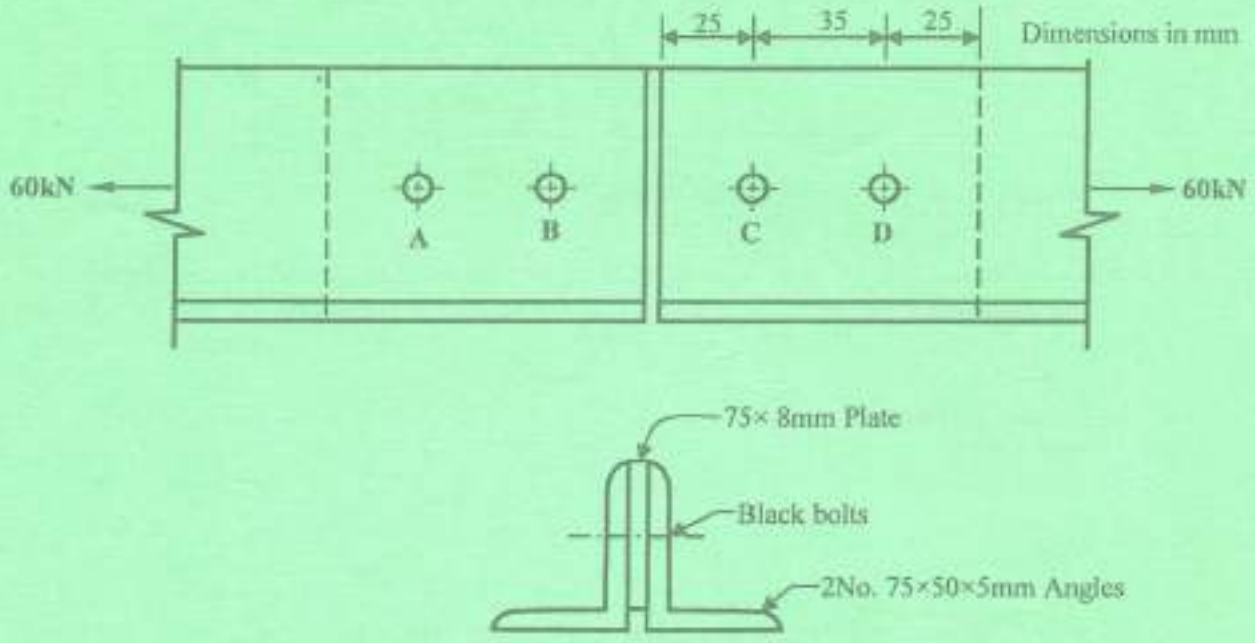

Fig. 5

8. (a) Illustrate a top side notch in timber joists. (2 marks)

(b) Explain the following terms as used in timber design:

(i) dry stress;
(ii) grade stress;
(iii) glue laminated timber.

(6 marks)

(c) Figure 6 shows the layout of a timber decking support. Using the data provided below, determine the maximum load intensity that can be carried by the joists considering bending and shear stresses only. Assume medium term loading.

Data:

- Size of joist section = 50 x 150 mm
- Grade stresses:
  - bending stress parallel to grain = 12.6 N/mm^2
  - shear stress parallel to grain = 1.6 N/mm^2

Take:

k3 = 1.25 and k7 = 1.08

(12 marks)

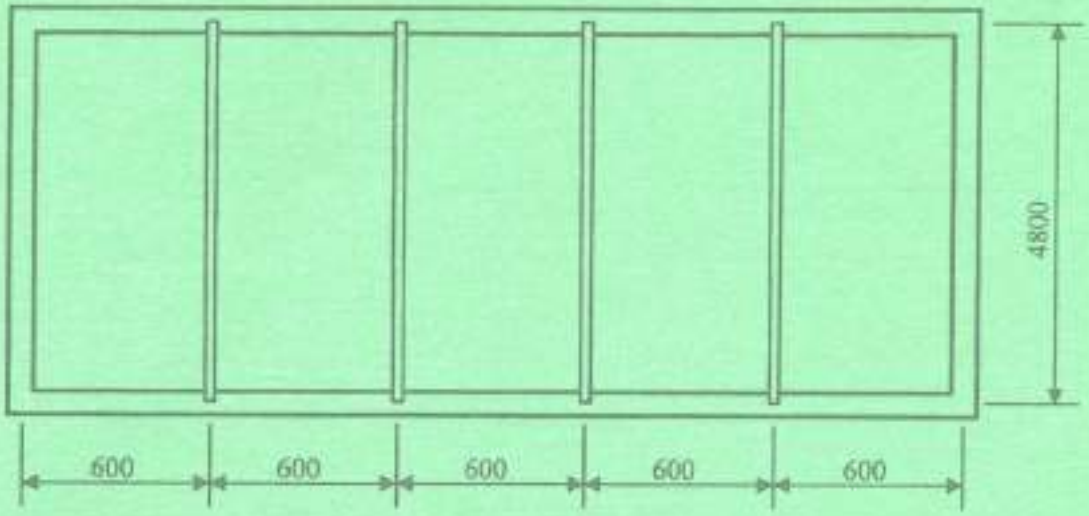

Fig. 6

Note: Dimensions in mm

Table 1 Design strength p_y of grade 43 steel

Thickness less than or equal to (mm)	p_y for rolled sections, plates and hollow sections (N/mm^2)
16	275
40	265
63	255
100	245

The modulus of elasticity E, for deflection purposes, may be taken as $205\,kN/mm^2$ for all grades of steel.

Table 2. Ordinary bolts in clearance holes

Strength of bolts and bearing strength of bolts and connected ply (N/mm^2)

Strength of bolts	Bolt grade	
	4.6	8.8
Shear strength p_s	160	375
Bearing strength p_{bb}	460	1035

Bearing strength of connected parts	Steel grade		
	43	50	55
Bearing strength p_{bs}	460	550	650

Table 3. Load capacity (Grade 4.6 bolts and Grade of 43 steel)

Nominal diameter (mm)	Shank area A (mm^2)	Tensile stress Area A_s, A_T (mm^2)
16	201	157
20	314	245
22	380	303
24	452	353

Table 4 Universal beams (abstracted from the *Steelwork Design Guide to BS 5950: Part 1*, published by the Steel Construction Institute)

(a) Dimensions

Designation		Depth of section	Width of section	Thickness		Root radius	Depth between fillets	Ratios for local buckling		Dimensions for detailing			Surface area	
Serial size	Mass per metre	D	B	Web t	Flange T	r	d	Flange b/T	Web d/t	End clearance C	Notch N	Notch n	Per metre	per tonne
(mm)	(kg)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)			(mm)	(mm)	(mm)	(m^2)	(m^2)
533 × 210	122	544.6	211.9	12.8	21.3	12.7	476.5	4.97	37.2	8	110	36	1.89	15.5
	109	539.5	210.7	11.6	18.8	12.7	476.5	5.60	41.1	8	110	32	1.88	17.2
	101	536.7	210.1	10.9	17.4	12.7	476.5	6.04	43.7	7	110	32	1.87	18.5
	92	533.1	209.3	10.2	15.6	12.7	476.5	6.71	46.7	7	110	30	1.86	20.2
	82	528.3	208.7	9.6	13.2	12.7	476.5	7.91	49.6	7	110	26	1.85	22.6
457 × 191	98	467.4	192.8	11.4	19.6	10.2	407.9	4.92	35.8	8	102	30	1.67	17.0
	89	463.6	192.0	10.6	17.7	10.2	407.9	5.42	38.5	7	102	28	1.66	18.6
	82	460.2	191.3	9.9	16.0	10.2	407.9	5.98	41.2	7	102	28	1.65	20.1
	74	457.2	190.5	9.1	14.5	10.2	407.9	6.57	44.8	7	102	26	1.64	22.2
	67	453.6	189.9	8.5	12.7	10.2	407.9	7.48	48.0	6	102	24	1.63	24.4
457 × 152	82	465.1	153.5	10.7	18.9	10.2	407.0	4.06	38.0	7	82	30	1.51	18.4
	74	461.3	152.7	9.9	17.0	10.2	407.0	4.49	41.1	7	82	28	1.50	20.2
	67	457.5	151.9	9.1	15.0	10.2	407.0	5.06	44.7	7	82	26	1.49	22.2
	60	454.7	152.9	8.0	13.3	10.2	407.0	5.75	51.0	6	84	24	1.49	24.8
	52	449.8	152.4	7.6	10.9	10.2	407.0	6.99	53.6	6	84	22	1.48	28.4

Table 5 Universal columns (abstracted from the *Steelwork Design Guide to BS 5950: Part 1*, published by the Steel Construction Institute)

(a) Dimensions

Designation		Depth of section	Width of section	Thickness		Root radius	Depth between fillets	Ratios for local buckling		Dimensions for detailing			Surface area	
Serial size	Mass per metre	D	B	Web t	Flange T	r	d	Flange b/T	Web d/t	End clearance C	Notch N	Notch n	Per metre	per tonne
(mm)	(kg)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)			(mm)	(mm)	(mm)	(m^2)	(m^2)
356 × 406	634	474.7	424.1	47.6	77.0	15.2	290.2	2.75	6.10	26	200	94	2.52	3.98
	551	455.7	418.5	42.0	67.5	15.2	290.2	3.10	6.91	23	200	84	2.48	4.49
	467	436.6	412.4	35.9	58.0	15.2	290.2	3.56	8.08	20	200	74	2.42	5.19
	393	419.1	407.0	30.6	49.2	15.2	290.2	4.14	9.48	17	200	66	2.38	6.05
	340	406.4	403.0	26.5	42.9	15.2	290.2	4.70	11.0	15	200	60	2.35	6.90
	287	393.7	399.0	22.6	36.5	15.2	290.2	5.47	12.8	13	200	52	2.31	8.06
	235	381.0	395.0	18.5	30.2	15.2	290.2	6.54	15.7	11	200	46	2.28	9.70
COLCORE	477	427.0	424.4	48.0	53.2	15.2	290.2	3.99	6.05	26	200	70	2.43	5.09
356 × 368	202	374.7	374.4	16.8	27.0	15.2	290.2	6.93	17.3	10	190	44	2.19	10.8
	177	368.3	372.1	14.5	23.8	15.2	290.2	7.82	20.0	9	190	40	2.17	12.3
	153	362.0	370.2	12.6	20.7	15.2	290.2	8.94	23.0	8	190	36	2.15	14.1
	129	355.6	368.3	10.7	17.5	15.2	290.2	10.5	27.1	7	190	34	2.14	16.6
305 × 305	283	365.3	321.8	26.9	44.1	15.2	246.6	3.65	9.17	15	158	60	1.94	6.85
	240	352.6	317.9	23.0	37.7	15.2	246.6	4.22	10.7	14	158	54	1.90	7.93
	198	339.9	314.1	19.2	31.4	15.2	246.6	5.00	12.8	12	158	48	1.87	9.45
	158	327.2	310.6	15.7	25.0	15.2	246.6	6.21	15.7	10	158	42	1.84	11.6
	137	320.5	308.7	13.8	21.7	15.2	246.6	7.11	17.9	9	158	38	1.82	13.3
	118	314.5	306.8	11.9	18.7	15.2	246.6	8.20	20.7	8	158	34	1.81	15.3
	97	307.8	304.8	9.9	15.4	15.2	246.6	9.90	24.9	7	158	32	1.79	18.4
254 × 254	167	289.1	264.5	19.2	31.7	12.7	200.3	4.17	10.4	12	134	46	1.58	9.44
	132	276.4	261.0	15.6	25.3	12.7	200.3	5.16	12.8	10	134	40	1.54	11.7
	107	266.7	258.3	13.0	20.5	12.7	200.3	6.30	15.4	9	134	34	1.52	14.2
	89	260.4	255.9	10.5	17.3	12.7	200.3	7.40	19.1	7	134	32	1.50	16.9
	73	254.0	254.0	8.6	14.2	12.7	200.3	8.94	23.3	6	134	28	1.49	20.3
203 × 203	86	222.3	208.8	13.0	20.5	10.2	160.9	5.09	12.4	9	108	32	1.24	14.4
	71	215.9	206.2	10.3	17.3	10.2	160.9	5.96	15.6	7	108	28	1.22	17.2
	60	209.6	205.2	9.3	14.2	10.2	160.9	7.23	17.3	7	108	26	1.20	20.1
	52	206.2	203.9	8.0	12.5	10.2	160.9	8.16	20.1	6	108	24	1.19	23.0
	46	203.2	203.2	7.3	11.0	10.2	160.9	9.24	22.0	6	108	22	1.19	25.8
152 × 152	37	161.8	154.4	8.1	11.5	7.6	123.5	6.71	15.2	6	84	20	0.912	24.6
	30	157.5	152.9	6.6	9.4	7.6	123.5	8.13	18.7	5	84	18	0.9	30.0
	23	152.4	152.4	6.1	6.8	7.6	123.5	11.2	20.2	5	84	16	0.889	38.7

Table 4. Universal beams *continued* (abstracted from the *Steelwork Design Guide to BS 5950: Part 1*, published by the Steel Construction Institute)

(b) Properties

Designation		Second moment of area		Radius of gyration		Elastic modulus		Plastic modulus		Buckling parameter	Torsional index	Warping constant	Torsional constant	Area of section
Serial size	Mass per metre	Axis x–x	Axis y–y	Axis x–x	Axis y–y	Axis x–x	Axis y–y	Axis x–x	Axis y–y	u	x	H	J	A
(mm)	(kg)	(cm^4)	(cm^4)	(cm)	(cm)	(cm^3)	(cm^3)	(cm^3)	(cm^3)			(dm^6)	(cm^4)	(cm^2)
533 × 210	122	76 200	3 390	22.1	4.67	2 860	320	3 200	501	0.876	27.6	2.32	180	156
	109	66 700	2 940	21.9	4.60	2 470	279	2 820	435	0.875	30.9	1.99	126	139
	101	61 700	2 690	21.8	4.56	2 300	257	2 620	400	0.874	33.1	1.82	102	129
	92	55 400	2 390	21.7	4.51	2 080	229	2 370	356	0.872	36.4	1.60	76.2	118
	82	47 500	2 010	21.5	4.38	1 800	192	2 060	300	0.865	41.6	1.33	51.3	104
457 × 191	98	45 700	2 360	19.1	4.33	1 960	243	2 230	378	0.88	25.8	1.17	121	125
	89	41 000	2 090	19.0	4.28	1 770	217	2 010	338	0.879	28.3	1.04	90.5	114
	82	37 100	1 870	18.8	4.23	1 610	196	1 830	304	0.877	30.9	0.923	69.2	105
	74	33 400	1 670	18.7	4.19	1 460	175	1 660	272	0.876	33.9	0.819	52.0	95.0
	67	29 400	1 450	18.5	4.12	1 300	153	1 470	237	0.873	37.9	0.706	37.1	85.4
457 × 152	83	36 200	1 140	18.6	3.31	1 560	149	1 800	235	0.872	27.3	0.569	89.3	106
	74	32 400	1 010	18.5	3.26	1 410	133	1 620	209	0.87	30.0	0.499	66.6	95.0
	67	28 600	878	18.3	3.21	1 250	116	1 440	182	0.867	33.6	0.429	47.5	85.4
	60	25 500	794	18.3	3.23	1 120	104	1 280	163	0.869	37.5	0.387	33.6	75.9
	52	21 300	645	17.9	3.11	949	84.6	1 090	133	0.859	43.9	0.341	21.3	66.5

Table 5. Universal columns *continued* (abstracted from the *Steelwork Design Guide to BS 5950: Part 1*, published by the Steel Construction Institute)

(b) Properties

Designation		Second moment of area		Radius of gyration		Elastic modulus		Plastic modulus		Buckling parameter	Torsional index	Warping constant	Torsional constant	Area of section
Serial size	Mass per metre	Axis x–x	Axis y–y	Axis x–x	Axis y–y	Axis x–x	Axis y–y	Axis x–x	Axis y–y	u	x	H	J	A
(mm)	(kg)	(cm^4)	(cm^4)	(cm)	(cm)	(cm^3)	(cm^3)	(cm^3)	(cm^3)			(dm^6)	(cm^4)	(cm^2)
356 × 406	634	275 000	98 200	18.5	11.0	11 600	4830	14 200	7110	0.843	5.46	38.8	13 700	808
	551	227 000	82 700	18.0	10.9	9960	3950	12 100	6060	0.841	6.05	31.1	9 240	702
	467	183 000	67 900	17.5	10.7	8 390	3290	10 000	5049	0.839	6.86	24.3	5 820	595
	393	147 000	55 400	17.1	10.5	7000	2720	8 230	4160	0.837	7.86	19.0	3 550	501
	340	122 000	46 800	16.8	10.4	6 030	2320	6 990	3540	0.836	8.85	15.5	2 340	433
	287	100 000	38 700	16.5	10.3	5 050	1940	5 820	2950	0.835	10.2	12.3	1 440	366
	235	79 100	31 000	16.2	10.2	4 150	1570	4 690	2380	0.834	12.1	9.54	812	300
COLCORE	477	172 000	48 100	16.8	10.6	8 080	3210	9 700	4980	0.815	6.91	23.8	5 700	607
356 × 368	202	66 300	23 600	16.0	9.57	3 540	1260	3 980	1920	0.844	13.3	7.14	660	258
	177	57 200	20 300	15.9	9.52	3 100	1100	3 460	1670	0.844	15.0	6.07	383	226
	153	48 500	17 500	15.8	9.46	2 680	944	2 960	1430	0.844	17.0	5.09	251	195
	129	40 200	14 600	15.6	9.39	2 260	790	2 490	1200	0.843	19.9	4.16	153	165
305 × 305	283	78 800	24 500	14.8	8.25	4 310	1530	5 100	2340	0.855	7.65	6.33	2 030	360
	240	64 200	20 200	14.5	8.14	3 640	1270	4 250	1950	0.854	8.73	5.01	1 270	306
	198	50 800	16 200	14.2	8.02	2 990	1030	3 440	1580	0.854	10.2	3.86	734	252
	158	38 700	12 500	13.8	7.89	2 370	806	2 680	1230	0.852	12.5	2.86	379	201
	137	32 800	10 700	13.7	7.82	2 050	681	2 300	1050	0.851	14.1	2.38	250	175
	118	27 600	9 010	13.6	7.75	1 760	587	1 950	892	0.851	16.2	1.97	160	150
	97	22 200	7 270	13.4	7.68	1 440	477	1 590	723	0.850	19.3	1.55	91.1	123
254 × 254	167	29 900	9 800	11.9	6.79	2 070	741	2 420	1130	0.852	8.49	1.62	623	212
	132	22 600	7 520	11.6	6.67	1 630	576	1 870	879	0.850	10.3	1.18	322	169
	107	17 500	5 900	11.3	6.57	1 310	457	1 490	695	0.848	12.4	0.894	173	137
	89	14 300	4 830	11.2	6.52	1 100	379	1 250	573	0.849	14.4	0.716	104	114
	73	11 400	3 870	11.1	6.46	896	305	989	462	0.848	17.3	0.557	57.3	92.9
203 × 203	86	9 460	3 120	9.27	5.32	831	299	939	458	0.85	10.2	0.317	138	110
	71	7 650	2 540	9.16	5.28	708	246	802	374	0.852	11.9	0.25	81.5	91.3
	60	6 090	2 060	8.96	5.19	581	199	652	303	0.847	14.1	0.195	46.6	75.8
	52	5 260	1 770	8.90	5.16	510	174	568	264	0.848	15.8	0.166	32.0	66.4
	46	4 560	1 540	8.81	5.11	449	151	497	230	0.846	17.7	0.142	22.2	58.8
152 × 152	37	2 220	705	6.84	3.87	274	91.8	310	140	0.848	13.3	0.04	19.3	47.4
	30	1 740	538	6.75	3.82	221	71.1	247	111	0.848	16.0	0.0306	10.5	38.2
	23	1 260	403	6.51	3.68	166	52.9	184	80.9	0.837	20.4	0.0214	4.87	29.8

Table 6 — Compressive strength P_{cx}

5) Values of p_c (N/mm²) with $\lambda < 119$ for strut curve b															
λ	Steel grade and design strength p_y (N/mm²)														
	S 275					S 355					S 460				
	265	345	255	265	275	315	325	335	345	355	390	409	420	430	440
15	235	245	255	265	275	315	325	335	345	355	390	409	420	430	440
20	234	243	253	263	272	310	320	330	339	349	381	401	420	429	448
25	229	239	248	258	267	304	314	323	332	342	384	393	411	421	439
30	225	234	243	252	262	298	307	316	325	336	375	384	402	411	428
35	220	229	238	247	256	291	300	309	318	327	366	374	392	400	417
40	216	224	233	241	250	284	293	301	310	319	355	364	380	388	404
42	215	222	231	239	248	281	289	298	306	314	351	359	375	383	399
44	211	220	228	237	245	278	286	294	302	310	346	354	369	377	392
46	209	218	226	234	242	275	283	291	298	306	341	349	364	371	386
48	207	215	223	231	239	271	279	287	294	302	336	343	358	365	379
50	206	213	221	229	237	267	275	283	290	298	330	337	351	358	372
52	203	210	218	226	234	264	271	278	286	293	324	331	344	351	364
54	200	208	215	223	230	260	267	274	281	288	318	325	337	344	356
56	198	205	213	220	227	256	263	269	276	283	312	318	330	336	347
58	195	202	210	217	224	252	258	265	271	278	305	311	322	328	339

Table 7 — Compressive strength P_{cy}

5) Values of p_c (N/mm²) with $\lambda < 119$ for strut curve c															
λ	Steel grade and design strength p_y (N/mm²)														
	S 275					S 355					S 460				
	265	345	255	265	275	315	325	335	345	355	398	409	427	436	450
30	233	242	252	261	271	308	317	326	336	345	387	396	414	424	442
25	226	235	245	254	263	299	308	317	326	335	375	384	402	410	428
30	220	228	237	246	255	289	298	307	315	324	363	371	388	396	413
35	213	221	230	238	247	280	288	296	305	313	349	357	374	382	397
40	206	214	222	230	238	270	278	286	293	301	335	343	358	365	380
42	203	211	219	227	235	266	273	281	288	296	329	337	351	358	373
44	200	208	216	224	231	261	269	276	284	291	323	330	344	351	365
46	197	205	213	220	228	257	264	271	279	286	317	324	337	344	357
48	195	202	209	217	224	253	260	267	274	280	311	317	330	337	349
50	192	199	206	213	220	248	255	262	268	275	304	310	323	329	341
52	189	196	203	210	217	244	250	257	263	270	297	303	315	321	333
54	186	193	199	206	213	239	245	252	258	264	291	296	308	313	324
56	183	189	196	202	209	234	240	246	252	258	284	289	300	305	315
58	179	186	192	199	205	229	235	241	247	252	277	282	292	297	306
60	176	182	189	195	201	225	230	236	241	247	270	274	284	289	298
62	173	179	185	191	197	220	225	230	236	241	262	267	276	280	289
64	170	176	182	188	193	215	220	225	230	235	255	260	268	272	280
66	167	173	178	184	189	210	215	220	224	229	248	252	260	264	271
68	164	169	175	180	185	205	210	214	219	223	241	245	252	256	262
70	161	166	171	176	181	200	204	209	213	217	234	238	244	248	254
72	157	163	168	172	177	195	199	203	207	211	227	231	237	240	246
74	154	159	164	169	173	190	194	198	202	205	220	223	229	232	238
76	151	156	160	165	169	185	189	193	196	200	214	217	222	225	230
78	148	152	157	161	165	180	184	187	191	194	207	210	215	217	222

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