UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: December 2018

Module Number: CE 6302 **Module Name: Design of Concrete Structures II**

[Three Hours]

[Answer **all questions**, each Question carries 25 marks]

Code of Practice BS 8110 Part 1: 1997 and BS 8007: 1987 are provided

Q1. Reinforced concrete underground water sump is to be designed in one of the luxury hotel project in Galle. Water is pumped through the pump house nearby to the overhead tank in the building. Sump is covered by a 200 mm thick concrete slab (on top). A neoprene pad is provided at the joint of top slab and tank walls. The proposed internal dimensions of the water sump are shown in the Figures Q1-a) and Q1-b). The water sump is constructed on level ground. The water table is 1 m below the existing ground level. Borehole data indicates that there is sandy soil up to 4 m below the ground level. Density of moist soil is 20 kN/m^3 and active soil pressure coefficient (ka) is 0.217. Take Design bearing capacity of the soil as 230kN/m^2. Consider the minimum factor of safety as 1.5.

State clearly all assumptions you may make (if any) to solve the problem.

a) Discuss the overall stability of the underground water sump under all possible unfavorable load combinations without performing any calculation. Describe three methodologis to improve the stability of the structure.

[6.0 Marks]

b) Determine the effective length, effective width and effective height of the water sump walls.

[5.0 Marks]

c) Calculate amount of reinforcement required for the wall-A to resist bending moments and axial forces at ULS in the vertical direction.

[8.0 Marks]

d) Check the stability of the water sump under serviceability limit state and check whether the design satisfies the required factor of safety

[6.0 Marks]

Q2. a) Derive the expressions for Prestressing forces (P_e and P_i) applied eccentrically in a concrete member based on the most critical stresses at service and transfer states. Clearly indicate all necessary stress and strain diagrams required in the derivation. Consider rectangular beam for above derivation.

[6.0 Marks]

b) A newly constructed prestressed concrete bridge has a post-tensioned solid concrete slab for the deck. This solid slab is designed to carry service load of 8 kN/m^2. The effective span of the slab is 16.0 m and is simply supported at the two edge beams. Take immediate losses and long term losses to be 10% and 20%, respectively. The concrete strength at 7 days (at transfer) and at 28 days of casting are 40 N/mm^2 and 60 N/mm^2, respectively. The unit weight of concrete is 25 kN/m^3. The slab is expected to design as a class II member.

i) Determine the required minimum depth of the bridge deck slab.

[5.0 Marks]

ii) Suppose the bridge deck with a depth of 525 mm, if the maximum eccentricity of the tendons at mid-span is 75 mm above the soffit, determine the required minimum value of the prestressed force to resist above loading. Use inequality expressions to solve above calculations.

[6.0 Marks]

iii) Construct a Magnel diagram for the bridge slab and find the required minimum prestressing force for a tendon eccentricity of 188 mm. Explain briefly, what would be the effect on the minimum prestressing force for reducing the eccentricity to 125 mm and increasing it to 250 mm?

[8.0 Marks]

Q3. A rectangular concrete beam of cross-section 300 mm deep and 200 mm wide is prestressed by means of 15 wires of 5 mm diameter located 65 mm from the bottom of the beam and 3 wires of diameter of 5 mm, 25 mm from the top as shown in Figure Q3. State clearly any assumptions used.

(a) Assuming the prestress in the steel as 840 N/mm^2, calculate the stresses at the extreme fibers of the mid-span section when the beam is supporting its own weight over a span of 6 m.

[10.0 Marks]

(b) If a uniformly distributed live load of 6 kN/m is imposed, evaluate the maximum working stress in concrete. The density of concrete is 24 kN/m^3.

[10.0 Marks]

(c) Draw resultant stress diagram.

[5.0 Marks]

Q4. A 10 m span post tensioned concrete beam with a cross section of 200 x 300 mm (as shown in Figure Q4) is pre-stressed by a cable carrying an initial pre-stressing force of 300 kN. The cross-sectional area of the wires in the cable is 308 mm^2.
Assume E_s = 210 kN/mm^2, E_c = 30 kN/mm^2, E_{ci} = 28 kN/mm^2 and age of concrete at transfer @ 8 days. f_{cu}: 50 MPa, f_{ci}: 40 MPa (8 days),

(a) Identify possible losses in the beam

[5.0 Marks]

(b) Calculate the total percentage loss of stress in the beam.

[12.0 Marks]

(c) Determine effective pre-stressing force in the beam after all losses.

[8.0 Marks]

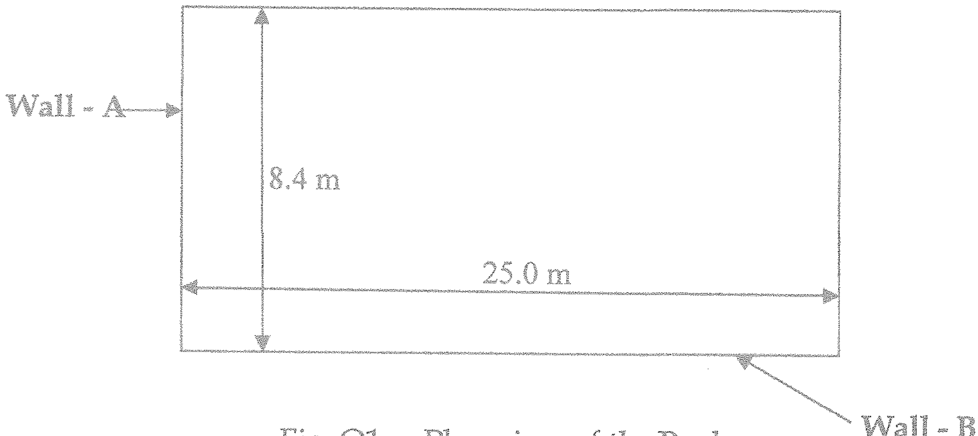


Fig. Q1-a: Plan view of the Pool

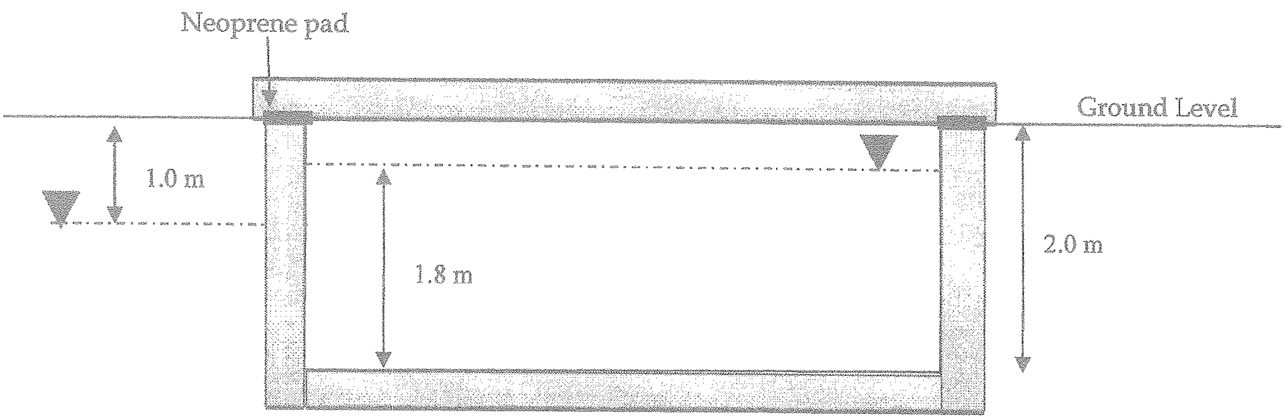


Fig. Q1-b: Internal Dimensions of the Pool

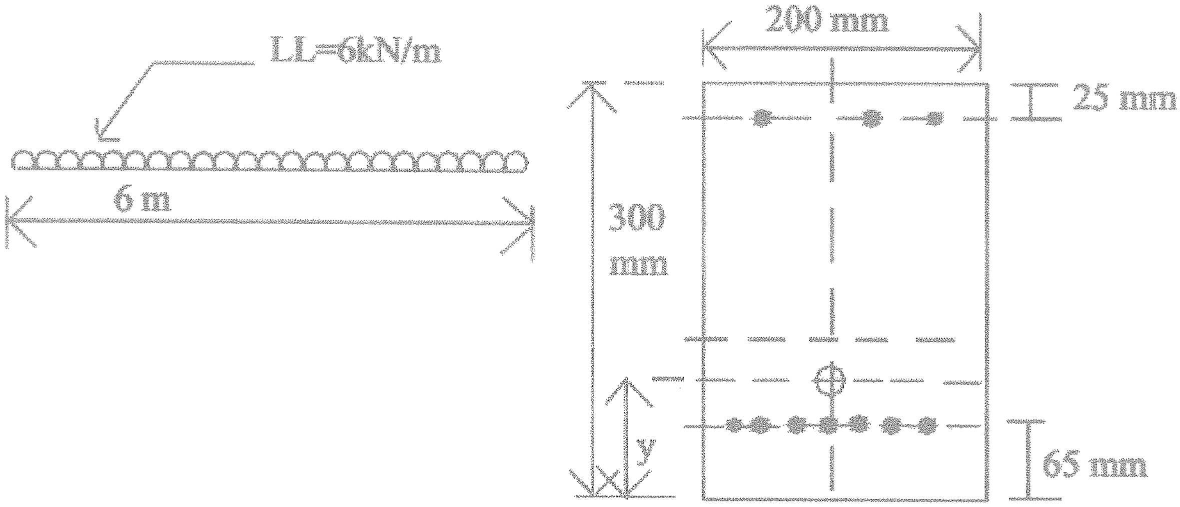


Fig. Q3: Cross sectional view

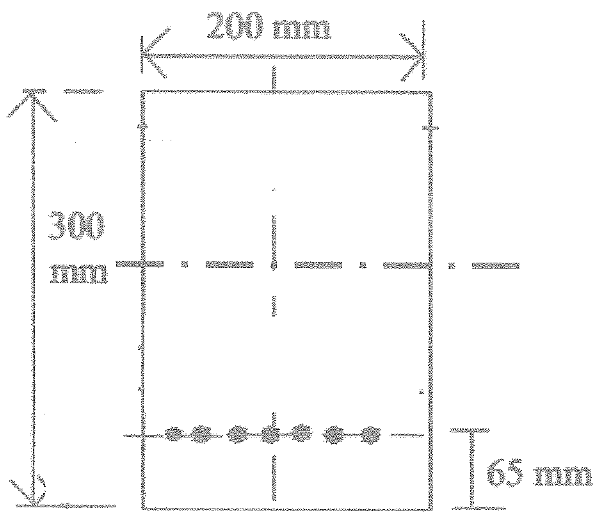
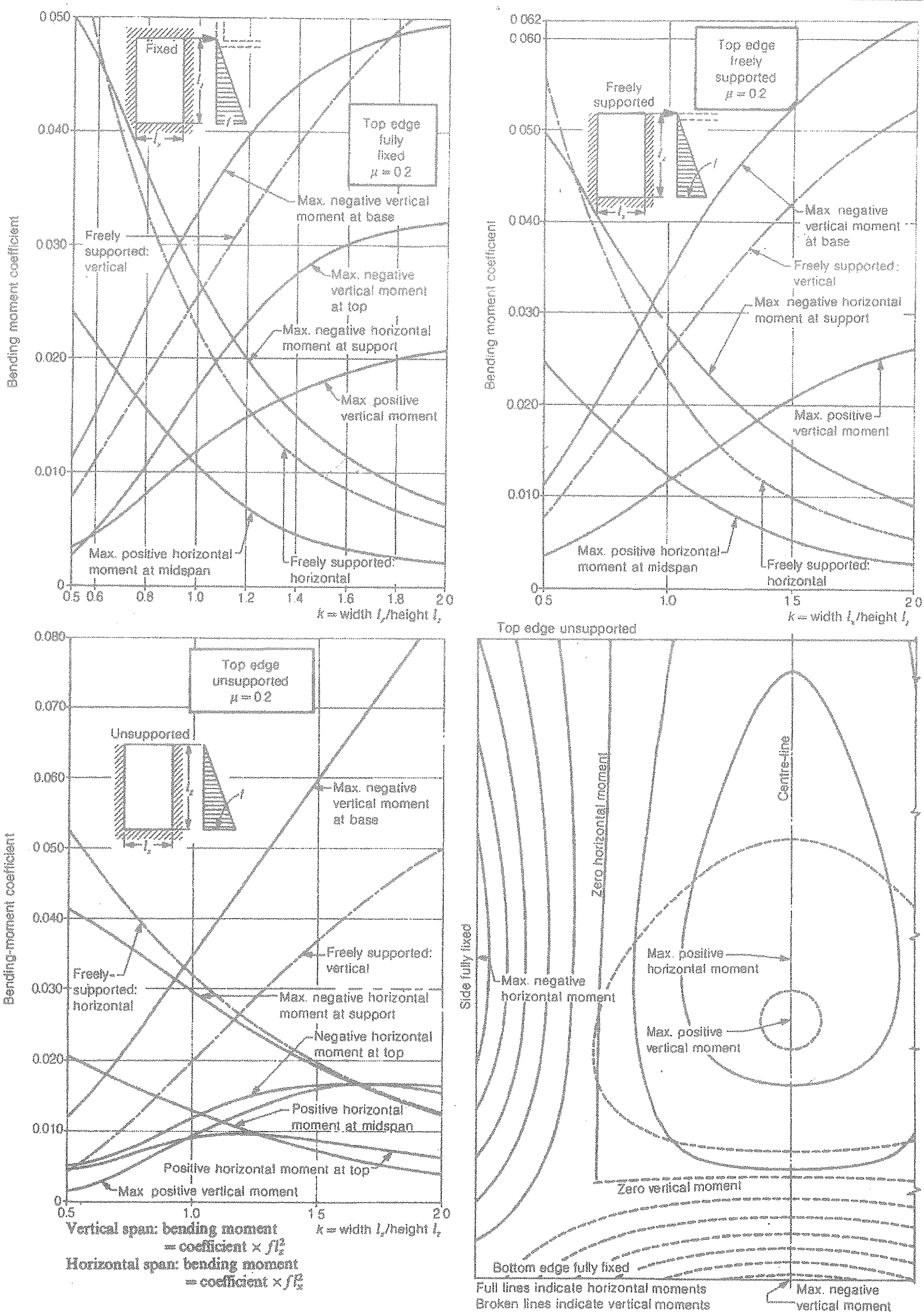


Fig. Q4: Cross sectional view

Annex_1_Steel Properties

BS	*Type of tendon*	*Nominal diameter and steel area*		*Nominal tensile strength f_{pu}*	*Specified characteristic load (kN)*		Maximum relaxation (%) after 1000 h	
					Breaking load (A)	*0.1% proof load or load at 1% elongation*	*at 70% of A*	*at 80% of A*
	Wire	*mm*	*mm^2*	*N/mm^2*		*0.1% proof load*		
5896	Cold-drawn steel wire (pre-straightened)	7	38.5	1670	64.3	53.4	Class 1	12
		7		1570	60.4	50.1	8	
		6	28.3	1770	50.1	41.6		4.5
		6		1670	47.3	39.3	Class 2	
		5	19.6	1770	34.7	28.8	2.5	
		5		1670	32.7	27.2		
		4.5	15.9	1620	25.8	21.4		
		4	12.6	1770	22.3	18.5		
		4		1670	21	17.5		

Annex 2



Vertical span: bending moment = coefficient × fl_z^2
Horizontal span: bending moment = coefficient × fl_x^2

Full lines indicate horizontal moments
Broken lines indicate vertical moments

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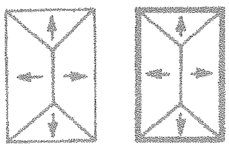
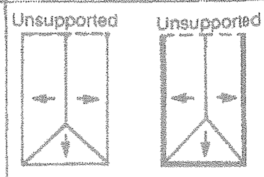
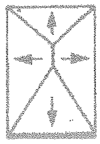
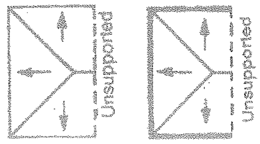
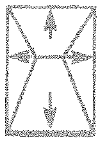
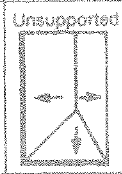
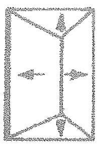
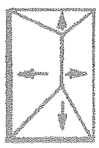
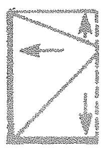
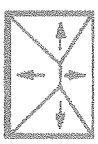
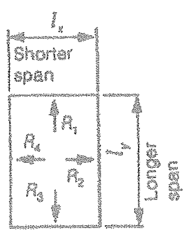
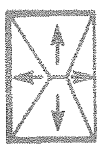
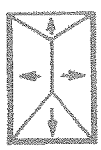
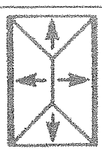
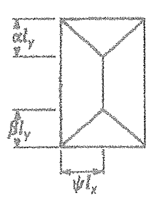
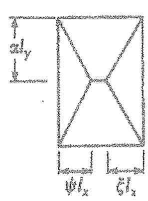
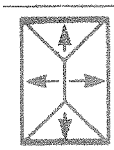
Two-way slabs: rectangular panels: loads on beams: common coefficients

Panels supported along four edges	Panels unsupported along one edge
 $k > 1$: $R_1 = R_3 = \frac{1}{4}wl_x^2$; $R_2 = R_4 = \frac{1}{2}(k - \frac{1}{2})wl_x^2$; $\alpha = \beta = 1/2k$; $k = 1$: $R_1 = R_2 = R_3 = R_4 = \frac{1}{4}wl_x^2$	 $R_1 = 0$; $R_2 = R_4 = \frac{1}{2}(k - \frac{1}{4})wl_x^2$; $R_3 = \frac{1}{4}wl_x^2$; $\beta = 1/2k$
 $k \nless 4/3$: $R_1 = \frac{1}{4}wl_x^2$ (min.) $\alpha = 1/2k$ (min.); $R_2 = R_4 = \frac{1}{2}(k - \frac{2}{3})wl_x^2$; $R_3 = \frac{5}{12}wl_x^2$ (max.) $\beta = 5/6k$ (max.)	 $k \ngtr 2$: $R_1 = R_3 = \frac{1}{2}k(1 - \frac{1}{4}k)wl_x^2$; $R_2 = 0$; $R_4 = \frac{1}{8}k^2wl_x^2$; $\psi = k/2$
 $k \leqslant 4/3$: $R_1 = \frac{3}{5}R_3$ approx. (min.) $\alpha = 3/8$ (min.); $\beta = 5/8$ (max.); $R_2 = R_4 = \frac{3}{16}k^2wl_x^2$ $\psi = \xi = 3k/8$; $R_3 = \frac{5}{8}k(1 - \frac{3}{8}k)wl_x^2$ approx. (max.)	 $R_1 = 0$ $\beta = 5/8k$; $R_2 = \frac{3}{5}R_4$ (min.) $\psi = 5/8$; $R_3 = \frac{5}{16}wl_x^2$; $R_4 = \frac{5}{8}(k - \frac{5}{16})wl_x^2$ (max.)
 $R_1 = R_3 = \frac{3}{16}wl_x^2$; $R_2 = \frac{3}{5}R_4$ (min.); $R_4 = \frac{5}{8}(k - \frac{3}{8})wl_x^2$ (max.); $\alpha = \beta = 3/8k$ $\psi = \frac{5}{8}$ (max.)	 $k \ngtr 8/5$: $R_1 = \frac{3}{5}R_3$ (min.) $R_2 = 0$; $R_3 = \frac{5}{8}k(1 - \frac{5}{16}k)wl_x^2$ (max.); $R_4 = \frac{5}{16}k^2wl_x^2$ $\alpha = 3/8k$ (min.); $\psi = 5k/8$ (max.)
 $R_1 = \frac{3}{16}wl_x^2$ (min.) $\alpha = 3/8k$ (min.); $R_2 = \frac{3}{5}R_4$ (min.) $\beta = 5/8k$ (max.); $R_3 = \frac{5}{16}wl_x^2$ (max.) $\psi = 5/8$ (max.); $R_4 = \frac{5}{8}(k - \frac{1}{2})wl_x^2$ (max.)	 $k \geqslant 8/5$: $R_1 = \frac{3}{16}wl_x^2$ (min.) $R_2 = 0$; $R_3 = \frac{1}{2}wl_x^2$; $R_4 = (k - \frac{4}{5})wl_x^2$ (max.); $\alpha = 3/5k$ $\beta = 1/k$
 $k \nless 5/4$: $R_1 = R_3 = \frac{5}{16}wl_x^2$ $\alpha = \beta = 5/8k$; $R_2 = \frac{3}{5}R_4$ (min.) $\psi = 5/8$ (max.); $R_4 = \frac{5}{8}(k - \frac{5}{8})wl_x^2$(max.)	 $k = \frac{l_y}{l_x} = \frac{\text{longer span}}{\text{shorter span}}$; w = intensity of uniformly distributed service load per unit area; If analysis due to ultimate loads is undertaken, substitute n for w in appropriate formulae; R_1, R_2, R_3, R_4 = total load carried by each support of panel
 $k \leqslant 5/4$: $R_1 = R_3 = \frac{1}{2}k(1 - \frac{2}{5}k)wl_x^2$ $\alpha = \beta = 1/2$; $R_2 = \frac{3}{20}k^2wl_x^2$ (min.); $R_4 = \frac{1}{4}k^2wl_x^2$ (max.) $\psi = k/2$; $\xi = 3k/10$	Condition of supports: - - - - no support; ——— freely support; ▬▬▬ continuity or fixity
 $R_1 = \frac{3}{20}wl_x^2$ (min.) $\alpha = 3/10k$ (min.); $R_2 = R_4 = \frac{1}{2}(k - \frac{2}{3})wl_x^2$; $R_3 = \frac{1}{4}wl_x^2$ (max.) $\beta = 1/2k$ (max.)	Loads marked (min.) apply if panel is entirely freely supported along edge indicated: if partially restrained, load will be slightly greater than given and load marked (max.) on opposite edge will be correspondingly reduced.
 $R_1 = R_3 = \frac{3}{20}wl_x^2$ (min.); $R_2 = R_4 = \frac{1}{2}(k - \frac{3}{10})wl_x^2$ (max.); $\alpha = \beta = 3/10k$ (min.)	 
 $k \nless 5/3$: $R_1 = R_3 = \frac{5}{12}wl_x^2$ (min.); $R_2 = R_4 = \frac{1}{2}(k - \frac{5}{6})wl_x^2$ (max.); $\alpha = \beta = 5/6k$ (min.)	

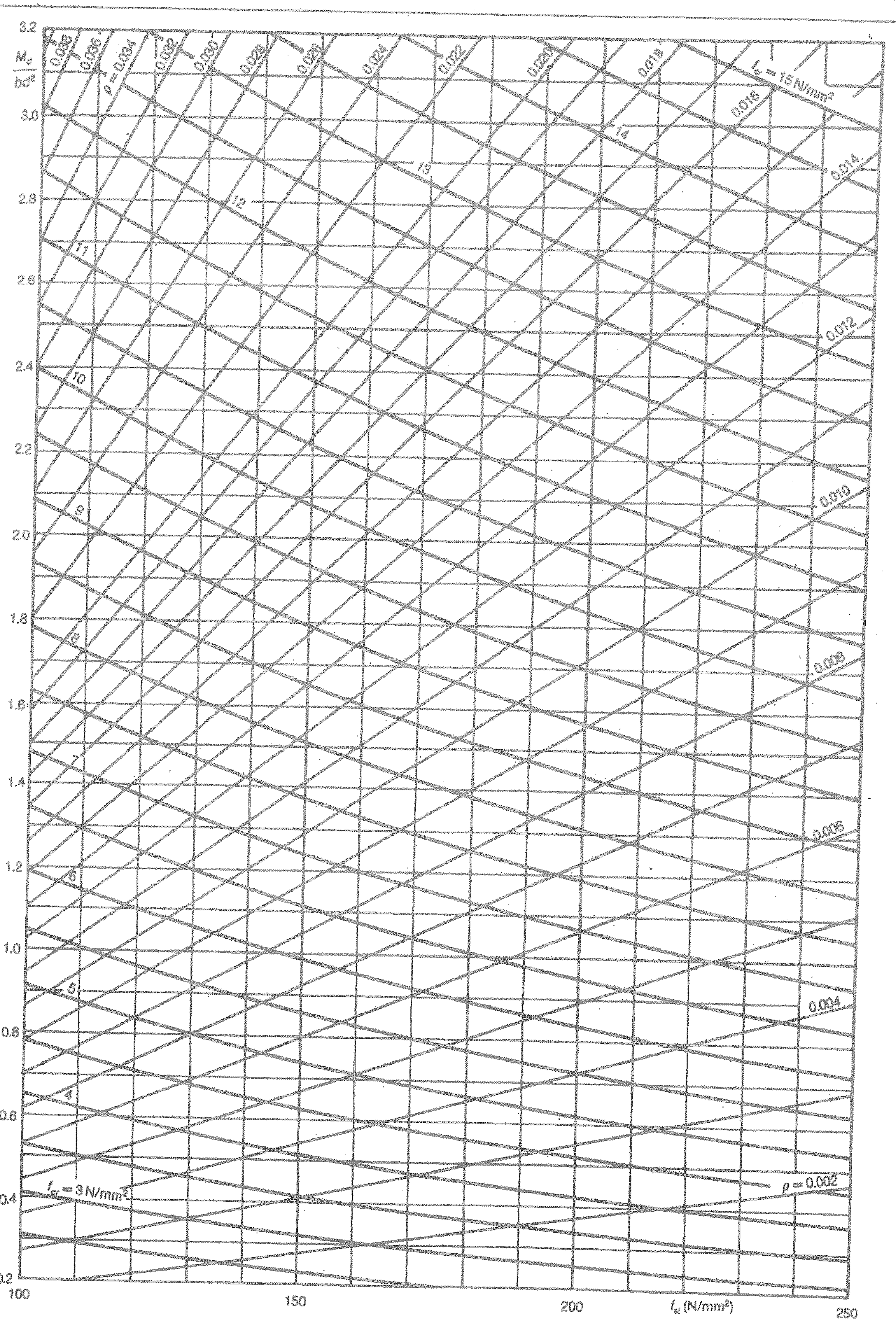
Reinforcement: metric bar data

			Bar size in millimetres									
			6	8	10	12	16	20	25	32	40	50
Cross-sectional areas of bars at specific spacings	Bar spacing in millimetres (non-preferred spacings shown in italics)	75	376	670	1047	1507	2680	4188	6544	—	—	—
		80	*353*	*628*	*981*	*1413*	*2513*	*3926*	*6135*	—	—	—
		90	*314*	*558*	*872*	*1256*	*2234*	*3490*	*5454*	—	—	—
		100	282	502	785	1130	2010	3141	4908	8042	—	—
		110	*257*	*456*	*713*	*1028*	*1827*	*2855*	*4462*	*7311*	—	—
		120	*235*	*418*	*654*	*942*	*1675*	*2617*	*4090*	*6702*	*10471*	—
		125	226	402	628	904	1608	2513	3926	6433	10053	—
		130	*217*	*386*	*604*	*869*	*1546*	*2416*	*3775*	*6186*	*9666*	—
		140	*201*	*359*	*560*	*807*	*1436*	*2243*	*3506*	*5744*	*8975*	—
		150	188	335	523	753	1340	2094	3272	5361	8377	13090
		160	*176*	*314*	*490*	*706*	*1256*	*1963*	*3067*	*5026*	*7853*	*12272*
		175	161	287	448	646	1148	1795	2804	4595	7180	11220
		180	*157*	*279*	*436*	*628*	*1117*	*1745*	*2727*	*4468*	*6981*	*10908*
		200	141	251	392	565	1005	1570	2454	4021	6283	9817
		220	*128*	*228*	*356*	*514*	*913*	*1427*	*2231*	*3655*	*5711*	*8925*
		225	125	223	349	502	893	1396	2181	3574	5585	8727
		240	*117*	*209*	*327*	*471*	*837*	*1308*	*2045*	*3351*	*5235*	*8181*
		250	113	201	314	452	804	1256	1963	3216	5026	7854
		275	102	182	285	411	731	1142	1784	2924	4569	7140
		300	94	167	261	376	670	1047	1636	2680	4188	6545
	Number of bars	1	28.3	50.3	78.5	113.1	201.1	314.2	490.9	804.2	1257	1963
		2	56.5	100.5	157.1	226.2	402.1	628.3	981.7	1608	2513	3927
		3	84.8	150.8	235.6	339.3	603.2	942.5	1473	2413	3770	5890
		4	113.1	201.1	314.2	452.4	804.2	1257	1963	3217	5027	7854
		5	141.4	251.3	392.7	565.5	1005	1571	2454	4021	6283	9817
		6	169.6	301.6	471.2	678.6	1206	1885	2945	4825	7540	11781
		7	197.9	351.9	549.8	791.7	1407	2199	3436	5630	8796	13744
		8	226.2	402.1	628.3	904.8	1608	2513	3927	6434	10053	15708
		9	254.5	452.4	706.9	1018	1810	2827	4418	7238	11310	17671
		10	282.7	502.7	785.4	1131	2011	3142	4909	8042	12566	19635
		11	311.0	552.9	863.9	1244	2212	3456	5400	8847	13823	21598
		12	339.3	603.2	942.5	1357	2413	3770	5890	9651	15080	23562
		13	367.6	653.5	1021	1470	2614	4084	6381	10455	16336	25525
		14	395.8	703.7	1100	1583	2815	4398	6872	11259	17593	27489
		15	424.1	754.0	1178	1696	3016	4712	7363	12064	18850	29452
		16	452.4	804.2	1257	1810	3217	5027	7854	12868	20106	31416
		17	480.7	854.5	1335	1923	3418	5341	8345	13672	21363	33379
		18	508.9	904.8	1414	2036	3619	5655	8836	14476	22619	35343
		19	537.2	955.0	1492	2149	3820	5969	9327	15281	23876	37306
		20	565.5	1005	1571	2262	4021	6283	9817	16085	25133	39270
Perimeters of specific numbers of bars	Number of bars	1	18.8	25.1	31.4	37.6	50.2	62.8	78.5	100.5	125.6	157.1
		2	37.6	50.2	62.8	75.3	100.5	125.6	157.0	201.0	251.3	314.2
		3	56.5	75.3	94.2	113.0	150.7	188.4	235.6	301.5	376.9	471.2
		4	75.3	100.5	125.6	150.7	201.0	251.3	314.1	402.1	502.6	628.3
		5	94.2	125.6	157.0	188.4	251.3	314.1	392.6	502.6	628.3	785.4
		6	113.0	150.7	188.4	226.1	301.5	376.9	471.2	603.1	753.9	942.5
		7	131.9	175.9	219.9	263.8	351.8	439.8	549.7	703.7	879.6	1100
		8	150.7	201.0	251.3	301.5	402.1	502.6	628.3	804.2	1005	1257
		9	169.6	226.1	282.7	339.2	452.3	565.4	706.8	904.7	1130	1414
		10	188.4	251.3	314.1	376.9	502.6	628.3	785.3	1005	1256	1571

Areas are given in square millimetres: perimeters in millimetres.

For additional notes see *Table 89*.

Annex 5


$\frac{M_d}{bd^2}$
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
100
150
200
250
f_{st} (N/mm²)
0.038
0.036
ρ = 0.034
0.032
0.030
0.028
0.026
0.024
0.022
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
ρ = 0.002
f_{cr} = 15 N/mm²
14
13
12
11
10
9
8
7
6
5
4
f_{cr} = 3 N/mm²