UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: January 2022

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

[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. A roof-top water storage tank is to be designed for a two-storied house in Wackwella. The water tank is supported on the reinforced concrete frame at the second floor of the building. The length of the tank is 6.0 m and other internal dimensions of the water tank are as shown in Figure Q1. The top of the wall was allowed to have free movements by providing a Neoprene pad between the roof slab and wall top. The following information is also available.

Grade of concrete to be used for the water tank: C35A
The density of concrete: 24 kN/m^3
Coefficient of thermal expansion of concrete: 10x10^{-6}/^{0}C
Fall in temperature between hydration peak and ambient (T$_1$): 30^{0}C
Fall in temperature due to seasonal variations (T2): 15^{0}C
The density of water: 9.81 kN/m^3
Reinforcement steel: Grade 460 (type 2 Deformed bars)

You may assume any missing information but state your assumptions clearly.

a) Determine the effective length, effective width, and effective height of the tank walls.

[2.0 Marks]

b) Calculate maximum water pressure acting on the short walls at ~~severability~~ serviceability and ultimate limit states.

[2.0 Marks]

c) Calculate required moments and forces acting (axial and shear) on the short wall under serviceability and ultimate limit state. Clearly indicates the forces and moments acting on the wall.

[4.0 Marks]

d) Calculate the amount of reinforcement required for the short walls to resist the ultimate bending moment due to water load.

[2.0 Marks]

e) Calculate amount of reinforcement required for the short walls to resist thermal and shrinkage movement in immature concrete.

[2.0 Marks]

f) Provide a suitable arrangement of reinforcement for the short walls.

[2.0 Marks]

g) Without performing calculations, discuss how you will determine the maximum crack width of a reinforced concrete wall in the tank under the maximum serviceability bending moment.

[2.0 Marks]

h) Why Grade C35A concrete is recommended for water retaining structures? Explain the constituents in selecting mix proportions and their limitation for Grade C35A concrete. Discuss issues arising when placing such concrete in large sections.

[4.0 Marks]

i) Suggest a suitable structural arrangement for the floor slab to reduce the slab thickness.

[2.0 Marks]

j) During construction, the entire length of the wall was concreted. After several weeks, vertical cracks at regular intervals were observed along the wall. Give possible reasons for this behavior and explain how ~~to avoid~~ this kind of cracking can be avoided.

[3.0 Marks]

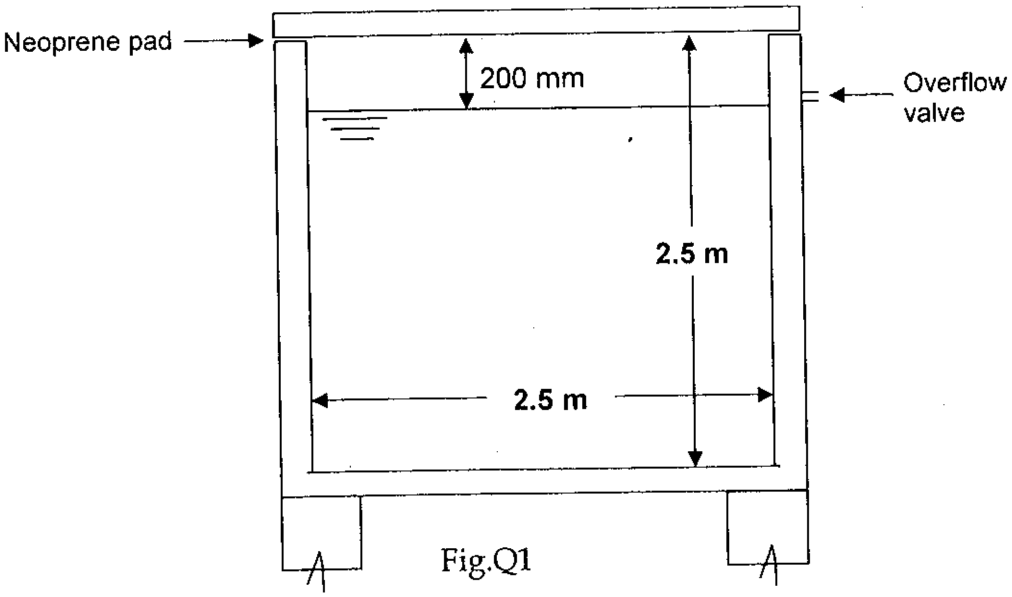

Fig.Q1

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. Consider a rectangular shape beam with eccentrically applied prestressing force and clearly indicate all the necessary stress and strain diagrams required in the above derivations..

[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/m². 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/mm² and 60 N/mm², respectively. The unit weight of concrete is 25 kN/m³. 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) Consider a bridge deck of 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 place eccentrically at 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..

(a) Assuming the prestress in the steel as 840 N/mm², 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/m³ . [10.0 Marks]

(c) Draw resultant stress diagrams. [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 mm². Assuming, E_s = 210 kN/mm², E_c = 30 kN/mm², E_{ci} = 28 kN/mm² 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]

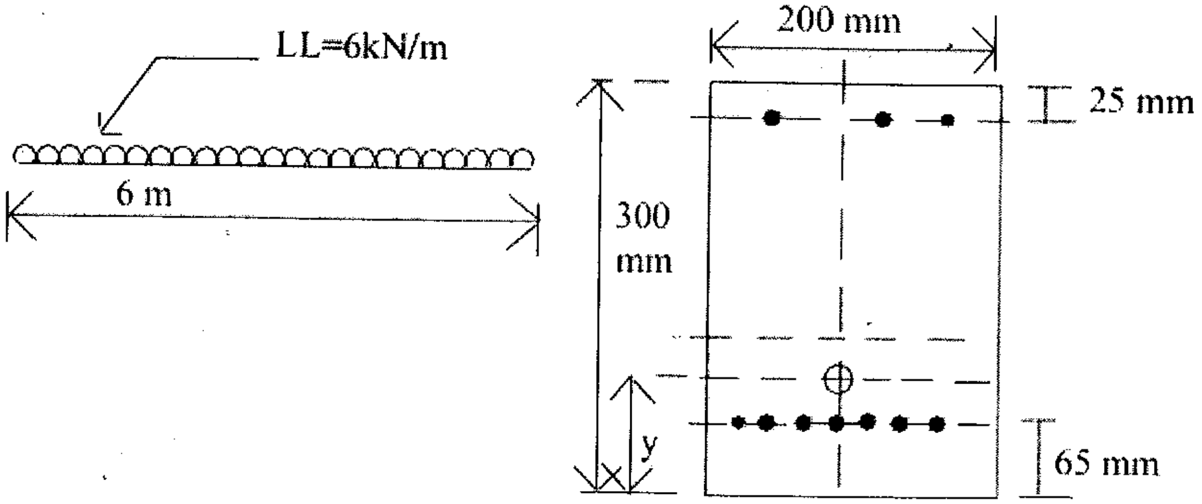

Fig. Q3: Cross sectional view

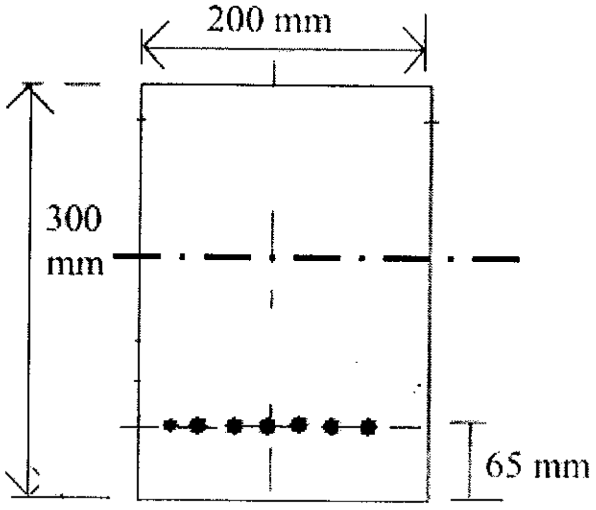

Fig. Q4: Cross sectional view

Annex_1_Steel Properties

BS	Type of tendon	Nominal diameter and steel area		Nominal tensile strength f_{pu}	Specified charactersitic 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	mm²	N/mm²		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

Two-way slabs: triangularly distributed loads: elastic analyses

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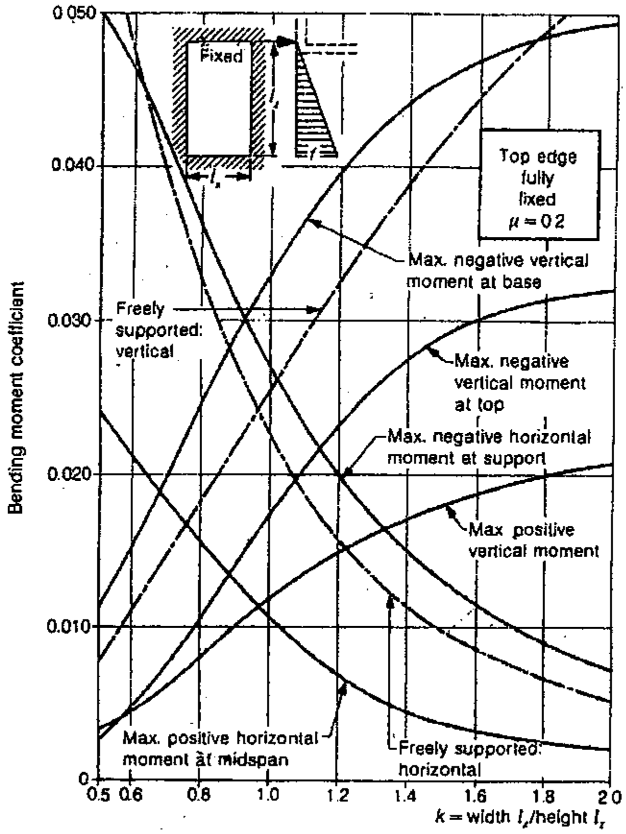
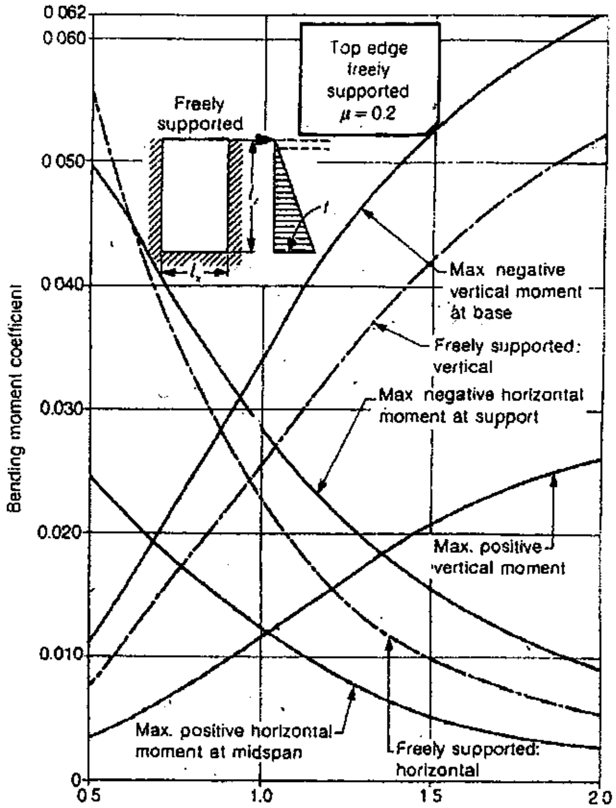
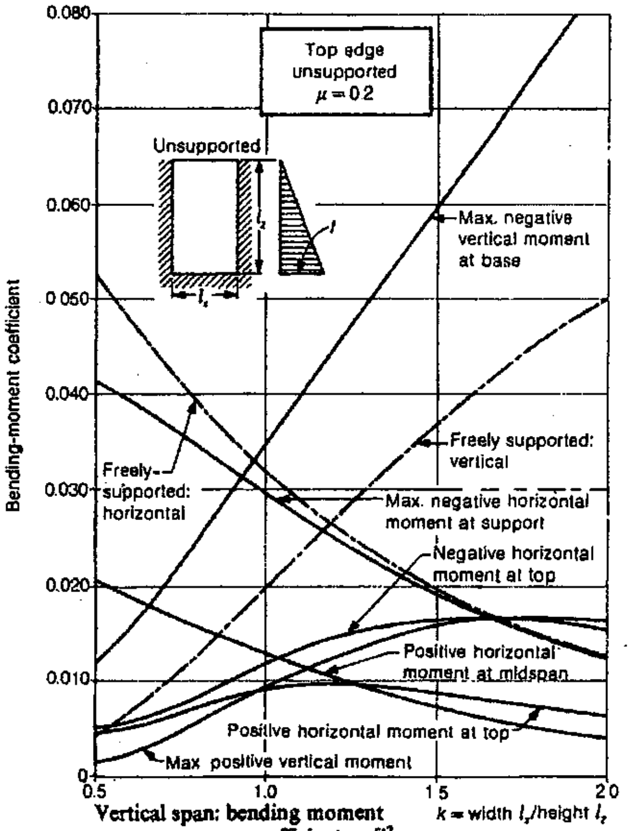
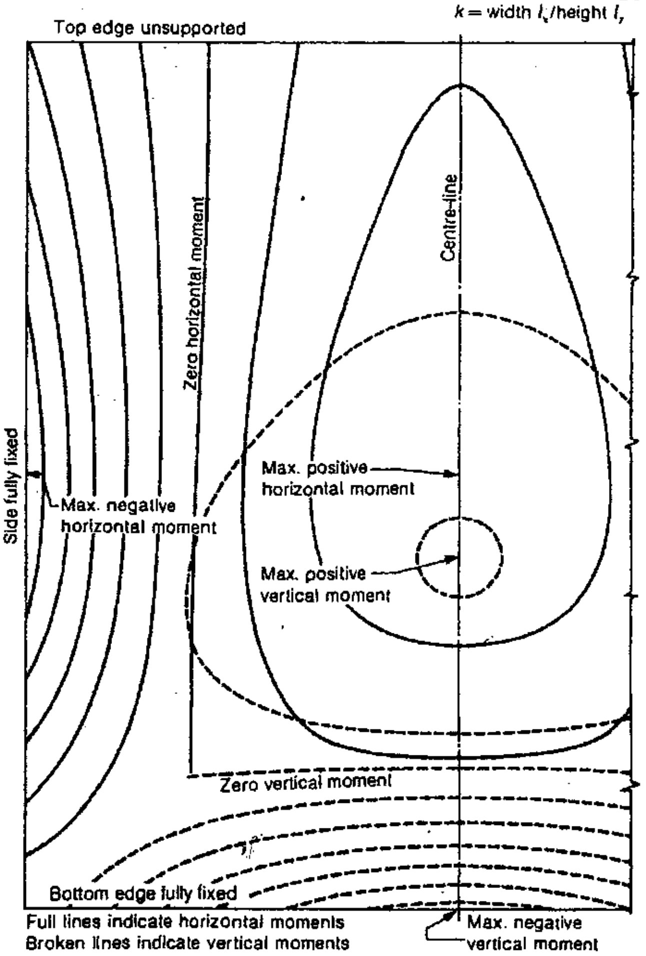






Vertical span: bending moment = coefficient × fl_z^2

Horizontal span: bending moment = coefficient × fl_x^2



Full lines indicate horizontal moments
Broken lines indicate vertical moments

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Annex 3

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

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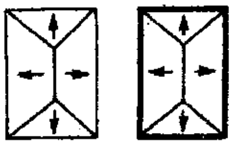
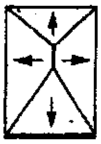
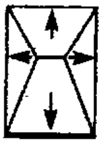
Panels supported along four edges



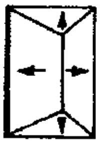
$k > 1$: $R_1 = R_3 = \frac{1}{4}wl_x^2$
$R_2 = R_4 = \frac{1}{2}(k - \frac{1}{2})wl_x^2$
$\alpha = \beta = 1/2k$
$k = 1$: $R_1 = R_2 = R_3 = R_4 = \frac{1}{4}wl_x^2$



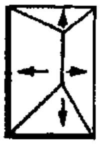
$k \nless 4/3$: $R_1 = \frac{1}{4}wl_x^2$ (min.) $\quad \alpha = 1/2k$ (min.)
$R_2 = R_4 = \frac{1}{2}(k - \frac{2}{3})wl_x^2$
$R_3 = \frac{5}{12}wl_x^2$ (max.) $\quad \beta = 5/6k$ (max.)



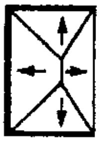
$k \leqslant 4/3$: $R_1 = \frac{3}{5}R_3$ approx. (min.) $\quad \alpha = 3/8$ (min.)
$\beta = 5/8$ (max.)
$R_2 = R_4 = \frac{3}{16}k^2wl_x^2 \quad \psi = \xi = 3k/8$
$R_3 = \frac{5}{8}k(1 - \frac{3}{8}k)wl_x^2$ approx. (max.)



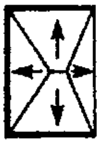
$R_1 = R_3 = \frac{3}{16}wl_x^2$
$R_2 = \frac{3}{5}R_4$ (min.)
$R_4 = \frac{5}{8}(k - \frac{3}{8})wl_x^2$ (max.)
$\alpha = \beta = 3/8k \quad \psi = \frac{5}{8}$ (max.)



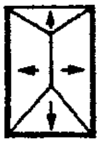
$R_1 = \frac{3}{16}wl_x^2$ (min.) $\quad \alpha = 3/8k$ (min.)
$R_2 = \frac{3}{5}R_4$ (min.) $\quad \beta = 5/8k$ (max.)
$R_3 = \frac{5}{16}wl_x^2$ (max.) $\quad \psi = 5/8$ (max.)
$R_4 = \frac{5}{8}(k - \frac{1}{2})wl_x^2$ (max.)



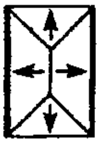
$k \nless 5/4$: $R_1 = R_3 = \frac{5}{16}wl_x^2 \quad \alpha = \beta = 5/8k$
$R_2 = \frac{3}{5}R_4$ (min.) $\quad \psi = 5/8$ (max.)
$R_4 = \frac{5}{8}(k - \frac{5}{8})wl_x^2$ (max.)



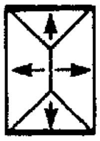
$k \leqslant 5/4$: $R_1 = R_3 = \frac{1}{2}k(1 - \frac{2}{5}k)wl_x^2 \quad \alpha = \beta = 1/2$
$R_2 = \frac{3}{20}k^2wl_x^2$ (min.)
$R_4 = \frac{1}{4}k^2wl_x^2$ (max.) $\quad \psi = k/2$
$\xi = 3k/10$



$R_1 = \frac{3}{20}wl_x^2$ (min.) $\quad \alpha = 3/10k$ (min.)
$R_2 = R_4 = \frac{1}{2}(k - \frac{2}{5})wl_x^2$
$R_3 = \frac{1}{4}wl_x^2$ (max.) $\quad \beta = 1/2k$ (max.)

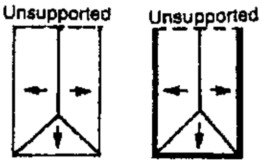


$R_1 = R_3 = \frac{3}{20}wl_x^2$ (min.)
$R_2 = R_4 = \frac{1}{2}(k - \frac{3}{10})wl_x^2$ (max.)
$\alpha = \beta = 3/10k$ (min.)

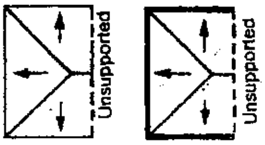


$k \nless 5/3$: $R_1 = R_3 = \frac{5}{12}wl_x^2$ (min.)
$R_2 = R_4 = \frac{1}{2}(k - \frac{5}{6})wl_x^2$ (max.)
$\alpha = \beta = 5/6k$ (min.)

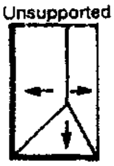
Panels unsupported along one edge



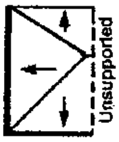
$R_1 = 0$
$R_2 = R_4 = \frac{1}{2}(k - \frac{1}{4})wl_x^2$
$R_3 = \frac{1}{4}wl_x^2$
$\beta = 1/2k$



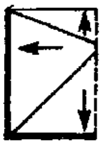
$k \ngtr 2$: $R_1 = R_3 = \frac{1}{2}k(1 - \frac{1}{4}k)wl_x^2$
$R_2 = 0$
$R_4 = \frac{1}{4}k^2wl_x^2$
$\psi = k/2$



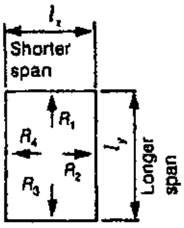
$R_1 = 0 \quad \beta = 5/8k$
$R_2 = \frac{3}{5}R_4$ (min.) $\quad \psi = 5/8$
$R_3 = \frac{5}{16}wl_x^2$
$R_4 = \frac{5}{8}(k - \frac{5}{16})wl_x^2$ (max.)



$k \ngtr 8/5$: $R_1 = \frac{3}{5}R_3$ (min.) $\quad R_2 = 0$
$R_3 = \frac{5}{8}k(1 - \frac{5}{16}k)wl_x^2$ (max.)
$R_4 = \frac{5}{16}k^2wl_x^2 \quad \alpha = 3/8k$ (min.)
$\psi = 5k/8$ (max.)



$k \geqslant 8/5$: $R_1 = \frac{3}{16}wl_x^2$ (min.) $\quad R_2 = 0$
$R_3 = \frac{1}{2}wl_x^2$
$R_4 = (k - \frac{4}{5})wl_x^2$ (max.)
$\alpha = 3/5k \quad \beta = 1/k$



$$k = \frac{l_y}{l_x} = \frac{\text{longer span}}{\text{shorter span}}$$

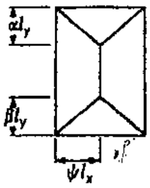
w = intensity of uniformly distributed service load per unit area

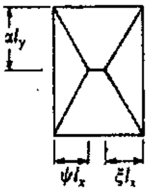
If analysis due to ultimate loads is undertaken, substitute n for w in appropriate formulae

R_1, R_2, R_3, R_4 = total load carried by each support of panel

Condition of supports
┄┄┄┄┄┄ no support
────── freely support
━━━━━━ continuity or fixity

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.





Annex 4

Reinforcement: metric bar data

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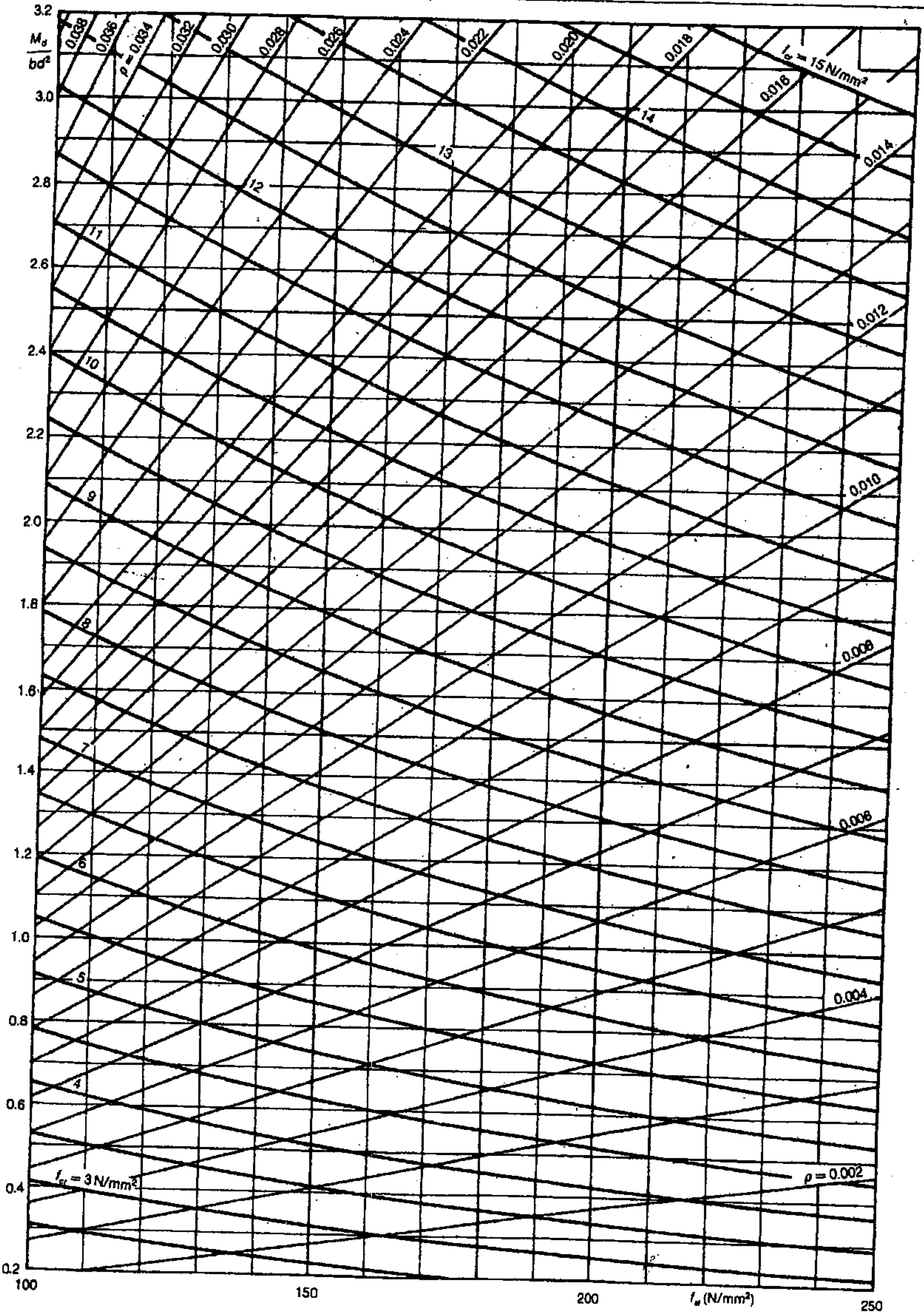
			Bar size in millimetres									
			6	8	10	12	16	20	25	32	40	50
Cross-sectional areas of bars at specific spacings	Bar spacing in millimetres (non-preferred spacings shown in italics)	75	376	670	1047	1507	2680	4188	6544	—	—	—
		80	*353*	*628*	*981*	*1413*	*2513*	*3926*	*6135*	—	—	—
		90	*314*	*558*	*872*	*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

Design data for singly-reinforced sections: SI units

Modular ratio **118**



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