UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: November 2017

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

[Three Hours]

[Answer **all questions**, each Question carries 15 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 multistory housing complex. The water tank is supported on the reinforced concrete frame. The tank is 6.0 m long. Cross section of the water tank with all dimensions is given in Figure Q1. The top of the wall of the water tank was allowed to have free movements by providing a Neoprene pad between roof slab and wall top.

The following information is also available.

Grade of concrete to be used for the water tank: C35A
Density of concrete: 24 kN/m^3
Coefficient of thermal expansion of concrete: $10x10^{-6}/^0C$
Fall in temperature between hydration peak and ambient (T_1): 30^0C
Fall in temperature due to seasonal variations (T2): 15^0C
Density of water: 9.81 kN/m^3
Reinforcement steel: Grade 460 (type 2 Deformed bars)

a) Determine the effective length, effective width and effective height of the tank walls and show that long wall is spanning as one-way slab.

[1.0 Mark]

b) Calculate maximum water pressure acting on the long wall at severability and ultimate limit state.

[2.0 Marks]

c) Calculate required moments and forces acting on the long wall at serviceability and ultimate limit state.

[4.0 Marks]

d) Calculate the amount of reinforcement required for the long-wall to resist ultimate bending moment due to water load.

[4.0 Marks]

g) Calculate maximum crack width of the long wall at serviceability bending moment.

[2.0 Marks]

i) Explain advantage of providing the steel requirement using smaller bars for crack control.

[2.0 Marks]

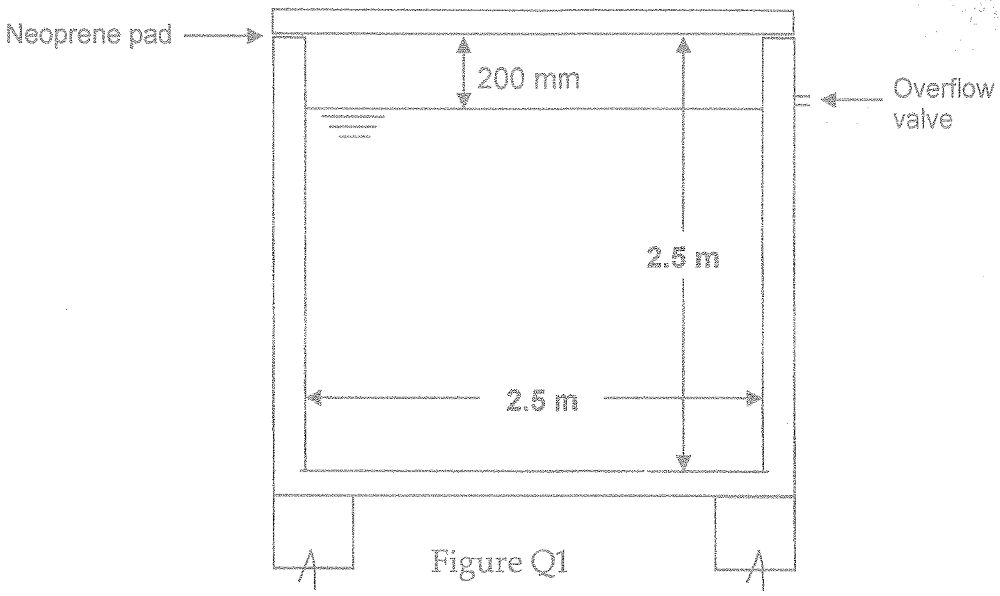


Figure Q1

Q2. Joints in liquid retaining structures are partial or complete discontinuities at section and may be formed or induced. Joints may be used in conjunction with a corresponding proportion of reinforcement, to control the crack widths arising from shrinkage and thermal changes to within acceptable limits. In addition, joint is intended to accommodate relative movement between adjoining parts of a structure ensure that water tightness of the tank under such movements

a) Discuss type of movement joints and their applications.

[3.0 Marks]

b) Discuss design options stipulated in BS 8007 for control early thermal contraction and shrinkage.

[4.0 Marks]

c) Design amount of reinforcement required and movement joint spacing for following type of constructions and method of control to control cracking due to shrinkage and thermal movement in immature concrete in a wall of 225 mm thick.

Grade of concrete to be used for the water tank: C35A
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): $15^{0}C$
Reinforcement steel: Grade 460 (type 2 Deformed bars)

i) Continuous wall under fully restrained condition
ii) Semi-continuous wall under partial restrained condition
iii) Movement joint spacing of the wall for full freedom of movement.

[8.0 Marks]

Q3. a) List four applications of prestressed concrete (PC).

[1.0 Mark]

b) 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. Indicate all necessary stress and strain diagrams used in the derivation.

[2.0 Marks]

c) 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 10.3 kN/m^2. The effective span of the slab is 20.0 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 33 N/mm^2 and 60 N/mm^2, respectively. The unit weight of concrete is 24 kN/m^3.

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

[2.0 Marks]

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

[4.0 Marks]

iii) Construct a Magnel diagram for the bridge slab and find the reqired 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?

[6.0 Marks]

Q4. An Inverted "T" beam is simply supported over a span of 16 m. The imposed load on the beam is 6.0 kN/m. Self-weight of the deck topping layer acting on the beam is 2.0 kN/m. The beam is expected to design as a class II pre tensioned member. Assume f_{cu}= 40 N/mm^2, f_{ci} = 30 N/mm2, f_{pu}=1670 N/mm^2 and loss ratio of 0.75. State clearly all additional information you may make to solve the problem.

a) Calculate allowable stress at service and transfer states.

[4.0 Marks]

b) Derive equations for minimum section moduli, Z_1 *and* Z_2, based on the most critical stresses at service and transfer state. Based on the section properties given in the attached detail sheet (Annex_1), select the most suitable section for the given loading and the required member classification. Give reasons for your selection.

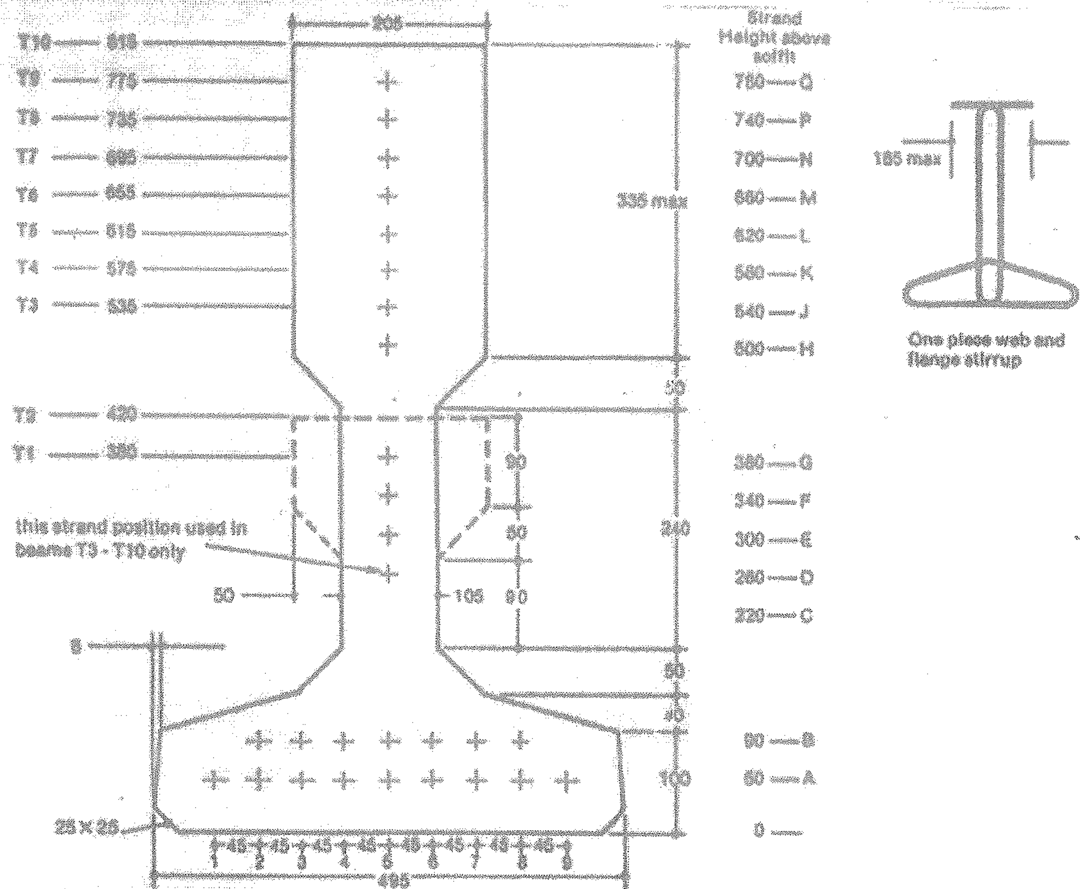
[8.0 Marks]

c) Determine critical range for the pre-stressing force and eccentricity.

[3.0 Marks]

Annex 1: Beam Details

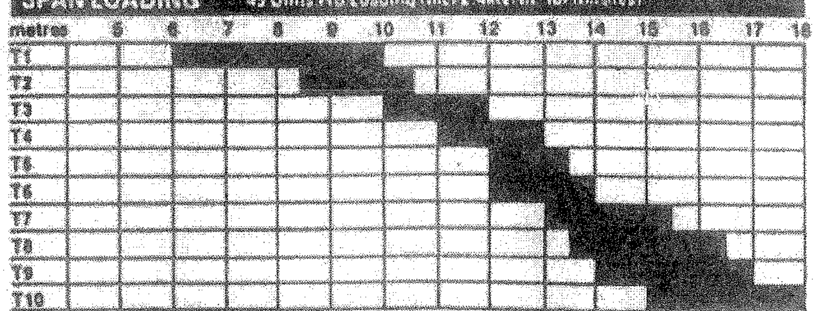
Inverted 'T' beams



SECTION PROPERTIES

Section	Depth mm	Area mm²	Height of centroid above bottom fibre mm Yb	Section moduli mm³ x 10⁶ Top fibre Zt	Section moduli mm³ x 10⁶ Bottom fibre Zb	Approximate self weight KN/m *
T1	380	98000	140	5.16	8.89	2.31
T2	420	106200	160	6.78	10.98	2.50
T3	535	114275	196	9.57	16.55	2.69
T4	575	122475	220	11.92	19.23	2.89
T5	615	130675	244	14.30	21.81	3.08
T6	655	138875	267	16.73	24.36	3.27
T7	695	147075	289	19.20	26.91	3.47
T8	735	155160	312	21.73	29.46	3.66
T9	775	163360	334	24.31	32.10	3.85
T10	815	171560	356	26.97	34.82	4.05

SPAN LOADING 45 Units HB Loading (incl 2.4kN/m² for finishes)



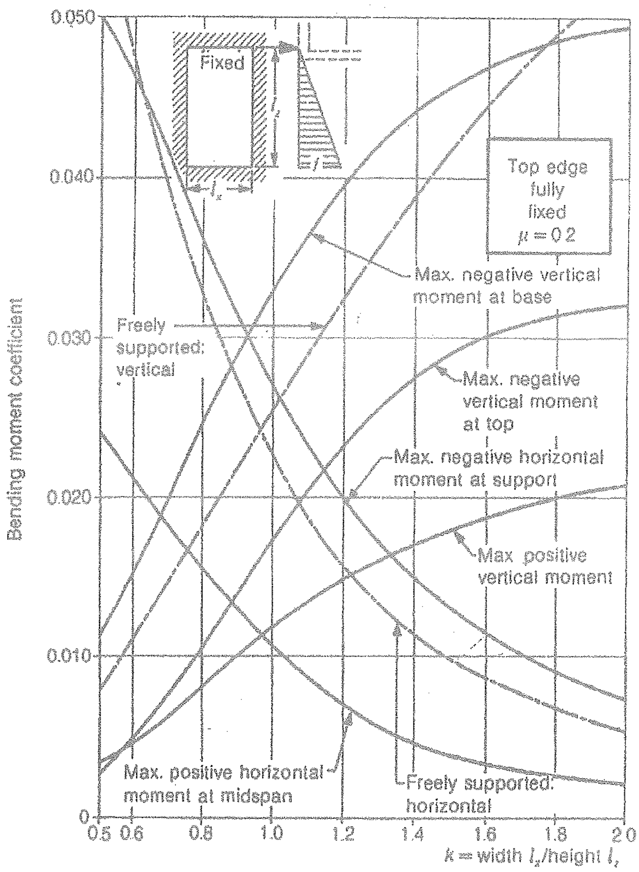
* Design self weight per unit volume has been taken as 23.6kN/m³.

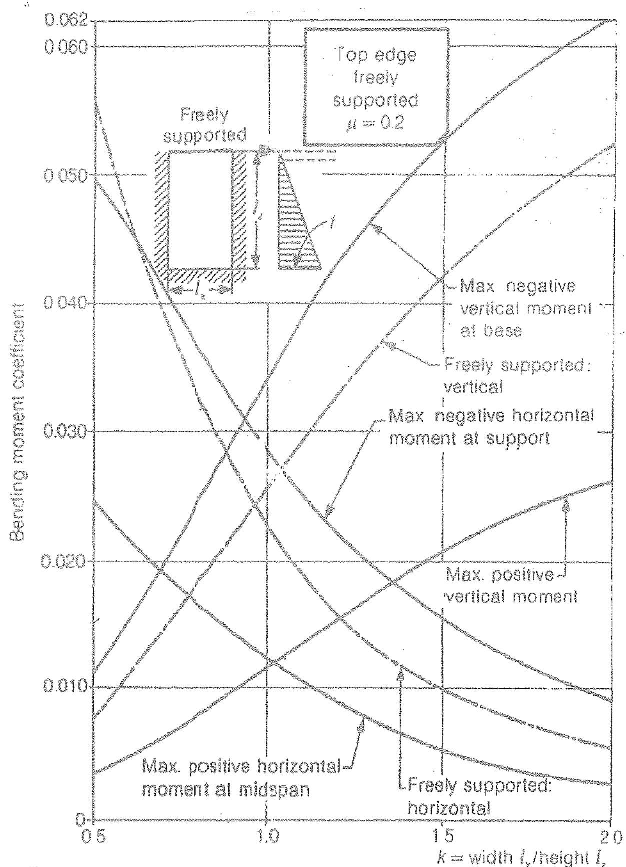
Annex 2: Steel Tendon Properties

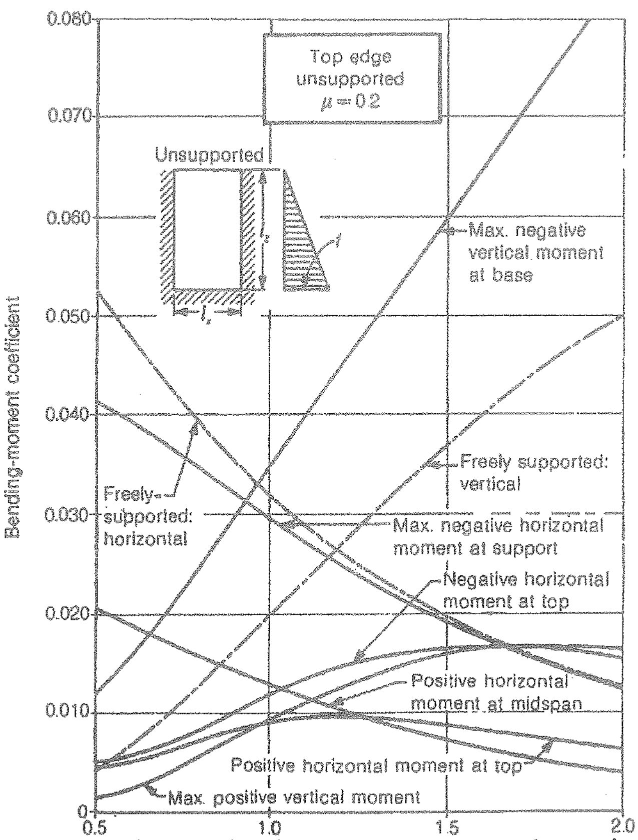
BS	*Type of tendon*	*Nominal diameter and steel area*		*Nominal tensile strength* f_{pu}	*Specified characteristic load (kN)*		Maximum relaxation (%) after 1000 h	
					Breaking load (A)	*0.1% proof load or load at 1% elongation*	*at 70% of A*	*at 80% of A*
	Wire	*mm*	*mm²*	*N/mm²*		*0.1% proof load*		
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 3

Two-way slabs: triangularly distributed loads: elastic analyses

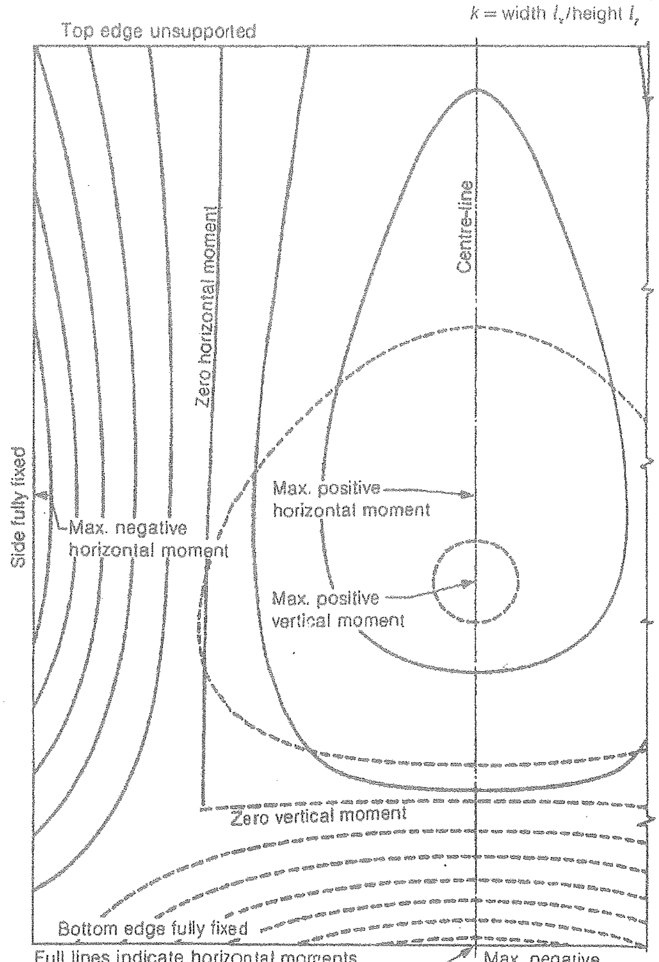






Vertical span: bending moment $= \text{coefficient} \times f l_z^2$

Horizontal span: bending moment $= \text{coefficient} \times f l_x^2$

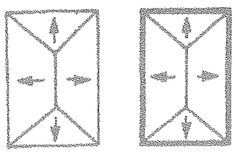


Full lines indicate horizontal moments
Broken lines indicate vertical moments

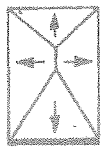
Annex 4

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

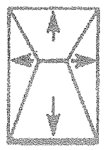
Panels supported along four edges



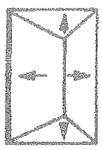
$k > 1$: $R_1 = R_3 = \frac{1}{4}wl_x^2$
$R_2 = R_4 = \frac{1}{2}(k - \frac{1}{2})wl_x^2$
$\alpha = \beta = 1/2k$
$k = 1$: $R_1 = R_2 = R_3 = R_4 = \frac{1}{4}wl_x^2$



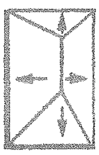
$k \nless 4/3$: $R_1 = \frac{1}{4}wl_x^2$ (min.) $\alpha = 1/2k$ (min.)
$R_2 = R_4 = \frac{1}{2}(k - \frac{2}{3})wl_x^2$
$R_3 = \frac{5}{12}wl_x^2$ (max.) $\beta = 5/6k$ (max.)



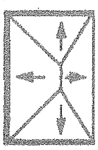
$k \leqslant 4/3$: $R_1 = \frac{3}{5}R_3$ approx. (min.) $\alpha = 3/8$ (min.)
$\beta = 5/8$ (max.)
$R_2 = R_4 = \frac{3}{16}k^2wl_x^2$ $\psi = \xi = 3k/8$
$R_3 = \frac{5}{8}k(1 - \frac{3}{8}k)wl_x^2$ approx. (max.)



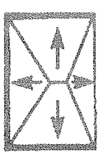
$R_1 = R_3 = \frac{3}{16}wl_x^2$
$R_2 = \frac{3}{5}R_4$ (min.)
$R_4 = \frac{5}{8}(k - \frac{3}{8})wl_x^2$ (max.)
$\alpha = \beta = 3/8k$ $\psi = \frac{5}{8}$ (max.)



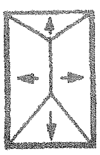
$R_1 = \frac{3}{16}wl_x^2$ (min.) $\alpha = 3/8k$ (min.)
$R_2 = \frac{3}{5}R_4$ (min.) $\beta = 5/8k$ (max.)
$R_3 = \frac{5}{16}wl_x^2$ (max.) $\psi = 5/8$ (max.)
$R_4 = \frac{5}{8}(k - \frac{1}{2})wl_x^2$ (max.)



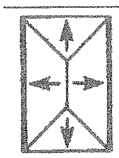
$k \nless 5/4$: $R_1 = R_3 = \frac{5}{16}wl_x^2$ $\alpha = \beta = 5/8k$
$R_2 = \frac{3}{5}R_4$ (min.) $\psi = 5/8$ (max.)
$R_4 = \frac{5}{8}(k - \frac{5}{8})wl_x^2$ (max.)



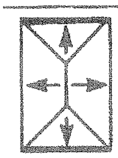
$k \leqslant 5/4$: $R_1 = R_3 = \frac{1}{2}k(1 - \frac{2}{5}k)wl_x^2$ $\alpha = \beta = 1/2$
$R_2 = \frac{3}{20}k^2wl_x^2$ (min.)
$R_4 = \frac{1}{4}k^2wl_x^2$ (max.) $\psi = k/2$
$\xi = 3k/10$



$R_1 = \frac{3}{20}wl_x^2$ (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.)

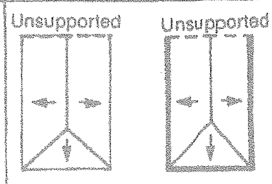


$R_1 = R_3 = \frac{3}{20}wl_x^2$ (min.)
$R_2 = R_4 = \frac{1}{2}(k - \frac{3}{10})wl_x^2$ (max.)
$\alpha = \beta = 3/10k$ (min.)

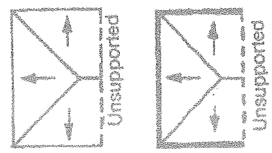


$k \nless 5/3$: $R_1 = R_3 = \frac{5}{12}wl_x^2$ (min.)
$R_2 = R_4 = \frac{1}{2}(k - \frac{5}{6})wl_x^2$ (max.)
$\alpha = \beta = 5/6k$ (min.)

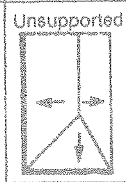
Panels unsupported along one edge



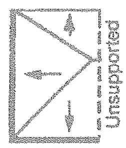
$R_1 = 0$
$R_2 = R_4 = \frac{1}{2}(k - \frac{1}{4})wl_x^2$
$R_3 = \frac{1}{4}wl_x^2$
$\beta = 1/2k$



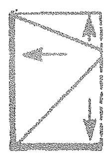
$k \ngtr 2$: $R_1 = R_3 = \frac{1}{2}k(1 - \frac{1}{4}k)wl_x^2$
$R_2 = 0$
$R_4 = \frac{1}{4}k^2wl_x^2$
$\psi = k/2$



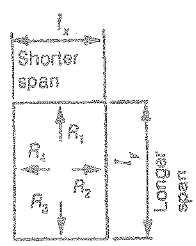
$R_1 = 0$ $\beta = 5/8k$
$R_2 = \frac{3}{5}R_4$ (min.) $\psi = 5/8$
$R_3 = \frac{5}{16}wl_x^2$
$R_4 = \frac{5}{8}(k - \frac{5}{16})wl_x^2$ (max.)



$k \ngtr 8/5$: $R_1 = \frac{3}{5}R_3$ (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.)



$k \geqslant 8/5$: $R_1 = \frac{3}{10}wl_x^2$ (min.) $R_2 = 0$
$R_3 = \frac{1}{2}wl_x^2$
$R_4 = (k - \frac{4}{5})wl_x^2$ (max.)
$\alpha = 3/5k$ $\beta = 1/k$



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

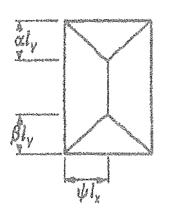
w = intensity of uniformly distributed service load per unit area

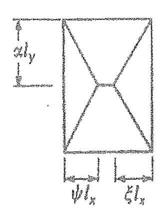
If analysis due to ultimate loads is undertaken, substitute n for w in appropriate formulae

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 5

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 6

Design data for singly-reinforced sections: SI units

Modular ratio **118**