



UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: December 2015

Module Number: CE 6302

Module Name: Design of Concrete Structures II

[Three Hours]

[Answer all questions, each Question carries 30 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 (k_a) is 0.217. Take Design bearing capacity of the soil as 230 kN/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) Check the stability of the underground water sump under all possible unfavorable load combinations. [2.0 Marks]
- b) Determine the effective length, effective width and effective height of the water sump walls. [2.0 Marks]
- c) Calculate amount of reinforcement required for the wall-A to resist bending moments and axial forces at ULS in the vertical direction. [12.0 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]
- e) Suppose water sump is unstable, recommend possible modifications to the structure to make it stable. Describe how your proposed methodologies improve the stability of the structure. [4.0 Marks]
- f) Explain the structural benefit of having neoprene pad on sump walls. [2.0 Marks]

- g) Propose methodologies to reduce the effect of ground water table on the water sump. [1.0 Mark]
- h) Explain the effect of uneven topography of ground condition in the construction of the water sump. [1.0 Mark]
- 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. [2.0 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. [6.0 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 ? [6.0 Marks]
- iv) Suppose the bridge deck slab is subjected to prestressing force of 5195 kN/m . Determine the cable zone for the full length of the bridge deck and provide a suitable cable profile. [6.0 Marks]
- v) Discuss why it is important to know cable profile in designing the end-blocks? [4.0 Marks]

Necessary Equations

$$\frac{1}{P_e} \geq \frac{\left[\frac{Z_1}{A} + e \right]}{\alpha [Z_1 f_{a\max t} + M_d]}$$

$$\frac{1}{P_e} \leq \frac{\left[\frac{Z_2}{A} - e \right]}{\alpha [Z_2 f_{a\min t} - M_d]}$$

$$\frac{1}{P_e} \leq \frac{\left[\frac{Z_1}{A} + e \right]}{[Z_1 f_{a\min} + M_d + M_{i\max}]}$$

$$\frac{1}{P_e} \geq \frac{\left[\frac{Z_2}{A} - e \right]}{[Z_2 f_{a\max} - M_d - M_{i\max}]}$$

$$Z_1 \geq \frac{M_{i\max} + M_d (1 - \alpha)}{\alpha f_{a\max t} - f_{a\min}}$$

$$Z_2 \geq \frac{M_{i\max} + M_d (1 - \alpha)}{f_{a\max} - \alpha f_{a\min t}}$$

All notations have the standard meanings.

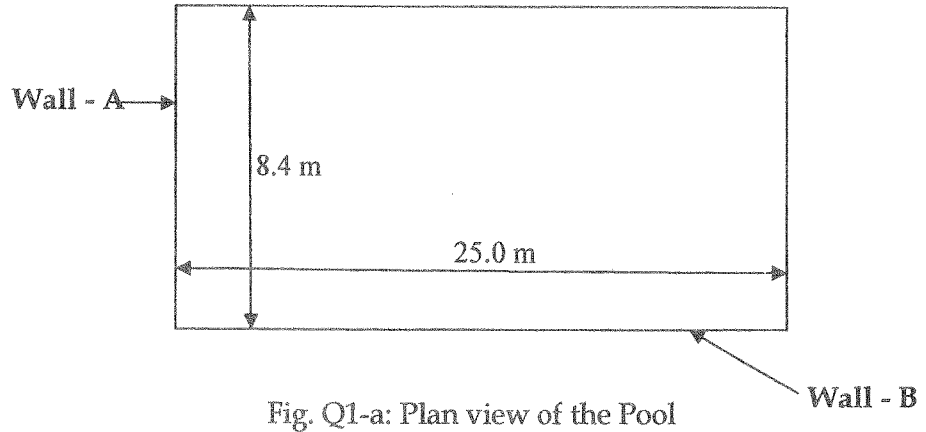


Fig. Q1-a: Plan view of the Pool

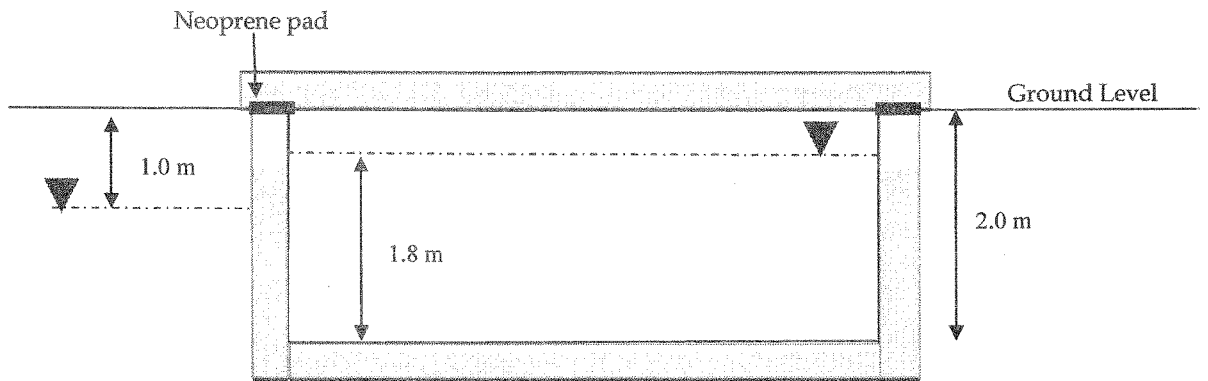
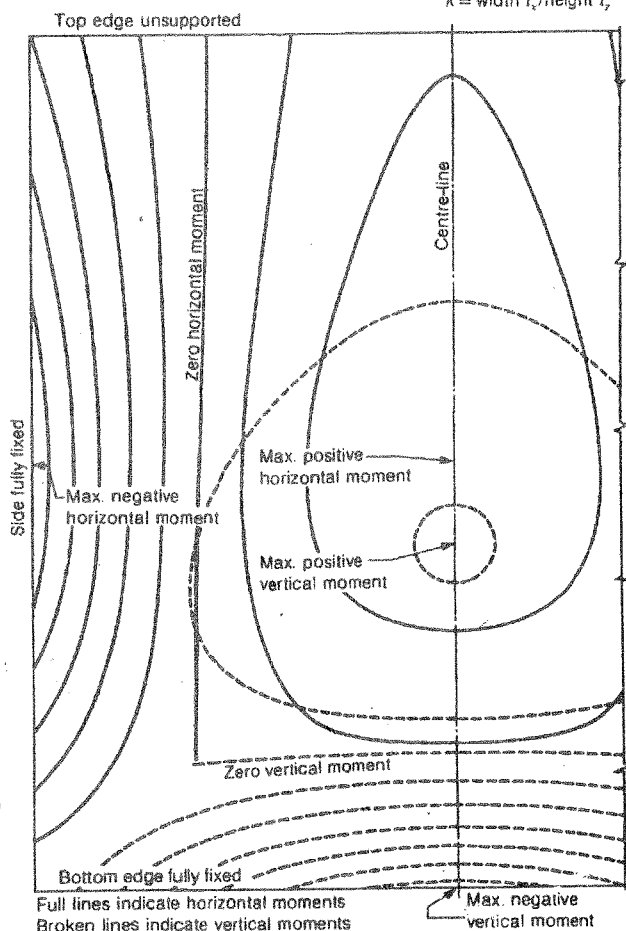
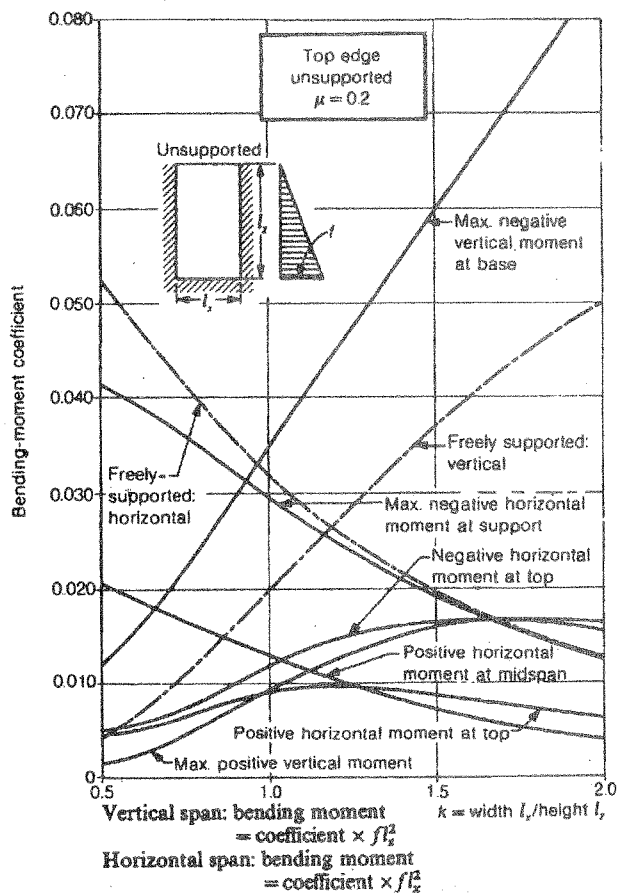
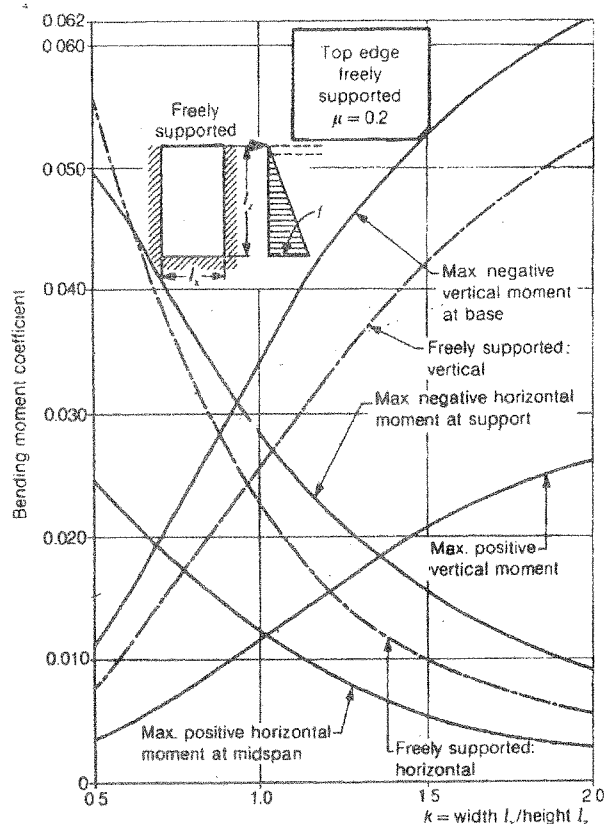
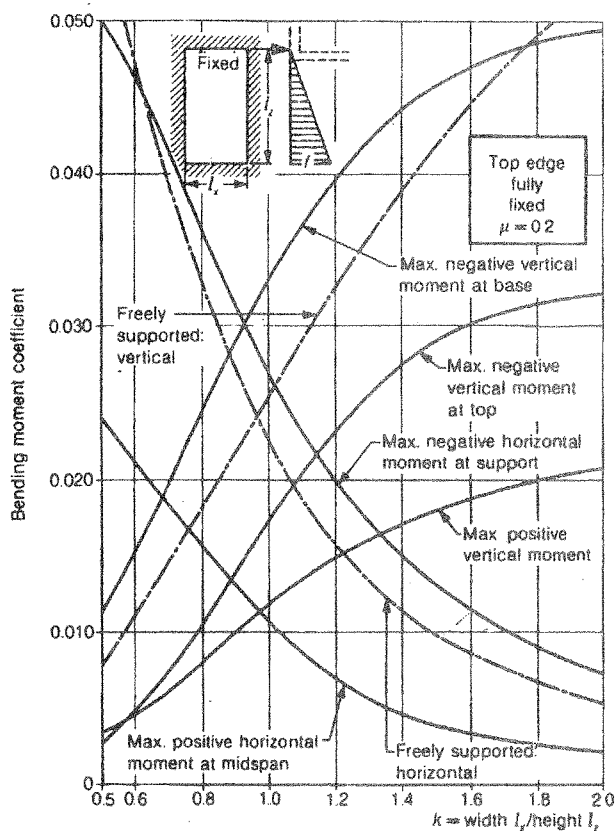


Fig. Q1-b: Internal Dimensions of the Pool

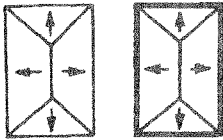
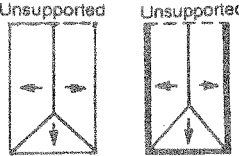
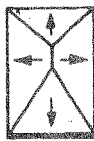
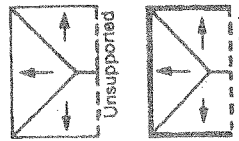

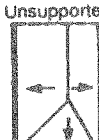
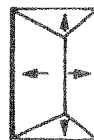





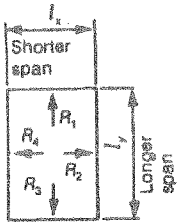
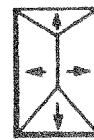
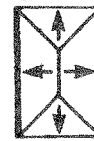

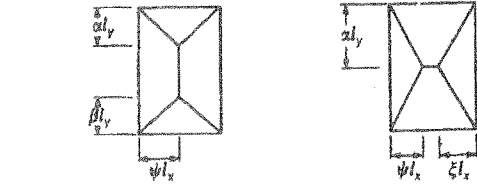
Annex_1_Steel Properties

BS	Type of tendon	Nominal diameter and steel area		Nominal tensile strength f_m	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				

Two-way slabs: triangularly distributed loads: elastic analyses



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

Panels supported along four edges	Panels unsupported along one edge
 $k > 1: R_1 = R_3 = \frac{1}{4} w l_x^2$ $R_2 = R_4 = \frac{1}{2} (k - \frac{1}{2}) w l_x^2$ $\alpha = \beta = 1/2k$ $k = 1: R_1 = R_2 = R_3 = R_4 = \frac{1}{4} w l_x^2$	 $R_1 = 0$ $R_2 = R_4 = \frac{1}{2} (k - \frac{1}{2}) w l_x^2$ $R_3 = \frac{1}{4} w l_x^2$ $\beta = 1/2k$
 $k \leq 4/3: R_1 = \frac{1}{4} w l_x^2 \text{ (min.)}$ $R_2 = R_4 = \frac{1}{2} (k - \frac{2}{3}) w l_x^2$ $R_3 = \frac{1}{2} w l_x^2 \text{ (max.)}$ $\alpha = 1/2k \text{ (min.)}$ $\beta = 5/6k \text{ (max.)}$	 $k > 2: R_1 = R_3 = \frac{1}{2} k (1 - \frac{1}{4} k) w l_x^2$ $R_2 = 0$ $R_4 = \frac{1}{4} k^2 w l_x^2$ $\psi = k/2$
 $k \leq 4/3: R_1 = \frac{2}{3} R_3 \text{ approx. (min.)}$ $R_2 = R_4 = \frac{1}{16} k^2 w l_x^2$ $R_3 = \frac{2}{3} k (1 - \frac{1}{6} k) w l_x^2 \text{ approx. (max.)}$ $\alpha = 3/8 \text{ (min.)}$ $\beta = 5/8 \text{ (max.)}$ $\psi = \xi = 3k/8$	 $R_1 = 0$ $R_2 = \frac{2}{3} R_4 \text{ (min.)}$ $R_3 = \frac{1}{16} k^2 w l_x^2$ $R_4 = \frac{2}{3} k (1 - \frac{1}{6} k) w l_x^2 \text{ (max.)}$ $\beta = 5/8k$ $\psi = 5/8$
 $R_1 = R_3 = \frac{3}{16} w l_x^2$ $R_2 = \frac{3}{8} R_4 \text{ (min.)}$ $R_4 = \frac{2}{3} (k - \frac{3}{8}) w l_x^2 \text{ (max.)}$ $\alpha = \beta = 3/8k$ $\psi = \frac{3}{8} \text{ (max.)}$	 $k > 8/5: R_1 = \frac{2}{3} R_3 \text{ (min.)}$ $R_2 = 0$ $R_3 = \frac{2}{3} k (1 - \frac{1}{16} k) w l_x^2 \text{ (max.)}$ $R_4 = \frac{1}{16} k^2 w l_x^2$ $\alpha = 3/8k \text{ (min.)}$ $\psi = 5k/8 \text{ (max.)}$
 $R_1 = \frac{1}{16} w l_x^2 \text{ (min.)}$ $R_2 = \frac{3}{8} R_4 \text{ (min.)}$ $R_3 = \frac{1}{16} k^2 w l_x^2 \text{ (max.)}$ $R_4 = \frac{2}{3} (k - \frac{1}{2}) w l_x^2 \text{ (max.)}$ $\alpha = 3/8k \text{ (min.)}$ $\beta = 5/8k \text{ (max.)}$ $\psi = 5/8 \text{ (max.)}$	 $k \geq 8/5: R_1 = \frac{1}{16} w l_x^2 \text{ (min.)}$ $R_2 = 0$ $R_3 = \frac{1}{2} w l_x^2$ $R_4 = (k - \frac{3}{8}) w l_x^2 \text{ (max.)}$ $\alpha = 3/5k$ $\beta = 1/k$
 $k \leq 5/4: R_1 = R_3 = \frac{2}{16} w l_x^2$ $R_2 = \frac{3}{8} R_4 \text{ (min.)}$ $R_4 = \frac{2}{3} (k - \frac{3}{8}) w l_x^2 \text{ (max.)}$ $\alpha = \beta = 5/8k$ $\psi = 5/8 \text{ (max.)}$	$k = \frac{l_y}{l_x} = \frac{\text{longer span}}{\text{shorter span}}$ <p>w = intensity of uniformly distributed service load per unit area</p>
 $k \leq 5/4: R_1 = R_3 = \frac{1}{2} k (1 - \frac{2}{3} k) w l_x^2$ $R_2 = \frac{1}{16} k^2 w l_x^2 \text{ (min.)}$ $R_4 = \frac{1}{4} k^2 w l_x^2 \text{ (max.)}$ $\alpha = \beta = 1/2$ $\psi = k/2$ $\xi = 3k/10$	 <p>If analysis due to ultimate loads is undertaken, substitute <i>n</i> for <i>w</i> in appropriate formulae</p> <p>R_1, R_2, R_3, R_4 = total load carried by each support of panel</p>
 $R_1 = \frac{2}{15} w l_x^2 \text{ (min.)}$ $R_2 = R_4 = \frac{1}{2} (k - \frac{2}{15}) w l_x^2$ $R_3 = \frac{1}{4} w l_x^2 \text{ (max.)}$ $\alpha = 3/10k \text{ (min.)}$ $\beta = 1/2k \text{ (max.)}$	<p>Condition of supports</p> <p>— no support</p> <p>— freely support</p> <p>— continuity or fixity</p>
 $R_1 = R_3 = \frac{3}{10} w l_x^2 \text{ (min.)}$ $R_2 = R_4 = \frac{1}{2} (k - \frac{3}{10}) w l_x^2 \text{ (max.)}$ $\alpha = \beta = 3/10k \text{ (min.)}$	<p>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.</p>
 $k \leq 5/3: R_1 = R_3 = \frac{1}{12} w l_x^2 \text{ (min.)}$ $R_2 = R_4 = \frac{1}{2} (k - \frac{1}{3}) w l_x^2 \text{ (max.)}$ $\alpha = \beta = 5/6k \text{ (min.)}$	

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	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.

Design data for singly-reinforced sections:
SI units

