First Semester Examination
2017/2018 Academic Session

January 2018

EAS353 – Reinforced Concrete Structural Design 1
(Rekabentuk Konkrit Bertetulang I)

Duration : 2 hours
(Masa : 2 jam)

Please check that this examination paper consists of TEN (10) pages of printed material including appendix before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi SEPULUH (10) muka surat yang bercetak termasuk lampiran sebelum anda memulakan peperiksaan ini.]

Instructions: This paper contains **FIVE (5)** questions. Answer **FOUR (4)** questions.

*[**Arahan :** Kertas ini mengandungi **LIMA (5)** soalan. Jawab **EMPAT (4)** soalan.]*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

1. A continuous beam as shown in **Figure 1** has a constant cross section supports a uniformly distributed permanent action including its self-weight of 25 kN/m and a variable action of 15 kN/m. The cross section of the continuous beam is reinforced by 2H25 and 2H16 of tension and compression reinforcements, respectively. The effective depth of the beam and the concrete cover for the reinforcement are 300 mm and 40 mm, respectively. The width of the beam is 200 mm. The yield strength of reinforcement and compressive strength of concrete are 500 N/mm^2 and 30 N/mm^2, respectively.

   *Sebuah rasuk selanjar seperti ditunjukkan dalam **Rajah 1** mempunyai keratan rentas seragam menyokong beban teragih seragam tindakan kekal sebanyak 25 kN/m termasuk berat-diri dan tindakan boleh ubah sebanyak 15 kN/m. Keratan rentas rasuk selanjar tersebut mempunyai 2H25 tetulang tegangan dan 2H16 tetulang mampatan. Kedalaman efektif rasuk dan pelindung konkrit untuk tetulang masing-masing ialah 300 mm dan 40 mm. Lebar rasuk ialah 200 mm. Tegasan alah tetulang dan kekuatan mampatan konkrit masing-masing ialah 500 N/mm^2 and 30 N/mm^2.*

   (i) Sketch four load arrangements recommended for buildings in accordance with BS EN 1992-1-1:2004+A1:2014. Calculate the load combinations considered for the load arrangement.

   Lakarkan empat susun atur beban yang disyorkan untuk bangunan berdasarkan BS EN 1992-1-1:2004+A1:2014. Kira beban gabung yang diambil kira untuk susun atur beban tersebut.

   [7 marks/*markah*]

   (ii) Sketch an equivalent rectangular stress block for the cross-section of the beam. The tensile and compressive forces on the section are in equilibrium. Formulate a bending moment equation about the tension reinforcement.

   Lakarkan satu blok tegasan segiempat setara untuk keratan rentas rasuk tersebut. Daya tegangan dan mampatan di keratan tersebut adalah dalam keseimbangan. Formulasikan persamaan momen lentur terhadap tetulang tegangan.

   [6 marks/*markah*]

   (iii) Determine the ultimate moment of resistance of the cross section given in **Figure 1**. Ignore the compression reinforcement.

   *Tentukan momen rintangan muktamad keratan rentas tersebut yang diberikan di dalam **Rajah 1**. Abaikan tetulang mampatan.*

   [12 marks/*markah*]

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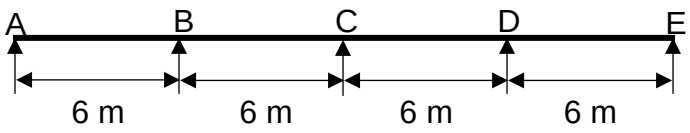
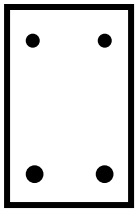


Continuous beam/ ***rasuk selanjar***



Cross section/*keratan rentas*

Figure 1/*Rajah 1*

2. **Figure 2** shows the third floor plan of a reinforced concrete office building. During construction, the slabs and beams are cast together. The characteristic strength of concrete, f_{cu} = 30 N/mm^2 and characteristic strength of reinforcement, f_y = 500 N/mm^2. Based on the information provided, design the reinforcement and shear for slab panel A-B/2-3.

Rajah 2 *menunjukkan pelan lantai bangunan pejabat konkrit bertetulang. Semasa pembinaan, lantai dan rasuk dituang serentak. Kekuatan ciri konkrit,* f_{cu} *= 30 N/mm^2 dan kekuatan ciri tetulang,* f_y *= 500 N/mm^2. Berdasarkan kepada maklumat yang diberikan, rekabentuk tetulang dan ricih bagi lantai panel A-B/2-3.*

Given;
Diberi;

Concrete cover = 30 mm.
Penutup konkrit = 30 mm.

Slab thickness = 150 mm
Ketebalan lantai = 150 mm

Load design action, $n_d = 1.35g_k + 1.5q_k = 12.26$ kN/m^2
Beban tindakan rekabentuk, $n_d = 1.35g_k + 1.5q_k = 12.26$ *kN/m^2*

.

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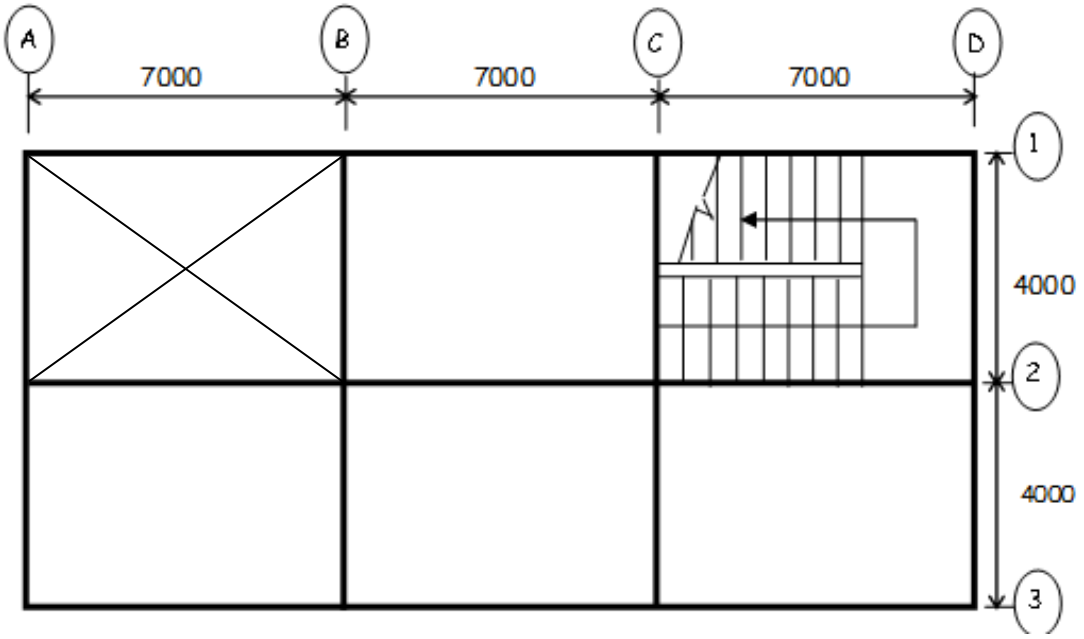

Figure 2/*Rajah 2*

[25 marks/*markah*]

3. A simply supported beam as shown in **Figure 3** has a cross section A-A supports uniformly distributed permanent actions (g_k) excluding it's self-weight of 22 kN/m and a variable action (q_k) of 17 kN/m. Design and provide the detailing for the beam. Take characteristic compressive strength of concrete, f_{ck} = 35 N/mm^2, characteristic strength of reinforcement, f_{yk} = 500 N/mm^2, diameter of main bar, ϕ = 32 mm, diameter of links, ϕ' = 12 mm and concrete cover, c = 25 mm. Ignore the shear check for the beam and take self-weight of the beam as 41.4 kN.

*Sebuah rasuk disokong mudah seperti di **Rajah 3** mempunyai keratan rentas A-A, menyokong beban teragih seragam tindakan kekal (g_k) tidak termasuk berat diri sebanyak 22 kN/m dan tindakan boleh ubah (q_k) sebanyak 17 kN/m. Rekabentuk dan sediakan perincian keratan untuk rasuk tersebut. Ambil kekuatan mampatan ciri konkrit, f_{ck}=35 N/mm^2, kekuatan ciri besi tetulang, f_{yk} =500 N/mm^2, diameter tetulang utama, ϕ=32 mm, diameter tetulang penyambung, ϕ'=12 mm dan penutup konkrit, c =25 mm. Abaikan semakan ricih untuk rasuk berkenaan dan ambil berat diri rasuk sebagai 41.4 kN.*

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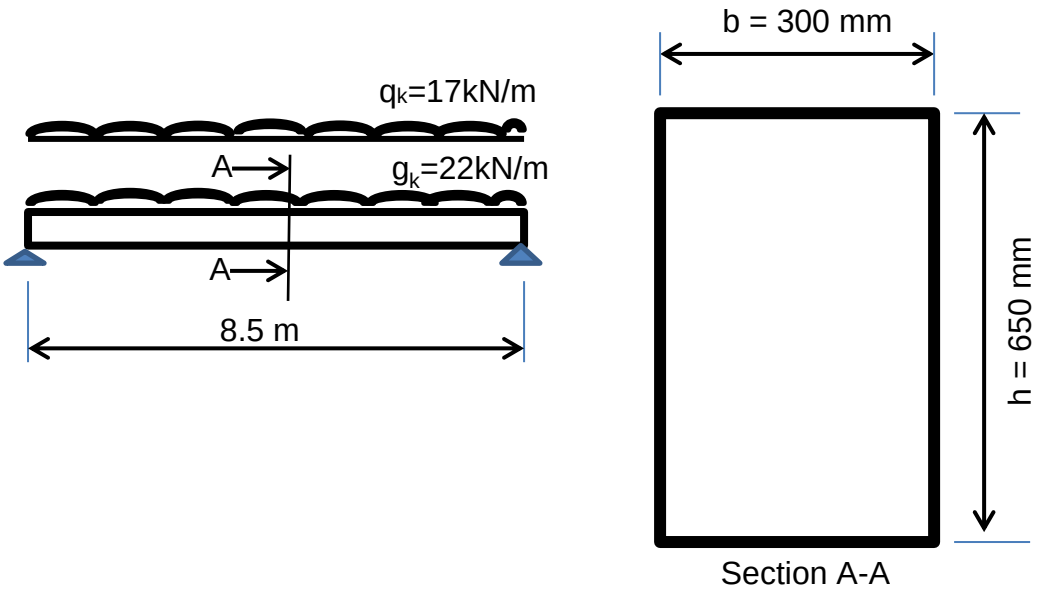

Figure 3/*Rajah 3*

[25 marks/*markah*]

4. A braced non-slender column as shown in **Figure 4** has a cross section of 300 mm x 250 mm. The column is subjected to an axial load of 1200 kN. Design and provide the longitudinal and transverse reinforcement for the column with assistance of the Design Chart in the **Appendix** by assuming the following information:

*Sebuah tiang berembat pendek seperti di **Rajah 4** mempuanyai keratan rentas 300 mm x 250 mm. Tiang berkenaan dikenakan beban tindakan paksi sebanyak 1200 kN. Rekabentuk dan sediakan perincian tetulang mendatar dan melintang bagi tiang tersebut dengan bantuan Carta Rekabentuk di **Lampiran** dengan mengambilkira maklumat berikut:*

(a) Characteristic compressive strength of concrete, f_{ck}=25 N/mm^2
Kekuatan mampatan ciri konkrit, f_{ck} =25 N/mm^2

(b) Characteristic strength of reinforcement, f_{yk}=500 N/mm^2
Kekuatan ciri besi tetulang, f_{yk} =500 N/mm^2

(c) Diameter of main bar, ϕ =20 mm
Diameter tetulang utama, ϕ =20 mm

(d) Diameter of links, ϕ' =6 mm
Diameter tetulang penyambung, ϕ' =6 mm

(e) Concrete cover, c =30 mm
Penutup konkrit, c =30 mm

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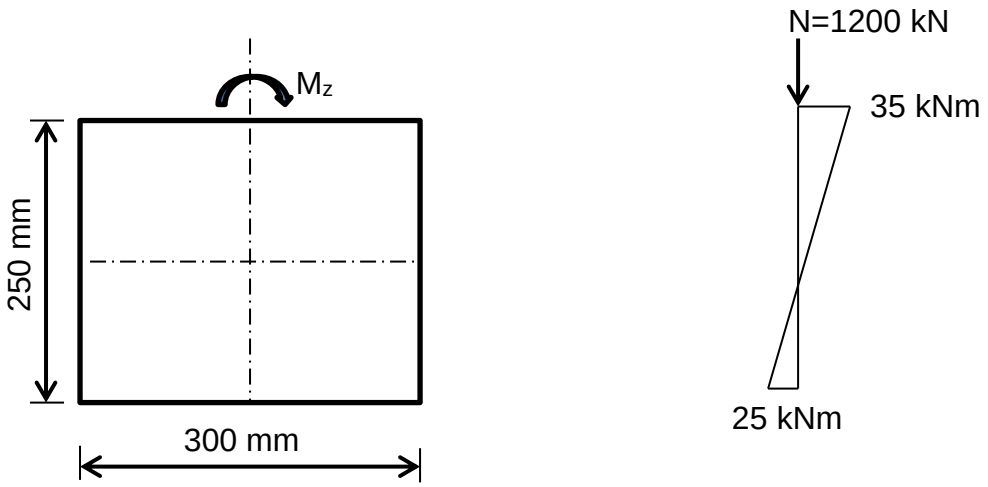
(f) Effective height, l_o =3.8 m
Ketinggian efektif, l_o =3.8 m



Braced non-slender column

Figure 4/*Rajah 4*

[25 marks/*markah*]

5. (a) The part plan of a pad footing layout is shown in **Figure 5**. Column 2/B and 2/C support service load G_k = 800 kN and Q_k = 250 kN. Due to construction requirement, the building work is limited up to gridline 1 only. If the allowable bearing pressure of the soil is 200 kN/m^2, design and provide the sectional detailing for a **square pad footing** at gridline 2/B. Take the concrete grade, f_{ck} = 30 N/mm^2, the overall depth of the footing, h = 500 mm, reinforcement size = 12 mm and assume the self-weight of the footing = 90 kN. Ignore the shear check at the column face and take z = 0.95d.

*Sebahagian pelan susunatur satu asas pad ditunjukkan di **Rajah 5**. Tiang 2/B dan 2/C menanggung beban kebolehkhidmatan G_k = 800 kN and Q_k = 250 kN. Oleh sebab keperluan pembinaan, kerja bangunan dihadkan sehingga garisan grid 1 sahaja. Jika tekanan galas tanah dibenarkan adalah 200 kN/m^2, rekabentuk dan sediakan perincian keratan untuk satu **asas pad berbentuk segiempat sama** pada garisan grid 2/B. Ambil gred konkrit f_{ck} = 30 N/mm^2, kedalaman asas keseluruhan, h = 500 mm, saiz tetulang = 12 mm dan anggap berat diri asas pad = 90 kN. Abaikan semakan ricih pada permukaan tiang dan ambil z = 0.95d.*

[20 marks/*markah*]

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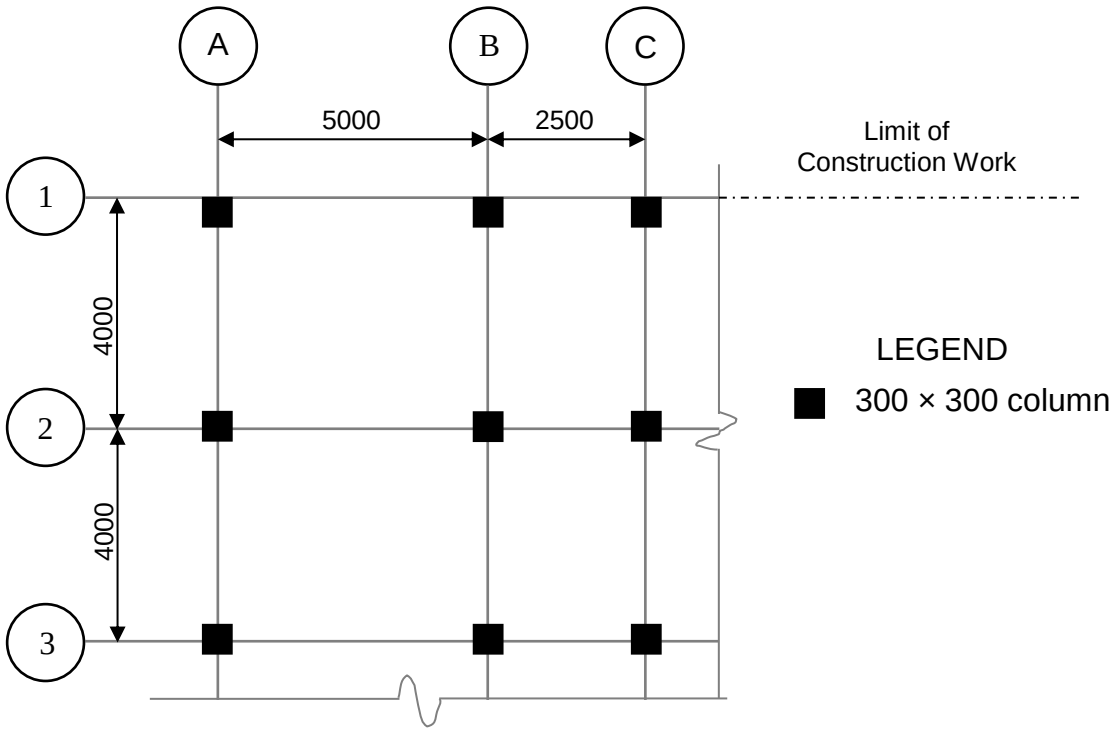


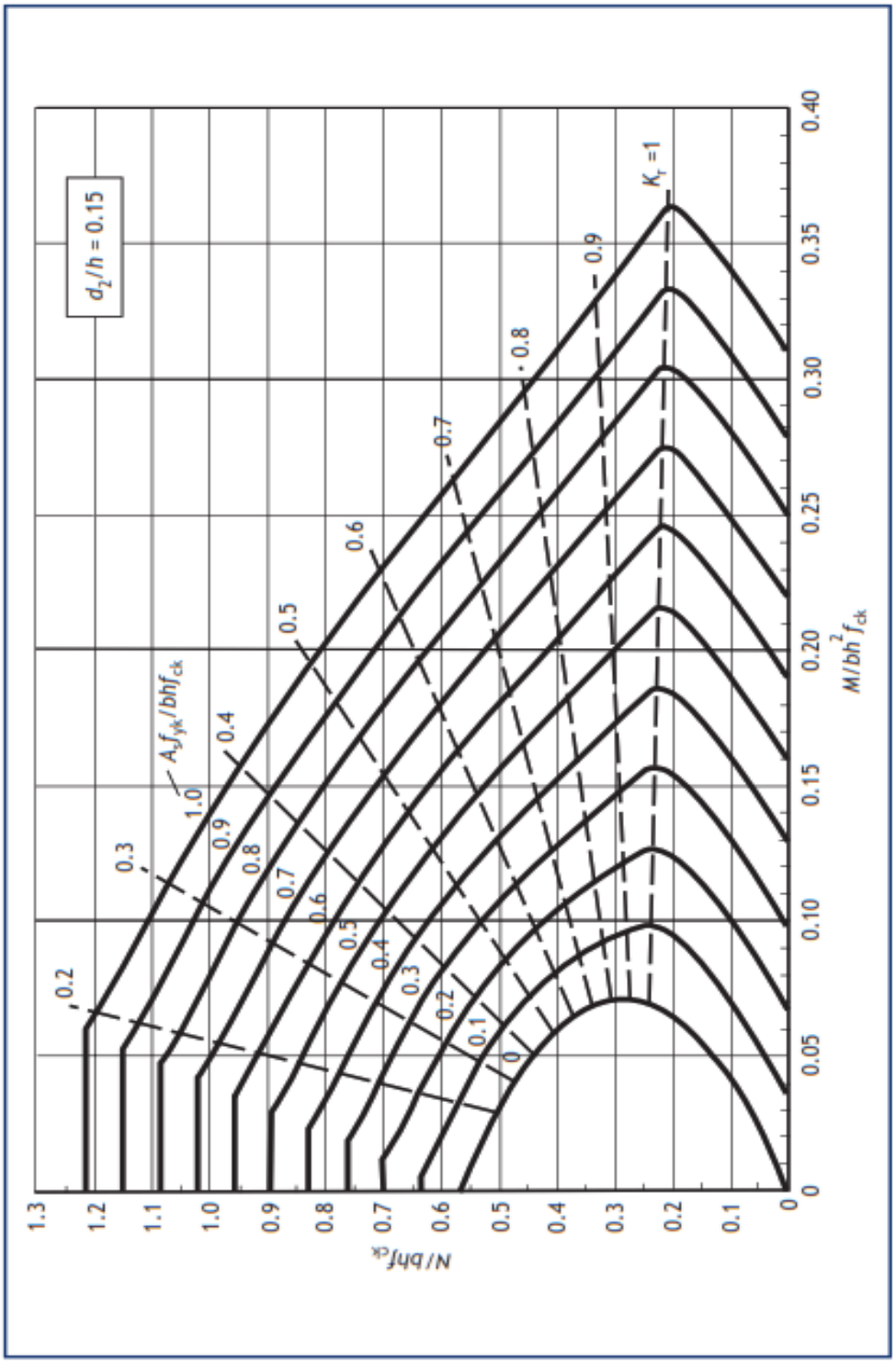
Figure 5 (all dimensions in mm)/*Rajah 5 (semua ukuran dalam mm)*

(b) Prior to tender stage, the project owner decided to change the floor usage. Upon performing analysis, the new service load for column 2/B and 2/C in Figure 5 is now G_k = 1000 kN and Q_k = 300 kN, respectively. As such, propose **TWO (2)** sketches showing the non-square shape pad footings at gridline 2/B and provide technical justification for each shape.

*Sebelum peringkat tender, pemilik projek membuat keputusan menukar penggunaan lantai. Setelah dibuat analisis, beban kebolehkhidmatan baru untuk tiang 2/B dan 2/C masing-masing adalah G_k = 1000 kN dan Q_k = 300 kN. Oleh yang demikian, cadangkan **DUA (2)** lakaran asas bukan berbentuk segiempat sama pada garisan grid 2/B dan sediakan justifikasi teknikal untuk setiap bentuk.*

[5 marks/*markah*]

APPENDIX /*LAMPIRAN*



Column design chart for rectangular columns $d_2/h = 0.15$

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Table 1: Shear resistance of slab without shear reinforcement, $v_{Rd,c}$ N/mm^2 (Class C30)

$\rho_1 = A_s/bd$	Effective depth, *d* (mm)						
	< 200	**225**	**250**	**300**	**350**	**400**	**500**
0.25%	0.54	0.52	0.50	0.47	0.45	0.43	0.40
0.50%	0.59	0.57	0.56	0.54	0.52	0.51	0.48
0.75%	0.68	0.66	0.64	0.62	0.59	0.58	0.55
1.00%	0.75	0.72	0.71	0.68	0.65	0.64	0.61
1.25%	0.8	0.78	0.76	0.73	0.71	0.69	0.66
1.50%	0.85	0.83	0.81	0.78	0.75	0.73	0.70
2.0%	0.94	0.91	0.89	0.85	0.82	0.80	0.77

Table 2: Minimum areas of reinforcement

Tension reinforcement in beams and slab	Concrete class (f_{yk} = 500 N/mm^2)			
	C25/30	**C30/37**	**C40/50**	**C50/60**
$\frac{A_{s,min}}{bd} > 0.26\frac{f_{ctm}}{f_{yk}}$ (> 0.0013)	0.0013	0.0015	0.0018	0.0021

Table 3: Steel stress (under quasi-permanent loading)

f_s	$= \frac{f_{yk}\,(G_k + 0.3Q_k)}{1.15(1.35G_k + 1.5Q_k)}\ x\ \frac{A_{s,req}}{A_{s,pro}}$

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Bar Areas and Perimeters

Sectional areas of groups of bars (mm^2)

Bar size (mm)	Number of bars									
	1	2	3	4	5	6	7	8	9	10
6	28.3	56.6	84.9	113	142	170	198	226	255	283
8	50.3	101	151	201	252	302	352	402	453	503
10	78.5	157	236	314	393	471	550	628	707	785
12	113	226	339	452	566	679	792	905	1020	1130
16	201	402	603	804	1010	1210	1410	1610	1810	2010
20	314	628	943	1260	1570	1890	2200	2510	2830	3140
25	491	982	1470	1960	2450	2950	3440	3930	4420	4910
32	804	1610	2410	3220	4020	4830	5630	6430	7240	8040
40	1260	2510	3770	5030	6280	7540	8800	10100	11300	12600

Sectional areas per metre width for various bar spacings (mm^2)

Bar size (mm)	Spacing of bars								
	50	75	100	125	150	175	200	250	300
6	566	377	283	226	189	162	142	113	94.3
8	1010	671	503	402	335	287	252	201	168
10	1570	1050	785	628	523	449	393	314	262
12	2260	1510	1130	905	754	646	566	452	377
16	4020	2680	2010	1610	1340	1150	1010	804	670
20	6280	4190	3140	2510	2090	1800	1570	1260	1050
25	9820	6550	4910	3930	3270	2810	2450	1960	1640
32	16100	10700	8040	6430	5360	4600	4020	3220	2680
40	25100	16800	12600	10100	8380	7180	6280	5030	4190

Shear Reinforcement

A_{sv}/s_v for varying stirrup diameter and spacing

Stirrup diameter (mm)	Stirrup spacing (mm)										
	85	90	100	125	150	175	200	225	250	275	300
8	1.183	1.118	1.006	0.805	0.671	0.575	0.503	0.447	0.402	0.366	0.335
10	1.847	1.744	1.57	1.256	1.047	0.897	0.785	0.698	0.628	0.571	0.523
12	2.659	2.511	2.26	1.808	1.507	1.291	1.13	1.004	0.904	0.822	0.753
16	4.729	4.467	4.02	3.216	2.68	2.297	2.01	1.787	1.608	1.462	1.34

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