UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	REINFORCED CONCRETE DESIGN 1
COURSE CODE	:	BFC32102
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	DECEMBER 2019/JANUARY 2020
DURATION	:	2 HOURS 30 MINUTES
INSTRUCTION	:	1. ANSWER **ALL** QUESTIONS 2. UNLESS OTHERWISE SPECIFIED, ALL DESIGN **MUST** BE BASED ON **EN 1990, EN 1991** and **EN 1992**.

THIS QUESTION PAPER CONSISTS OF **THIRTEEN (13)** PAGES

Q1 **Figure Q1(a)** shows the structural layout plan at first floor for a factory-office building. The front part of the building (D-E/2-5) is used for office and the back (A-D/1-6) is used for production area. All beams and slabs are reinforced concrete and the concrete is cast simultaneously. A 4 m height brickwall is sitting on the beams at gridline 2/D-E, 5/D-E, 1/A-D, 6/A-D and 4a/A-B.

Some vertical and diagonal cracks were found on the surface of beam 2/D-E as shown in **Figure Q1(b)**. The detailing of the steel reinforcement for beam 2/D-E is shown in **Figure Q1(c)**.

Given as follows are design data to be used in the design and based on BS EN 1992-1-1 and information in Appendix:

All slab thickness	= 150 mm
Characteristic strength of concrete	= 30 MPa
Characteristic strength of steel reinforcement	= 500 MPa
Tensile strength of concrete (C30), f_{ctm}	= 2.9 MPa
Unit weight of reinforced concrete	= 25 kN/m^3
Finishes and services	= 1.5 kN/m^2
Brickwall	= 2.6 kN/m^2
Variable action (office)	= 3.0 kN/m^2
Variable action (Production area)	= 5.0 kN/m^2

(a) Classify type of panel for all slabs.
(5 marks)

(b) Sketch the tributary area for all slabs.
(5 marks)

(c) Discuss types of cracks appear in beam 2/D-E.
(4 marks)

(d) Check whether beam 2/D-E is safe in resisting the design shear force and bending moment. Use rectangular beam section.
(23 marks)

(e) Suggest a method to repair and overcome the cracks on beam 2/D-E.
(3 marks)

Q2 Referring to **Figure Q1(a)** and based on the information given in **Q1.** Assume the outer supports for the continuous slab D-E/2-5 (S1, S2 and S3) as simple connection:

(a) Determine the ultimate bending moment and shear forces for the continuous slab at gridline D-E/2-5 (S1, S2 and S3).
(8 marks)

(b) Design all the flexural reinforcement required by the slabs. Use nominal concrete cover 25 mm and diameter of main reinforcement 12 mm.
(12 marks)

(c) Check shear and cracking of the slabs.
(7 marks)

(d) Draw the detailing of the slabs.
(3 marks)

Q3 Referring to **Figure Q1(a)** and based on the information given in **Q1.** Beam 4a/A-B of 200 mm x 450 mm is a simply supported flanged beam.

(a) Determine the effective width of beam 4a/A-B.
(6 marks)

(b) Calculate the design action on beam 4a/A-B.
(6 marks)

(c) Analyse beam 4a/A-B to get the maximum bending moment and shear force.
(4 marks)

(d) Design all main reinforcement for beam 4a/A-B. Use nominal concrete cover 30 mm, diameter of main reinforcement 20 mm and diameter of link 10 mm.
(8 marks)

(e) Check deflection of beam 4a/A-B.
(6 marks)

- END OF QUESTIONS-

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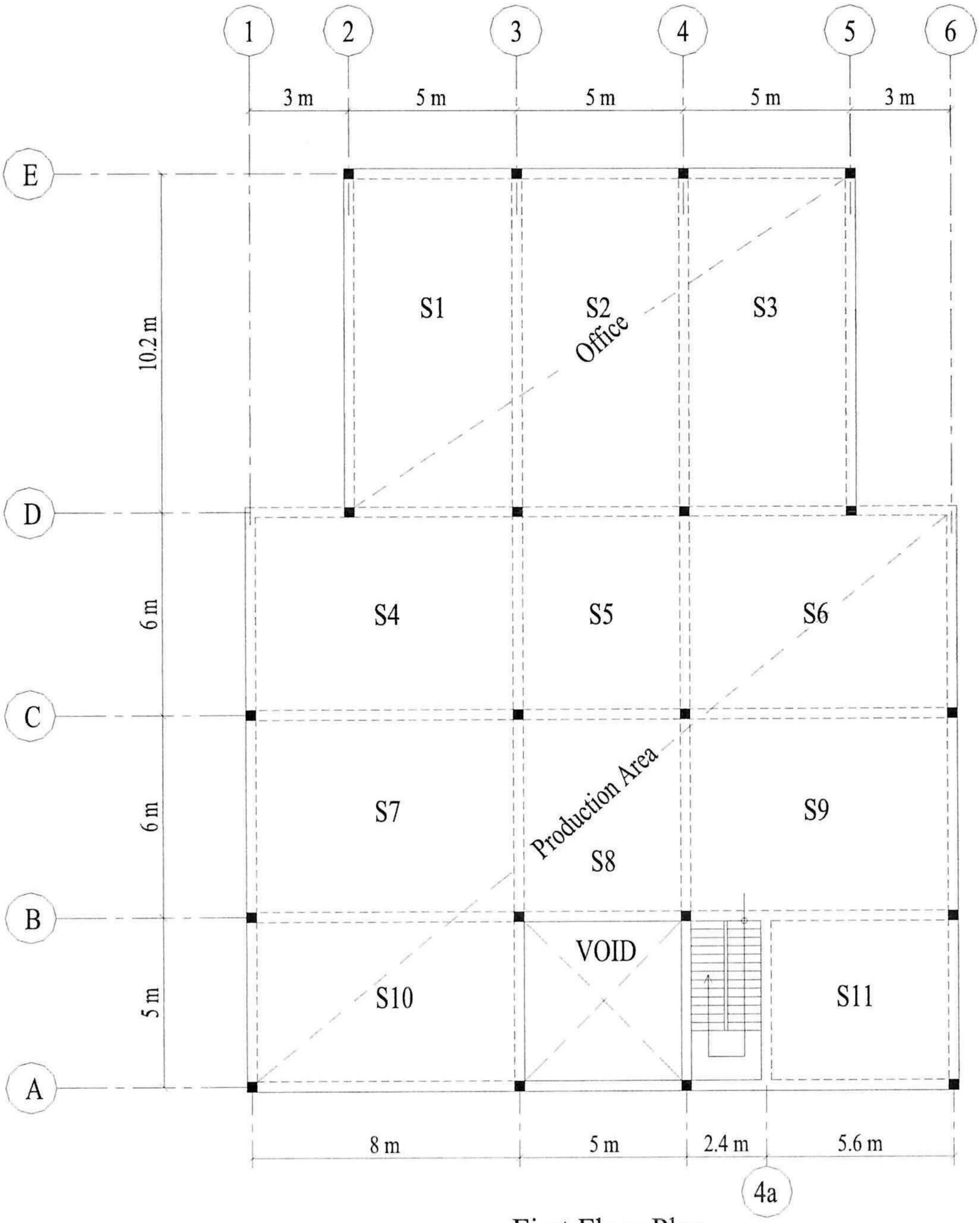

First Floor Plan

FIGURE Q1(a)

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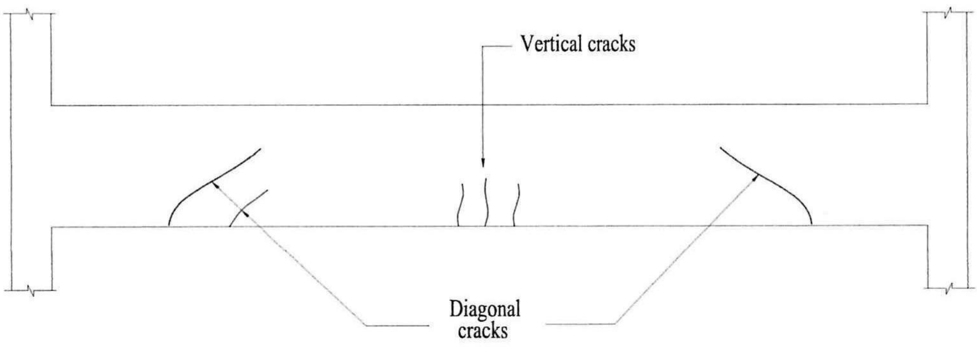
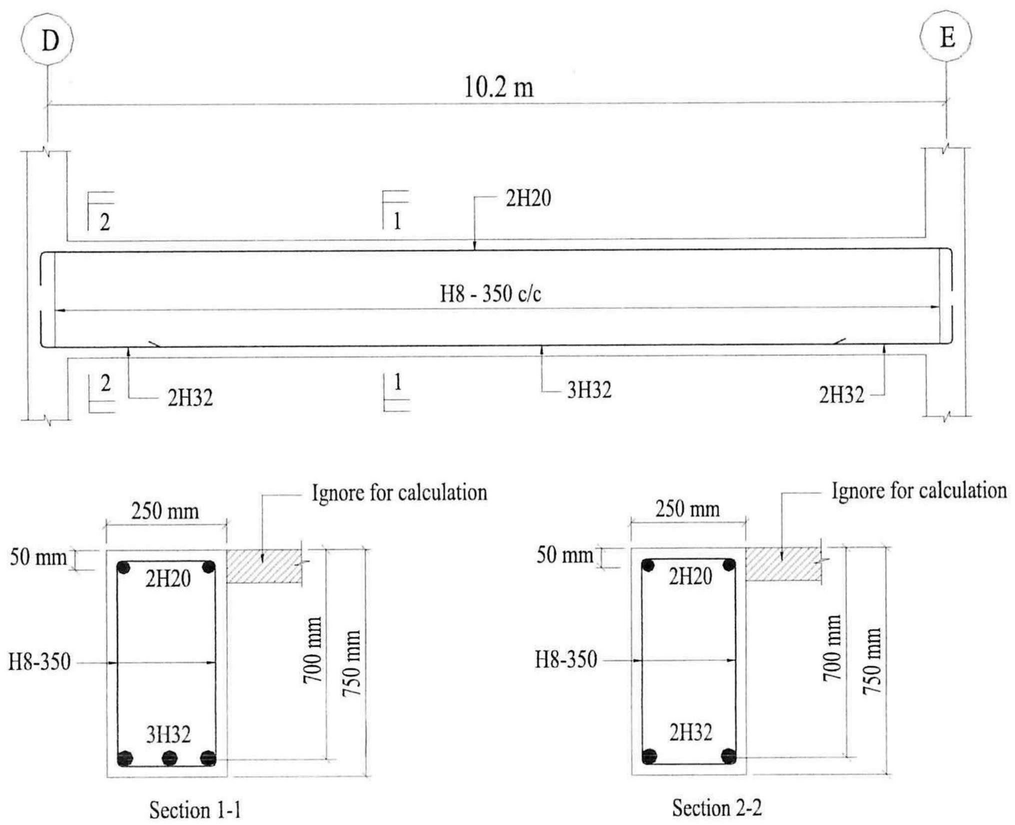


Elevation of Beam 2/D-E

FIGURE Q1(b)



Detailing of Beam 2/D-E

FIGURE Q1(c)

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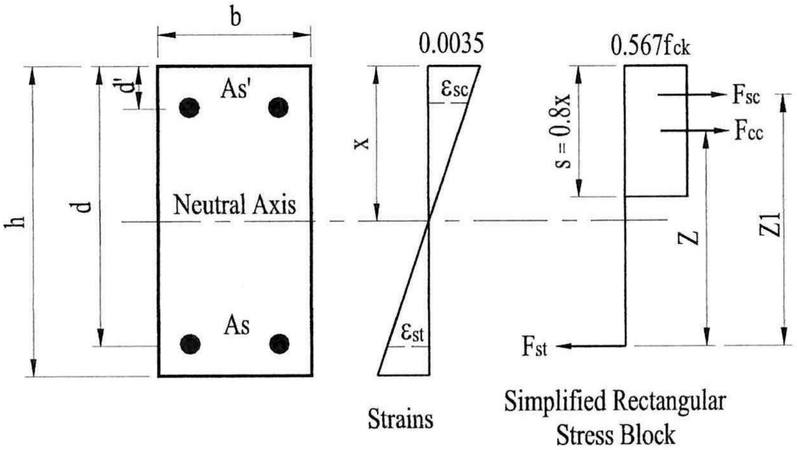
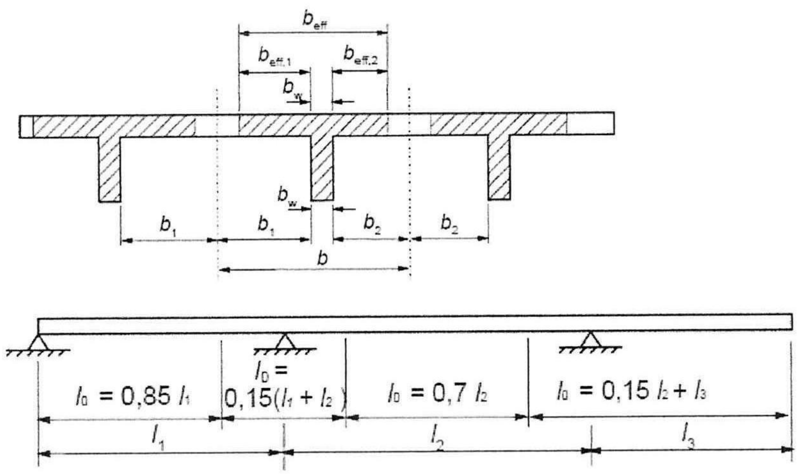
APPENDIX

1. Stress Strain Relationship of Doubly Reinforced Rectangular Section ($f_{ck} \leq 50$ MPa)



2. Effective Width of Flanged Beam (b_{eff})



$$b_{eff} = \sum b_{eff,i} + b_w \leq b$$

where

$$b_{eff,i} = 0,2 b_i + 0,1 l_0 \leq 0,2 l_0$$

and

$$b_{eff,i} \leq b_i$$

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3. Equation for Flanged Beam Design

1. Calculate $M_f = 0.567 f_{ck}\, b h_f (d - 0.5 h_f)$

2. If $M \leq M_f$, neutral axis in the flange

   i. $K = M / bd^2 f_{ck}$

   ii. $z = d\{0.5 + \sqrt{(0.25 - K / 1.134)}\} \leq 0.95d$

   iii. $A_s = M / 0.87 f_{yk}\, z$

3. If $M > M_f$, neutral axis in the web

   i. Calculate $\beta_f = 0.167 \dfrac{b_w}{b} + 0.567 \dfrac{h_f}{d}\left(1 - \dfrac{b_w}{b}\right)\left(1 - \dfrac{h_f}{2d}\right)$

   ii. Calculate $M_{bal} = \beta_f\, f_{ck} b d^2$

   iii. Compare M and M_{bal}

4. If $M \leq M_{bal}$, compression reinforcement is not required.

   i. $A_s = \dfrac{M + 0.1 f_{ck} b_w d (0.36d - h_f)}{0.87 f_{yk} (d - 0.5 h_f)}$

5. If $M > M_{bal}$, compression reinforcement is required.

   i. $A_s' = \dfrac{(M - M_{bal})}{0.87 f_{yk} (d - d')}$

   ii. $A_s = \dfrac{0.167 f_{ck} b_w d + 0.567 f_{ck} h_f (b - b_w)}{0.87 f_{yk}} + A_s'$

4. Design of Flexural Reinforcement (Rectangular Section)

Calculate $K = M / bd^2 f_{ck}$

If $K \leq K_{bal}$ (= 0.167), compression reinforcement is not required, and

(a) $z = d\{0.5 + \sqrt{0.25 - k/1.134}\}$

(b) $A_s = M / 0.87 f_{yk} z$

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5. Design of Shear

$$V_{Rd,max} = \frac{0.36 b_w d f_{ck}(1 - f_{ck}/250)}{(\cot\theta + \tan\theta)}$$

If $V_{Ed} < V_{Rd,max}$ $\theta = 22^o$, use $\theta = 22^o$,

$$\frac{A_{sw}}{s} = \frac{V_{Ed}}{0.78 f_{yk} d \cot\theta}$$

$$= \frac{0.513 V_{Ed}}{f_{yk} d}$$

If $V_{Rd,max}\ \theta = 22^o < V_{Ed} < V_{Rd,max}\ \theta = 45^o$

(a) Calculate $\theta = 0.5 \sin^{-1}\left[\frac{V_{Ed}}{0.18 b_w d f_{ck}(1 - f_{ck}/250)}\right]$

(b) Calculate shear link,

$$\frac{A_{sw}}{s} = \frac{V_{Ed}}{0.78 f_{yk} d \cot\theta}$$

Section Not Requiring Shear Reinforcement ($V_{Ed} < V_{Rd,c}$)

$$V_{Rd,c} = [0.12 k (100 \rho_1 f_{ck})^{1/3}]\, b_w d \quad \geq \quad [0.035 k^{3/2} f_{ck}^{1/2}]\, b_w d$$

where:

k = $[1 + (200/d)^{1/2}] \leq 2.0$ with d expressed in mm

ρ_1 = $(A_{s1}/b_w d) \leq 0.02$

A_{s1} = the area of tensile reinforcement that extends $\geq (l_{bd} + d)$ beyond the section considered

b_w = the smallest width of the section in tensile area (mm).

6. Deflection

$$\frac{l}{d} = K\left[11 + 1.5\sqrt{f_{ck}}\frac{\rho_0}{\rho} + 3.2\sqrt{f_{ck}}\left(\frac{\rho_0}{\rho} - 1\right)^{3/2}\right] \quad \text{if } \rho \leq \rho_0$$

$$\frac{l}{d} = K\left[11 + 1.5\sqrt{f_{ck}}\frac{\rho_0}{\rho - \rho'} + \frac{1}{12}\sqrt{f_{ck}}\sqrt{\frac{\rho'}{\rho_0}}\right] \quad \text{if } \rho > \rho_0$$

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where:

l/d is the limit span/depth

K is the factor to take into account the different structural systems

ρ_0 is the reference reinforcement ratio = $10^{-3}\sqrt{f_{ck}}$

ρ is the required tension reinforcement ratio at mid-span to resist the moment due to the design loads (at support for cantilevers)

ρ' is the required compression reinforcement ratio at mid-span to resist the moment due to design loads (at support for cantilevers)

f_{ck} is in MPa units

For flanged sections where the ratio of the flange breadth to the rib breadth exceeds 3, the values of l/d given by Expression (7.16) should be multiplied by 0,8.

For beams and slabs, other than flat slabs, with spans exceeding 7 m, which support partitions liable to be damaged by excessive deflections, the values of l/d given by Expression (7.16) should be multiplied by 7 / l_{eff} (l_{eff} in metres, see 5.3.2.2 (1)).

Table 7.4N: Basic ratios of span/effective depth for reinforced concrete members without axial compression

Structural System	K	Concrete highly stressed ρ = 1,5%	Concrete lightly stressed ρ = 0,5%
Simply supported beam, one- or two-way spanning simply supported slab	1,0	14	20
End span of continuous beam or one-way continuous slab or two-way spanning slab continuous over one long side	1,3	18	26
Interior span of beam or one-way or two-way spanning slab	1,5	20	30
Slab supported on columns without beams (flat slab) (based on longer span)	1,2	17	24
Cantilever	0,4	6	8

Note 1: The values given have been chosen to be generally conservative and calculation may frequently show that thinner members are possible.
Note 2: For 2-way spanning slabs, the check should be carried out on the basis of the shorter span. For flat slabs the longer span should be taken.
Note 3: The limits given for flat slabs correspond to a less severe limitation than a mid-span deflection of span/250 relative to the columns. Experience has shown this to be satisfactory.

7. Ultimate Bending Moment and Shear Forces of One-Way Slabs (minimum 3 spans)

Table 3.12 — Ultimate bending moment and shear forces in one-way spanning slabs

	End support/slab connection				At first interior support	Middle interior spans	Interior supports
	Simple		Continuous				
	At outer support	Near middle of end span	At outer support	Near middle of end span			
Moment	0	$0.086Fl$	$-0.04Fl$	$0.075Fl$	$-0.086Fl$	$0.063Fl$	$-0.063Fl$
Shear	$0.4F$	—	$0.46F$	—	$0.6F$	—	$0.5F$

Notes:
(i) $F = 1.35g_k + 1.5q_k$
(ii) Bay area ≥ 30 m^2.
(iii) $q_k / g_k \leq 1.25$
(iv) $q_k \leq 5$ kN/m^2

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8. Minimum Area of Reinforcement

$A_{s,min} = 0,26 \frac{f_{ctm}}{f_{yk}} b_t d$ but not less than $0,0013 b_t d$

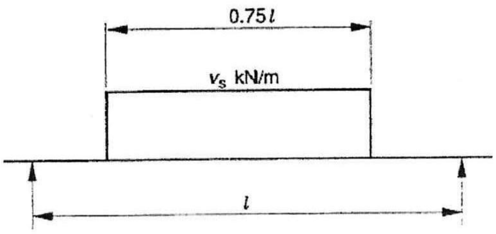
Where:

b_t denotes the mean width of the tension zone; for a T-beam with the flange in compression, only the width of the web is taken into account in calculating the value of b_t.

9. Cracking / Maximum Spacing of Reinforcement for Slabs Not Exceeding 200 mm Thick

Principal / main reinforcement	$\leq$	3h or 400 mm whichever is the lesser
Secondary reinforcement	$\leq$	3.5h or 450 mm whichever is the lesser

10. Loads / Actions On Beam Supporting Two-Way Solid Slabs



$$v_{sy} = \beta_{vy} n l_x$$
$$v_{sx} = \beta_{vx} n l_x$$

Where,

v_s	=	*Shear force (kN/m)*
β_v	=	*Shear force coefficient (Table 3.15, BS8110)*
n	=	*Characteristic action (g_k or q_k)*

10. Bending Moments Of Two-Way Rectangular Solid Slabs

$$m_{sx} = \beta_{sx} n l_x^2$$
$$m_{sy} = \beta_{sy} n l_x^2$$

Where,

m_s	=	*Bending moment (kNm/m)*
β_s	=	*Bending moment coefficient (Table 3.14, BS8110)*
n	=	*Characteristic action (g_k or q_k)*

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Table 3.14 — Bending moment coefficients for rectangular panels supported on four sides with provision for torsion at corners

Type of panel and moments considered	Short span coefficients, β_{sx}								Long span coefficients, β_{sy} for all values of l_y/l_x
	Values of l_y/l_x								
	1.0	1.1	1.2	1.3	1.4	1.5	1.75	2.0	
Interior panels									
Negative moment at continuous edge	0.031	0.037	0.042	0.046	0.050	0.053	0.059	0.063	0.032
Positive moment at mid-span	0.024	0.028	0.032	0.035	0.037	0.040	0.044	0.048	0.024
One short edge discontinuous									
Negative moment at continuous edge	0.039	0.044	0.048	0.052	0.055	0.058	0.063	0.067	0.037
Positive moment at mid-span	0.029	0.033	0.036	0.039	0.041	0.043	0.047	0.050	0.028
One long edge discontinuous									
Negative moment at continuous edge	0.039	0.049	0.056	0.062	0.068	0.073	0.082	0.089	0.037
Positive moment at mid-span	0.030	0.036	0.042	0.047	0.051	0.055	0.062	0.067	0.028
Two adjacent edges discontinuous									
Negative moment at continuous edge	0.047	0.056	0.063	0.069	0.074	0.078	0.087	0.093	0.045
Positive moment at mid-span	0.036	0.042	0.047	0.051	0.055	0.059	0.065	0.070	0.034
Two short edges discontinuous									
Negative moment at continuous edge	0.046	0.050	0.054	0.057	0.060	0.062	0.067	0.070	—
Positive moment at mid-span	0.034	0.038	0.040	0.043	0.045	0.047	0.050	0.053	0.034
Two long edges discontinuous									
Negative moment at continuous edge	—	—	—	—	—	—	—	—	0.045
Positive moment at mid-span	0.034	0.046	0.056	0.065	0.072	0.078	0.091	0.100	0.034
Three edges discontinuous (one long edge continuous)									
Negative moment at continuous edge	0.057	0.065	0.071	0.076	0.081	0.084	0.092	0.098	—
Positive moment at mid-span	0.043	0.048	0.053	0.057	0.060	0.063	0.069	0.074	0.044
Three edges discontinuous (one short edge continuous)									
Negative moment at continuous edge	—	—	—	—	—	—	—	—	0.058
Positive moment at mid-span	0.042	0.054	0.063	0.071	0.078	0.084	0.096	0.105	0.044
Four edges discontinuous									
Positive moment at mid-span	0.055	0.065	0.074	0.081	0.087	0.092	0.103	0.111	0.056

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Table 3.15 — Shear force coefficient for uniformly loaded rectangular panels supported on four sides with provision for torsion at corners

Type of panel and location	β_{vx} for values of l_y/l_x								β_{vy}
	1.0	1.1	1.2	1.3	1.4	1.5	1.75	2.0	
Four edges continuous									
Continuous edge	0.33	0.36	0.39	0.41	0.43	0.45	0.48	0.50	0.33
One short edge discontinuous									
Continuous edge	0.36	0.39	0.42	0.44	0.45	0.47	0.50	0.52	0.36
Discontinuous edge	—	—	—	—	—	—	—	—	0.24
One long edge discontinuous									
Continuous edge	0.36	0.40	0.44	0.47	0.49	0.51	0.55	0.59	0.36
Discontinuous edge	0.24	0.27	0.29	0.31	0.32	0.34	0.36	0.38	—
Two adjacent edges discontinuous									
Continuous edge	0.40	0.44	0.47	0.50	0.52	0.54	0.57	0.60	0.40
Discontinuous edge	0.26	0.29	0.31	0.33	0.34	0.35	0.38	0.40	0.26
Two short edges discontinuous									
Continuous edge	0.40	0.43	0.45	0.47	0.48	0.49	0.52	0.54	—
Discontinuous edge	—	—	—	—	—	—	—	—	0.26
Two long edges discontinuous									
Continuous edge	—	—	—	—	—	—	—	—	0.40
Discontinuous edge	0.26	0.30	0.33	0.36	0.38	0.40	0.44	0.47	—
Three edges discontinuous (one long edge discontinuous)									
Continuous edge	0.45	0.48	0.51	0.53	0.55	0.57	0.60	0.63	—
Discontinuous edge	0.30	0.32	0.34	0.35	0.36	0.37	0.39	0.41	0.29
Three edges discontinuous (one short edge discontinuous)									
Continuous edge	—	—	—	—	—	—	—	—	0.45
Discontinuous edge	0.29	0.33	0.36	0.38	0.40	0.42	0.45	0.48	0.30
Four edges discontinuous									
Discontinuous edge	0.33	0.36	0.39	0.41	0.43	0.45	0.48	0.50	0.33

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11. Cross Sectional Area of Reinforcement

Table 1: Cross Sectional Area (mm^2) according to Size and Numbers of Bar

Bar Size (mm)	Number of bar								Perimeter (mm)
	1	2	3	4	5	6	7	8	
6	28.3	56.6	84.9	113	141	170	198	226	18.9
8	50.3	101	151	201	251	302	352	402	25.1
10	78.6	157	236	314	393	471	550	629	31.4
12	113	226	339	453	566	679	792	905	37.7
16	201	402	603	805	1006	1207	1408	1609	50.3
20	314	629	943	1257	1571	1886	2200	2514	62.9
25	491	982	1473	1964	2455	2946	3438	3929	78.6
32	805	1609	2414	3218	4023	4827	5632	6437	100.6
40	1257	2514	3771	5029	6286	7543	8800	10057	125.7

Table 2: Cross Sectional Area (mm^2) for every meter width at distance between bar

Bar Size (mm)	Distance between Bar (mm)								
	50	75	100	125	150	175	200	250	300
6	566	377	283	226	189	162	141	113	94
8	1006	670	503	402	335	287	251	201	168
10	1571	1048	786	629	524	449	393	314	262
12	2263	1509	1131	905	754	647	566	453	377
16	4023	2682	2011	1609	1341	1149	1006	805	670
20	6286	4190	3143	2514	2095	1796	1571	1257	1048
25	9821	6548	4911	3929	3274	2806	2455	1964	1637
32	16091	10728	8046	6437	5364	4598	4023	3218	2682
40	25143	16762	12571	10057	8381	7184	6286	5029	4190