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Member Design - RC Two Way Spanning Slab		Made by XX	Date 21/11/2021	Chd.	

Material Properties

Characteristic strength of concrete, f_{cu} (≤ 60N/mm^2; HSC N/A)		35	N/mm^2	OK
Yield strength of longitudinal steel, f_y		460	N/mm^2	
Yield strength of shear link steel, f_{yv}		460	N/mm^2	
Type of concrete and density, ρ_c	Normal Weight	24	kN/m^3	

Slab Parameters

Shorter span (defined as in x) and number, l_x (number affe	Multi Span	5.000	m	
Longer span (defined as in y) and number, l_y (number affec	Single Span	6.000	m	OK
Slab support conditions (affects effective beam section, mo	Continuous		ia)	
Panel (affects moments for continuous case,	Corner			

shear for continuous case and whether interior or edge beam for both precast and continuous cases)

Overall slab depth, h_{slab} (l/24-l/35 s/s; l/34-l/40 cont)		175	mm
Cover to all reinforcement, cover (usually MAX(25, ϕ) internal; 40 external)		30	mm
Effective depth to sagging steel in x, $d_{x,s}$ = h_{slab} - cover - $\phi_{sx}/2$		140	mm
Effective depth to sagging steel in y, $d_{y,s}$ = h_{slab} - cover - ϕ_{sx} - $\phi_{sy}/2$		130	mm
Effective depth to hogging steel in x, $d_{x,h}$ = h_{slab} - cover - $\phi_{link,x}$ - $\phi_{hx}/2$		140	mm
Effective depth to hogging steel in y, $d_{y,h}$ = h_{slab} - cover - $\phi_{link,y}$ - ϕ_{hx} - $\phi_{hy}/2$		130	mm
Sagging steel reinforcement diameter in x, ϕ_{sx}	10		mm
Sagging steel reinforcement pitch for resistance in x, p_{sx}		200	mm
Sagging steel area provided in x, $A_{s,prov,x,s}$ = $(\pi.\phi_{sx}^2/4)/p_{sx}$		393	mm^2/m
Sagging steel reinforcement diameter in y, ϕ_{sy}	10		mm
Sagging steel reinforcement pitch for resistance in y, p_{sy}		200	mm
Sagging steel area provided in y, $A_{s,prov,y,s}$ = $(\pi.\phi_{sy}^2/4)/p_{sy}$		393	mm^2/m
Hogging steel reinforcement diameter in x, ϕ_{hx}	10		mm
Hogging steel reinforcement pitch for resistance in x, p_{hx}		200	mm
Hogging steel area provided in x, $A_{s,prov,x,h}$ = $(\pi.\phi_{hx}^2/4)/p_{hx}$		393	mm^2/m
Hogging steel reinforcement diameter in y, ϕ_{hy}	10		mm
Hogging steel reinforcement pitch for resistance in y, p_{hy}		200	mm
Hogging steel area provided in y, $A_{s,prov,y,h}$ = $(\pi.\phi_{hy}^2/4)/p_{hy}$		393	mm^2/m
Shear link diameter for bending in x, $\phi_{link,x}$	None		mm
Number of links per metre for bending in x, $n_{link,x}$		4	/m
Area provided by all links per metre for bending in x, $A_{sv,prov,x}$ = $n_{link,x}.\pi.\phi_{link,x}^2/$		0	mm^2/m
Pitch of links for bending in x, S_x		150	mm
Shear link diameter for bending in y, $\phi_{link,y}$	None		mm
Number of links per metre for bending in y, $n_{link,y}$		4	/m
Area provided by all links per metre for bending in y, $A_{sv,prov,y}$ = $n_{link,y}.\pi.\phi_{link,y}^2/$		0	mm^2/m
Pitch of links for bending in y, S_y		150	mm

Slab Loading (Plan Loading) — Redistributed Moments Effects

(Internal elev load not on beam must be checked on effective widths [span/(5 or 7.14)] within slab depth)

Live load, LL	2.00	kPa
Superimposed dead load, SDL_{plan}	1.20	kPa
Dead load of slab, DL = $h_{slab}.\rho_c$	4.20	kPa
ULS slab loading, $\omega_{ULS,slab}$ (a.k.a. n) = 1.4 (DL + SDL_{plan}) + 1.6 LL	10.76	kPa

Beam Loading (Elevation Loading) — Elastic Moments Effects

Superimposed dead load on y direction beam, $SDL_{elev,x}$	0.00	kN/m
Superimposed dead load on x direction beam, $SDL_{elev,y}$	0.00	kN/m

Parameters of Beam Spanning in y Direction (Slab in x Direction)

Interior or edge beam ?		Edge Beam	
(affects tributary width for loading on beam, available beam spacing for effective width in cont case)			
Downstand depth of beam (excluding slab) spanning in y direction, $h_{d,beam,x}$		225	mm
Width of beam spanning in y direction, $b_{w,beam,x}$		150	mm
Dead load on y direction beam downstand, $DL_{beam,x} = h_{d,beam,x} b_{w,beam} \rho_c$		0.81	kN/m
Sag moment beam span y, $M_{x,sag}$		80	kNm
Hog moment beam span y, $M_{x,hog}$		40	kNm
Shear beam span y, V_x		53	kN
Span (for effective width and deflection calcs)		6.000	m
Available beam spacing (effective width calcs in continuous case)		2.500	m
Sag section type		L - s/s	
Hog section type		Rect - s/s	
Overall depth, $h_{beam,x}$ (downstand if precast, downstand + slab if cont)		400	mm
For sagging: tension steel diameter, $\phi_{t,sag,x}$ and number	20	2	
For sagging: compression steel diameter, $\phi_{c,sag,x}$ and number	None	0	
For sagging: add cover to compression steel, $cover_{add,x,c,sag} = \phi_{hx}$		10	mm
For hogging: tension steel diameter, $\phi_{t,hog,x}$ and number	20	2	
For hogging: add cover to tensile steel, $cover_{add,x,t,hog} = cover_{add,x,c,sag}$		10	mm
For hogging: compression steel diameter, $\phi_{c,hog,x}$ and number	None	0	
Link diameter $\phi_{link,x}$, number and pitch	10 2	250	mm
For sagging: number of layers of tensile steel, $n_{layers,tens,sag}$		1	layer(s)
For sagging: number of layers of compression steel, $n_{layers,comp,sag}$		1	layer(s)
Ratio β_b=1.2 (sagging) or 0.8 (hogging) unless single span or conti	1.0	1.0	
For hogging: number of layers of tensile steel, $n_{layers,tens,hog}$		1	layer(s)
For hogging: number of layers of compression steel, $n_{layers,comp,hog}$		1	layer(s)

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Parameters of Beam Spanning in x Direction (Slab in y Direction)

Interior or edge beam ?		Edge Beam	
(affects tributary width for loading on beam, available beam spacing for effective width in cont case)			
Downstand depth of beam (excluding slab) spanning in x direction, $h_{d,beam,y}$		225	mm
Width of beam spanning in x direction, $b_{w,beam,y}$		150	mm
Dead load on x direction beam downstand, $DL_{beam,y} = h_{d,beam,y} b_{w,beam} \rho_c$		0.81	kN/m
Sag moment beam span x, $M_{y,sag}$		38	kNm
Hog moment beam span x, $M_{y,hog}$		59	kNm
Shear beam span x, V_y		57	kN
Span (for effective width and deflection calcs)		5.000	m
Available beam spacing (effective width calcs in continuous case)		3.000	m
Sag section type		L - continuous	
Hog section type		Rect - continuous	
Overall depth, $h_{beam,y}$ (downstand if precast, downstand + slab if cont)		400	mm
For sagging: tension steel diameter, $\phi_{t,sag,y}$ and number	20	2	
For sagging: add cover to tension steel, $cover_{add,y,t,sag} = cover_{add,y,c,hog}$		20	mm
For sagging: compression steel diameter, $\phi_{c,sag,y}$ and number	None	0	
For sagging: add cover to compression steel, $cover_{add,y,c,sag} = cover_{add,y,t,hog}$		30	mm
For hogging: tension steel diameter, $\phi_{t,hog,y}$ and number	20	2	
For hogging: add cover to tensile steel, $cover_{add,y,t,hog}$ = MAX{ϕ_{hx} + ϕ_{hy}, MAX(ϕ_l		30	mm
For hogging: compression steel diameter, $\phi_{c,hog,y}$ and number	None	0	
For hogging: add cover to compression steel, $cover_{add,y,c,hog}$ = MAX{0, MAX($\phi_{t,s}$		20	mm
Link diameter $\phi_{link,y}$, number and pitch	10	2	250 mm
For sagging: number of layers of tensile steel, $n_{layers,tens,sag}$		1	layer(s)
For sagging: number of layers of compression steel, $n_{layers,comp,sag}$		1	layer(s)
Ratio β_b=1.2 (sagging) or 0.8 (hogging) unless single span or conti	1.0	1.0	
For hogging: number of layers of tensile steel, $n_{layers,tens,hog}$		1	layer(s)
For hogging: number of layers of compression steel, $n_{layers,comp,hog}$		1	layer(s)

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Utilisation Summary (Slab)

Item	UT	Remark
Sag moment, m_x	63%	OK
Sag moment, m_y	74%	OK
Hog moment, m_1	37%	OK
Hog moment, m_2	37%	OK
Hog moment, m_3	83%	OK
Hog moment, m_4	0%	OK
% Min sag reinforcement in x	58%	OK
% Min sag reinforcement in y	58%	OK
% Min hog reinforcement 1	58%	OK
% Min hog reinforcement 2	58%	OK
% Min hog reinforcement 3	58%	OK
% Min hog reinforcement 4	58%	OK
Ultimate shear stress for bending in x and y	3%	OK
Shear design capacity for bending in x	20%	OK
Shear design capacity for bending in y	22%	OK
Shear design capacity for bending in x and y combined	42%	OK
Deflection requirements	78%	OK
Total utilisation precast slab	**78%**	**OK**
Total utilisation continuous slab	**83%**	**OK**
Detailing requirements	**OK**	

Utilisation Summary (Beam)

Automatic design **All Beams**

Item	UT	Detailing	Remark	
Beam spanning in y (slab in x) sagging	**88%**	**NOT OK**	**NOT OK**	Beam y Sag
Beam spanning in y (slab in x) hogging	**45%**	**NOT OK**	**NOT OK**	Beam y Hog
Beam spanning in x (slab in y) sagging	**48%**	**NOT OK**	**NOT OK**	Beam x Sag
Beam spanning in x (slab in y) hogging	**65%**	**NOT OK**	**NOT OK**	Beam x Hog

Overall Utilisation Summary

Overall utilisation	**88%**	
Overall detailing requirements	**NOT OK**	
% Sag reinforcement in x	**0.22**	%
% Sag reinforcement in y	**0.22**	%
% Hog reinforcement in x	**0.22**	%
% Hog reinforcement in y	**0.22**	%
Estimated steel reinforcement quantity (130 – 220kg/m^3)	**70**	kg/m^3

[7.850 . ($A_{s,prov,x,s}$ +$A_{s,prov,y,s}$ +$A_{s,prov,x,h}$ +$A_{s,prov,x,h}$) / h_{slab}]; No curtailment; No laps; Links ignored;

Estimated steel reinforcement quantity (130 – 220kg/m^3)	**99**	kg/m^3	*IStructE*

[11.0 . ($A_{s,prov,x,s}$ +$A_{s,prov,y,s}$ +$A_{s,prov,x,h}$ +$A_{s,prov,x,h}$) / h_{slab}]; Curtailment; Laps; Links ignored;

[Note that steel quantity in kg/m^3 can be obtained from 110.0 x % rebar];

Material cost:	concrete, c	180	units/m^3	steel, s	4500 units/tonne
Reinforced concrete material cost = [c+(est. rebar quant).s].h_{slab}				**109**	units/m^2

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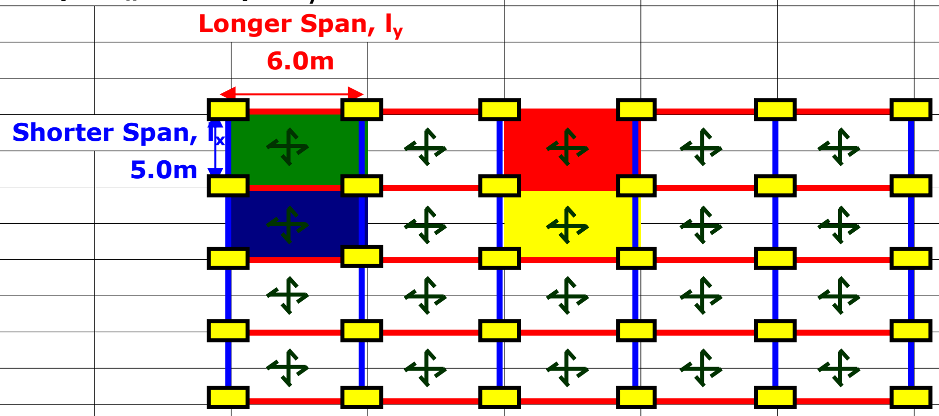
Plan Layout

Multi-Span l_x Multi-Span l_y Floor Plate



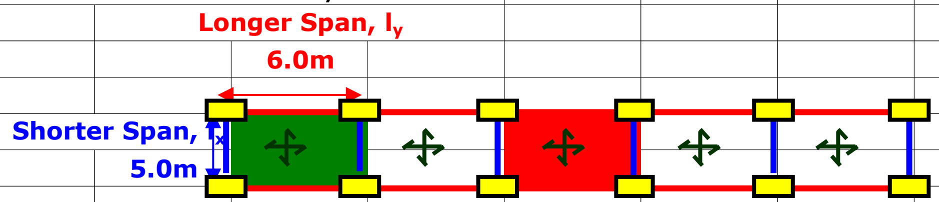
Relevant Panels

Interior	(yellow)
Edge for Span in x Direction	(red)
Edge for Span in y Direction	(blue)
Corner	(green)

Construction Type	***Support Conditions***
Continuous	*Continuous*
Precast	*Simply Supported*

Number of spans in l_x	*Multi-span*
Number of spans in l_y	*Multi-span*

Single-Span l_x Multi-Span l_y Floor Plate



Relevant Panels

Interior	N/A
Edge for Span in x Direction	(red)
Edge for Span in y Direction	N/A
Corner	(green)

Construction Type	***Support Conditions***
Continuous	*Continuous*
Precast	*Simply Supported*

Number of spans in l_x	*Single-span*
Number of spans in l_y	*Multi-span*

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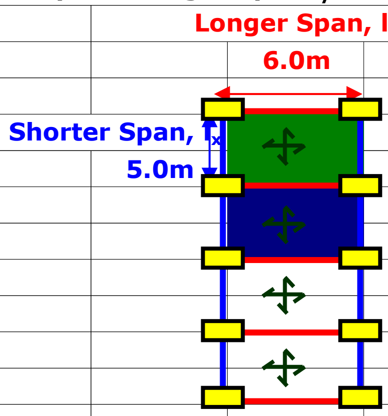
Multi-Span l_x Single-Span l_y Floor Plate



4 leg

Relevant Panels		
	Interior	N/A
	Edge for Span in x Direction	N/A
	Edge for Span in y Direction	
	Corner	

Torsio

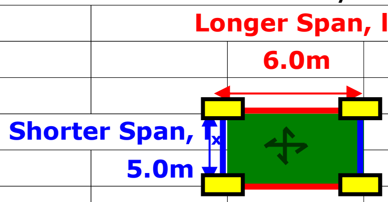
Construction Type	***Support Conditions***
Continuous	*Continuous*
Precast	*Simply Supported*

Torsio

Number of spans in l_x	*Multi-span*
Number of spans in l_y	*Single-span*

4 leg

Single-Span l_x Single-Span l_y Floor Plate



Relevant Panels		
	Interior	N/A
	Edge for Span in x Direction	N/A
	Edge for Span in y Direction	N/A
	Corner	

Construction Type	***Support Conditions***
Continuous	*Continuous*
Precast	*Simply Supported*

Number of spans in l_x	*Single-span*
Number of spans in l_y	*Single-span*

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Assumptions and Limitations

1 *Moment effects for slabs may only be calculated based on redistributed effects (not elastic effects).*

2 *Moment effects for beams may be calculated based on redistributed effects or elastic effects.*

Detailing Instructions *Not to Scale*

0.750 m

4.500 m

Cover = 30 mm

Concrete = 35 MPa

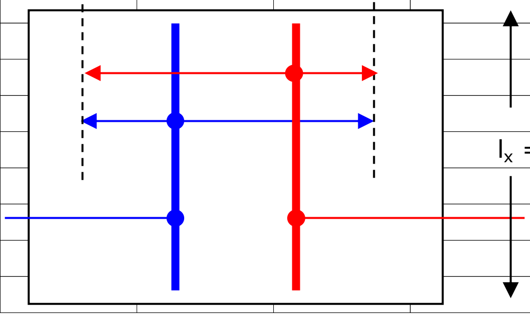
Rebars = 460 MPa

Links = 460 MPa

l_x = 5.000 m

Links for Direction x
s of T0@150mm pitch
per metre

Bottom Steel
T10@200mm centres
Min steel @ edges
n steel at free corners



Top Steel
T10@200mm centres
Min steel @ edges
Torsion steel at free corners

Reinforcement for Span in x

$d_{x,s}$ = 140 mm

$d_{x,h}$ = 140 mm

l_y = 6.000 m

Bottom Steel
T10@200mm centres
Min steel @ edges
n steel at free corners

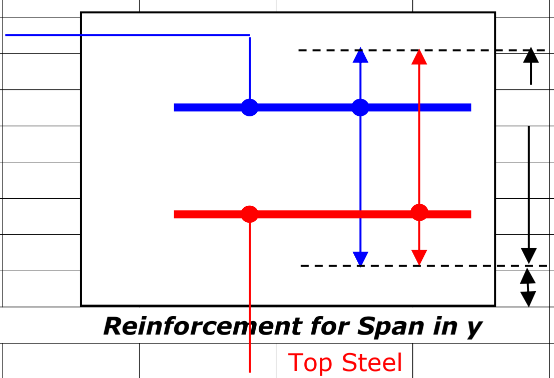
3.750 m

Links for Direction y
s of T0@150mm pitch
per metre

$d_{y,s}$ = 130 mm

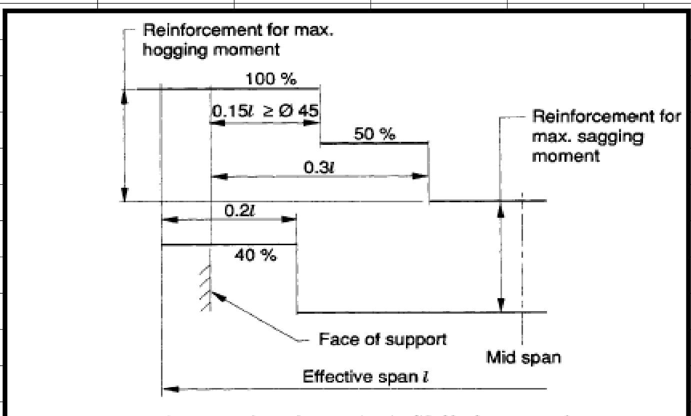
$d_{y,h}$ = 130 mm

0.625 m

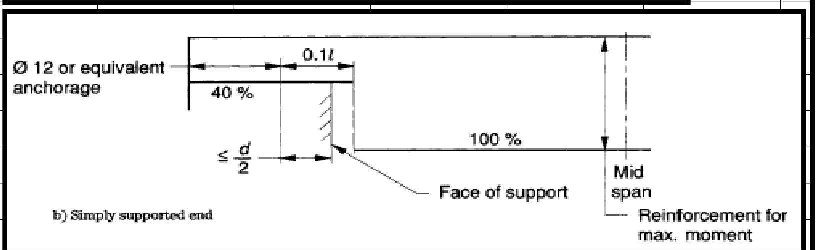


Reinforcement for Span in y

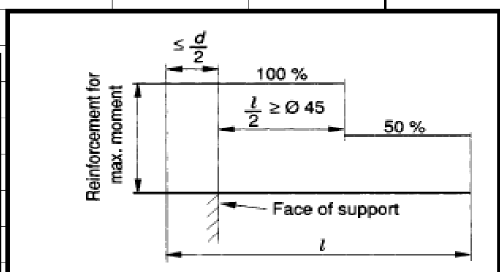
Top Steel
T10@200mm centres
Min steel @ edges
Torsion steel at free corners



a) Continuous member (approximately equal spans using simplified load arrangement)



b) Simply supported end



c) Cantilever

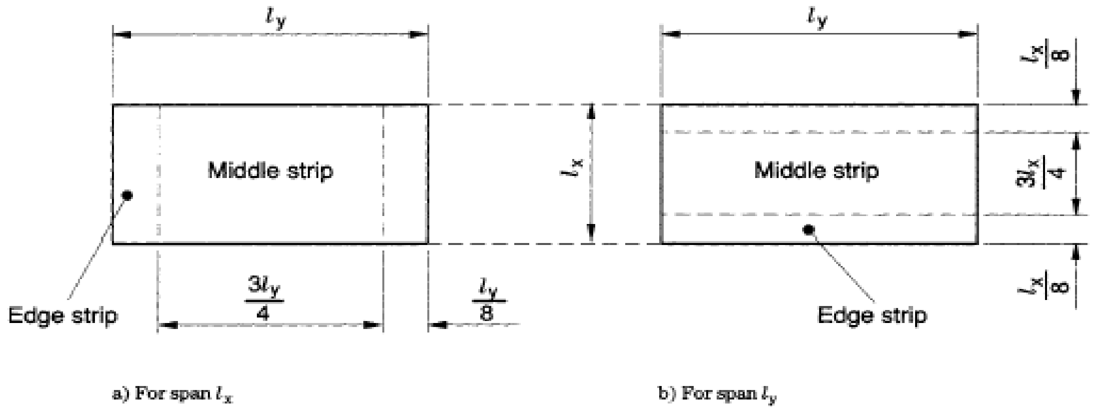
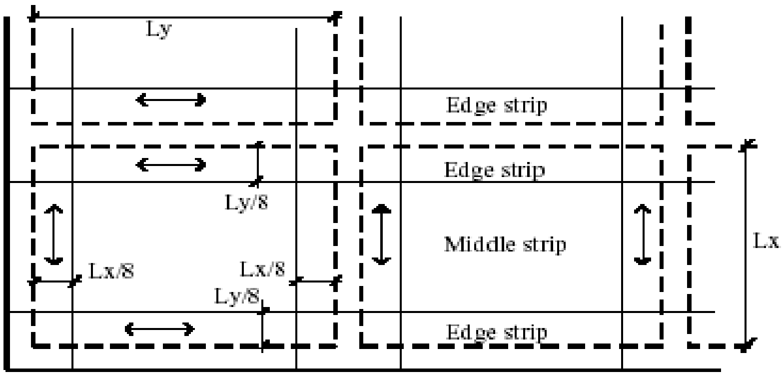


Figure 3.9 — Division of slab into middle and edge strips

Two Way Slabs: The reinforcement is arranged into strips and areas as shown.

Edge strips. Nominal bars spanning in direction of arrows.



Bars in the edge strips should be the same length and diameter as those in the middle strips, but the pitch may be increased to give the minimum reinforcement permitted.

The rules to be observed when the equations are applied to restrained slabs (continuous or discontinuous) are as follows.

1) Slabs are considered as divided in each direction into middle strips and edge strips as shown in Figure 3.9, the middle strip being three-quarters of the width and each edge strip one-eighth of the width.

2) The maximum design moments calculated as above apply only to the middle strips and no redistribution should be made.

3) Reinforcement in the middle strips should be detailed in accordance with **3.12.10** (simplified rules for curtailment of bars).

4) Reinforcement in an edge strip, parallel to the edge, need not exceed the minimum given in **3.12.5** (minimum areas of tension reinforcement), together with the recommendations for torsion given in 5), 6) and 7).

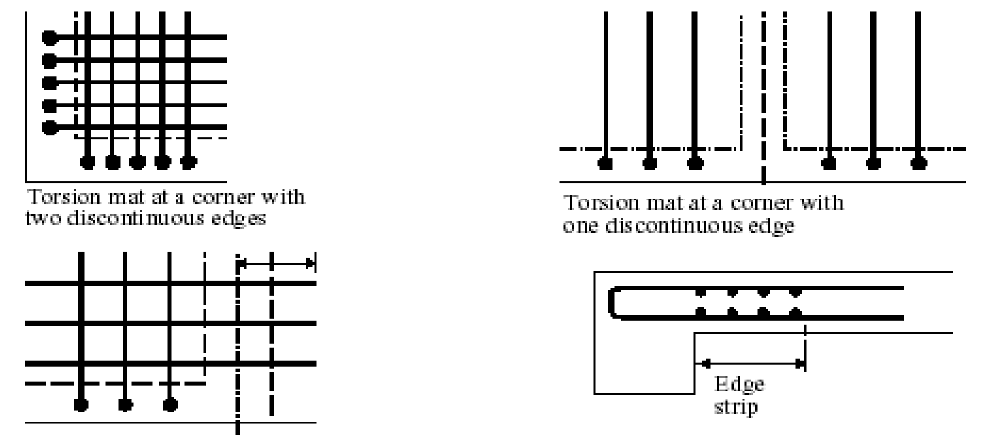
5) Torsion reinforcement should be provided at any corner where the slab is simply supported on both edges meeting at that corner. It should consist of top and bottom reinforcement, each with layers of bars placed parallel to the sides of the slab and extending from the edges a minimum distance of one-fifth of the shorter span. The area of reinforcement in each of these four layers should be three-quarters of the area required for the maximum mid-span design moment in the slab.

6) Torsion reinforcement equal to half that described in the preceding paragraph should be provided at a corner contained by edges over only one of which the slab is continuous.

7) Torsion reinforcement need not be provided at any corner contained by edges over both of which the slab is continuous.

Torsion reinforcement is required at corners supported on both sides.

This may be supplied in the form of 'U' bars. They should extend into the slab a minimum distance of one fifth of the shorter span. The area of reinforcement required in each leg should be at least three quarters of the area required for the maximum mid-span design moments in the slab. Only half this area is required at a corner with only one discontinuous edge.



Torsion mat at a corner with two discontinuous edges

Torsion mat at a corner with one discontinuous edge

Torsion mat at a corner with one discontinuous edge and no torsion mat required in adjacent bay

Detailing Steel Positions

Note that the main slab reinforcement in y is assumed to be interior to main slab reinforcement in x;
Note that the main beam in y reinforcement is assumed to be interior to main slab reinforcement in x;
Note that the main beam in x reinforcement is assumed to be interior to main beam in y reinforcement;

Note the same cover to all reinforcement used for the slab is used for the beam;

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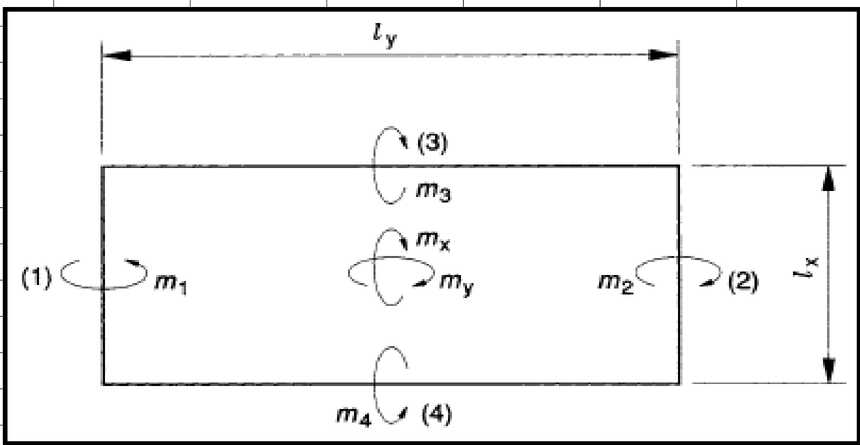
Structural Analysis Slab Bending Moments

Slab Simply Supported

Sag moment in x	$m_{sx} = \alpha_{sx} n l_x^2$	23	kNm/m
(precast or single span)	$\alpha_{sx} = \frac{(l_y/l_x)^4}{8\{1+(l_y/l_x)^4\}}$	0.084	
Sag moment in y	$m_{sy} = \alpha_{sy} n l_x^2$	16	kNm/m
(precast or single span)	$\alpha_{sy} = \frac{(l_y/l_x)^2}{8\{1+(l_y/l_x)^4\}}$	0.059	
Hog moment in x = *0 (precast),* m_{sx}*/2 (single span continuous)*		11	kNm/m
Hog moment in y = *0 (precast),* m_{sy}*/2 (single span continuous)*		8	kNm/m

Slab Continuous



Continuity of side (1)		Discontinuous	
Continuity of side (2)		Discontinuous	
Continuity of side (3)		Continuous	
Continuity of side (4)		Discontinuous	
Number of discontinuous edges, N_d		3	
	$\beta y = (24 + 2N_d + 1.5N_d^2)/1\,000$	0.044	
β_1 ($4/3\beta_y$ if continuous, 0 if discontinuous)		0.000	
β_2 ($4/3\beta_y$ if continuous, 0 if discontinuous)		0.000	
	$\gamma = \frac{2}{9}[3 - \sqrt{(18)}\,\frac{l_x}{l_y}\{\sqrt{(\beta_y+\beta_1)} + \sqrt{(\beta_y+\beta_2)}\}]$	0.339	
β_3 ($4/3\beta_x$ if continuous, 0 if discontinuous)			
β_4 ($4/3\beta_x$ if continuous, 0 if discontinuous)			
β_x	$\sqrt{\gamma} = \sqrt{(\beta_x+\beta_3)} + \sqrt{(\beta_x+\beta_4)}$	0.053	
β_3 ($4/3\beta_x$ if continuous, 0 if discontinuous)		0.071	
β_4 ($4/3\beta_x$ if continuous, 0 if discontinuous)		0.000	
Sag moment in x	$m_{sx} = \beta_{sx} n l_x^2$	14	kNm/m
Sag moment in y	$m_{sy} = \beta_{sy} n l_x^2$	12	kNm/m
Hog moment, $m_1 = \beta_1 n l_x^2$		0	kNm/m
Hog moment, $m_2 = \beta_2 n l_x^2$		0	kNm/m
Hog moment, $m_3 = \beta_3 n l_x^2$		19	kNm/m
Hog moment, $m_4 = \beta_4 n l_x^2$		0	kNm/m

Table 3.13 — Bending moment coefficients for slabs spanning in two directions at right angles, simply-supported on four sides

l_y/l_x	1.0	1.1	1.2	1.3	1.4	1.5	1.75	2.0
α_{sx}	0.062	0.074	0.084	0.093	0.099	0.104	0.113	0.118
α_{sy}	0.062	0.061	0.059	0.055	0.051	0.046	0.037	0.029

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

The data for single freely supported two-way slabs given in BS8110 and CP110 derive from an elastic analysis, while those for continuous series of slabs relate to collapse conditions.

Note that 4 edges discontinuous does not imply precast as the edges are still prevented from lifting, and adequate torsion provisions are made.

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Structural Analysis Slab Shear Forces

Slab

Shear force for bending in direction of span x	$v_{sx} = \beta_{vx} n l_x$	**17**	kN/m
Coefficient	β_{vx}	0.310	
Shear force for bending in direction of span y	$v_{sy} = \beta_{vy} n l_x$	**18**	kN/m
Coefficient	β_{vy}	0.330	

Note that for edge and corner panels, the shear force has been calculated for the less critical discontinuous part of the panel instead of the continuous part because the SDL will be more critical here due to external cladding.

Beam

Slab UDL on beam spanning in y (slab in x), $\omega_{beam,x} = \nu_{sx}$	17	kN/m
Slab UDL on beam spanning in x (slab in y), $\omega_{beam,y} = \nu_{sy}$	18	kN/m
ULS beam spanning y, $\omega_{ULS,beam,x} = F.\omega_{beam,x}+1.4SDL_{elev,x}+1.4DL_{bear}$	18	kN/m
ULS beam spanning x, $\omega_{ULS,beam,y} = F.\omega_{beam,y}+1.4SDL_{elev,y}+1.4DL_{bear}$	19	kN/m

(Factor F: Interior beams have got two slabs spanning onto them hence F = 2 whilst edges beams have only one slab hence F = 1)

Table 3.5 — Design ultimate bending moments and shear forces

	At outer support	Near middle of end span	At first interior support	At middle of interior spans	At interior supports
Moment	0	$0.09Fl$	$-0.11Fl$	$0.07Fl$	$-0.08Fl$ *−0.083Fl*
Shear	$0.45F$	*0.08Fl*	$0.6F$ *−0.125Fl*	*0.05Fl*#PL	$0.55F$

NOTE l is the effective
F is the total desi
No redistribution of the mo

Note elastic moment effects. #PL pattern loading factor 1.2;

Note allowance has been made in this table for 20% moment redistribution;

Sag moment beam span y, $M_{x,sag}$ = coeff.$(\omega_{ULS,beam,x} . l_y)l_y$	**80**	kNm
Hog moment beam span y, $M_{x,hog}$ = coeff.$(\omega_{ULS,beam,x} . l_y)l_y$	**40**	kNm
Shear beam span y, V_x = coeff.$(\omega_{ULS,beam,x} . l_y)$	**53**	kN
Sag moment beam span x, $M_{y,sag}$ = coeff.$(\omega_{ULS,beam,y} . l_x)l_x$	**38**	kNm
Hog moment beam span x, $M_{y,hog}$ = coeff.$(\omega_{ULS,beam,y} . l_x)l_x$	**59**	kNm
Shear beam span x, V_y = coeff.$(\omega_{ULS,beam,y} . l_x)$	**57**	kN

Note that the coefficients above are appropriate to the panel as follows.

Panel	*Sag y*	*Hog y*	*Shear y*	*Sag x*	*Hog x*	*Shear x*
Interior	*0.050*	*0.083*	*0.550*	*0.050*	*0.083*	*0.550*
Edge in x	*0.050*	*0.083*	*0.550*	*0.080*	*0.125*	*0.600*
Edge in y	*0.080*	*0.125*	*0.600*	*0.050*	*0.083*	*0.550*
Corner	*0.080*	*0.125*	*0.600*	*0.080*	*0.125*	*0.600*
Single Span	*0.125*	*0.063*	*0.500*	*0.125*	*0.063*	*0.500*

Note that the beams are always continuous (unless single span) since monolithic with columns, but the slab can be continuous (unless single span) or precast.

Shear Force Coefficients for Simply Supported Slab

These have been taken to be the same as the continuous slab with all 4 edges having the same continuity, i.e. continuous or discontinuous, as the coefficients are the same in either case.

Shear Force Coefficients for Continuous Slab

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

Slab Moment Design

Sag moment, m_x	14	kNm/m
Sag moment, m_y	16	kNm/m
Hog moment, m_1	8	kNm/m
Hog moment, m_2	8	kNm/m
Hog moment, m_3	19	kNm/m
Hog moment, m_4	0	kNm/m

Ensure singly reinforced $K = M/bd^2f_{cu}$ $z = d\left\{0.5 + \sqrt{\left(0.25 - \frac{K}{0.9}\right)}\right\}$ z <=0.95d $A_s = \frac{M}{(0.95f_y)z}$

$K' = 0.156$ $K' = 0.402(\beta_b - 0.4) - 0.18(\beta_b - 0.4)^2$

	K'	K	z	A_s	$A_{s,prov}$	UT	
Sag moment, m_x	0.156	0.021	133	246	393	63%	OK
Sag moment, m_y	0.156	0.027	124	292	393	74%	OK
Hog moment, m_1	0.156	0.013	124	146	393	37%	OK
Hog moment, m_2	0.156	0.013	124	146	393	37%	OK
Hog moment, m_3	0.132	0.028	133	327	393	83%	OK
Hog moment, m_4	0.132	0.000	133	0	393	0%	OK

Note unless precast or single span whereby β_b = 1.00 and K' = 0.156, K' calculated with β_b = 1.20 (sagging) or 0.80 (hogging), however K' for $\beta_b \geq 0.90$ truncated at 0.156.
If K > K', then UT = 999%. Note that A_s and $A_{s,prov}$ above are in units of mm^2/m.
Note that $A_{s,prov}$ is really specified for the middle strip.

% Min sag reinforcement in x (>= 0.0024bh G250; >= 0.0013bh G460)	0.22	%	
% Min sag reinforcement in x utilisation	58%		OK
% Min sag reinforcement in y (>= 0.0024bh G250; >= 0.0013bh G460)	0.22	%	
% Min sag reinforcement in y utilisation	58%		OK
% Min hog reinforcement 1 (>= 0.0024bh G250; >= 0.0013bh G460)	0.22	%	
% Min hog reinforcement 1 utilisation	58%		OK
% Min hog reinforcement 2 (>= 0.0024bh G250; >= 0.0013bh G460)	0.22	%	
% Min hog reinforcement 2 utilisation	58%		OK
% Min hog reinforcement 3 (>= 0.0024bh G250; >= 0.0013bh G460)	0.22	%	
% Min hog reinforcement 3 utilisation	58%		OK
% Min hog reinforcement 4 (>= 0.0024bh G250; >= 0.0013bh G460)	0.22	%	
% Min hog reinforcement 4 utilisation	58%		OK

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Slab Shear Design for Bending in x

Ultimate shear stress for bending in x, $v_{ult,x}=v_{sx}/bd_{x,h}$ (< $0.8f_{cu}^{0.5}$ & $5N/mm^2$)	**0.12**	N/mm^2	
Ultimate shear stress for bending in x utilisation	**3%**		**OK**
Design shear stress for bending in x, $v_{d,x}=v_{sx}/bd_{x,h}$	**0.12**	N/mm^2	
(Conservatively, shear capacity enhancement by ***either*** *calculating v_d at d from support and comparing against unenhanced v_c as clause 3.4.5.10 BS8110* ***or*** *calculating v_d at support and comparing against enhanced v_c within 2d of the support as clause 3.4.5.8 BS8110 ignored;)*			
Area of tensile steel reinforcement provided, $A_{s,prov,x,h}$	393	mm^2/m	
$\rho_w = 100A_{s,prov,x,h}/bd_{x,h}$	0.28	%	
$v_{c,x} = (0.79/1.25)(\rho_w f_{cu}/25)^{1/3}(400/d_{x,h})^{1/4}$; $\rho_w<3$; $f_{cu}<40$; $(400/d_{x,h})^{1/4}>0.67$	**0.60**	N/mm^2	
Check $v_{d,x} < v_{c,x}$ for no links	**VALID**		
Concrete shear capacity $v_{c,x}.(bd_{x,h})$	**84**	kN/m	
Check $v_{c,x} < v_{d,x} < 0.4 + v_{c,x}$ for nominal links	**N/A**		
Provide nominal links such that A_{sv} / S > $0.4b/(0.95f_{yv})$ i.e. A_{sv} / S	**0.92**	$mm^2/mm/m$	
Concrete and nominal links shear capacity $(0.4 + v_{c,x}).(bd_{x,h})$	**140**	kN/m	
Check $v_{d,x} > 0.4 + v_{c,x}$ for design links	**N/A**		
Provide shear links A_{sv} / S > $b(v_{d,x}-v_{c,x})/(0.95f_{yv})$ i.e. A_{sv} / S >	**0.92**	$mm^2/mm/m$	
Concrete and design links shear capacity $(A_{sv,prov,x}/S_x).(0.95f_{yv}).d_{x,h}$	**84**	kN/m	
Area provided by all links per metre, $A_{sv,prov,x}$	0	mm^2/m	
Tried $A_{sv,prov,x}$ / S_x value	0.00	$mm^2/mm/m$	
Design shear resistance for bending in x utilisation	**20%**		**OK**

Slab Shear Design for Bending in y

Ultimate shear stress for bending in y, $v_{ult,y}=v_{sy}/bd_{y,h}$ (< $0.8f_{cu}^{0.5}$ & $5N/mm^2$)	**0.14**	N/mm^2	
Ultimate shear stress for bending in y utilisation	**3%**		**OK**
Design shear stress for bending in y, $v_{d,y}=v_{sy}/bd_{y,h}$	**0.14**	N/mm^2	
(Conservatively, shear capacity enhancement by ***either*** *calculating v_d at d from support and comparing against unenhanced v_c as clause 3.4.5.10 BS8110* ***or*** *calculating v_d at support and comparing against enhanced v_c within 2d of the support as clause 3.4.5.8 BS8110 ignored;)*			
Area of tensile steel reinforcement provided, $A_{s,prov,y,h}$	393	mm^2/m	
$\rho_w = 100A_{s,prov,y,h}/bd_{y,h}$	0.30	%	
$v_{c,y} = (0.79/1.25)(\rho_w f_{cu}/25)^{1/3}(400/d_{y,h})^{1/4}$; $\rho_w<3$; $f_{cu}<40$; $(400/d_{y,h})^{1/4}>0.67$	**0.63**	N/mm^2	
Check $v_{d,y} < v_{c,y}$ for no links	**VALID**		
Concrete shear capacity $v_{c,y}.(bd_{y,h})$	**82**	kN/m	
Check $v_{c,y} < v_{d,y} < 0.4 + v_{c,y}$ for nominal links	**N/A**		
Provide nominal links such that A_{sv} / S > $0.4b/(0.95f_{yv})$ i.e. A_{sv} / S	**0.92**	$mm^2/mm/m$	
Concrete and nominal links shear capacity $(0.4 + v_{c,y}).(bd_{y,h})$	**134**	kN/m	
Check $v_{d,y} > 0.4 + v_{c,y}$ for design links	**N/A**		
Provide shear links A_{sv} / S > $b(v_{d,y}-v_{c,y})/(0.95f_{yv})$ i.e. A_{sv} / S >	**0.92**	$mm^2/mm/m$	
Concrete and design links shear capacity $(A_{sv,prov,y}/S_y).(0.95f_{yv}).d_{y,h}$	**82**	kN/m	
Area provided by all links per metre, $A_{sv,prov,y}$	0	mm^2/m	
Tried $A_{sv,prov,y}$ / S_y value	0.00	$mm^2/mm/m$	
Design shear resistance for bending in y utilisation	**22%**		**OK**

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Detailing Requirements

All detailing requirements met ?	OK		
Max sagging steel reinforcement pitch in x (<$3d_{x,s}$, <750mm)	200	mm	OK
Max sagging steel reinforcement pitch in y (<$3d_{y,s}$, <750mm)	200	mm	OK
Max hogging steel reinforcement pitch in x (<$3d_{x,h}$, <750mm)	200	mm	OK
Max hogging steel reinforcement pitch in y (<$3d_{y,h}$, <750mm)	200	mm	OK

Maximum pitch of bars: (Notation as for BS 8110)

	$\%A_s/bh$	Maximum Pitch (mm)
Main bars :	0.5 or less	300
	1.0 or more	150

Max sagging steel reinforcement pitch in x	200	mm	OK
Max sagging steel reinforcement pitch in y	200	mm	OK
Max hogging steel reinforcement pitch in x	200	mm	OK
Max hogging steel reinforcement pitch in y	200	mm	OK
Min sagging steel reinforcement pitch in x (>75mm+ϕ_{sx}, >100mm+ϕ_{sx} if T40)	200	mm	OK
Min sagging steel reinforcement pitch in y (>75mm+ϕ_{sy}, >100mm+ϕ_{sy} if T40)	200	mm	OK
Min hogging steel reinforcement pitch in x (>75mm+ϕ_{hx}, >100mm+ϕ_{hx} if T40)	200	mm	OK
Min hogging steel reinforcement pitch in y (>75mm+ϕ_{hy}, >100mm+ϕ_{hy} if T40)	200	mm	OK

Note an allowance has been made for laps in the min pitch by increasing the criteria by the bar diameter.

% Max sag reinforcement in x (<= 0.04bh)	0.22	%	OK
% Max sag reinforcement in y (<= 0.04bh)	0.22	%	OK
% Max hog reinforcement x (<= 0.04bh)	0.22	%	OK
% Max hog reinforcement y (<= 0.04bh)	0.22	%	OK
Sagging steel reinforcement diameter in x, ϕ_{sx} (>=6mm)	10	mm	OK
Sagging steel reinforcement diameter in y, ϕ_{sy} (>=6mm)	10	mm	OK
Hogging steel reinforcement diameter in x, ϕ_{hx} (>=6mm)	10	mm	OK
Hogging steel reinforcement diameter in y, ϕ_{hy} (>=6mm)	10	mm	OK

Deflection Criteria

Span in x

Span, x	5.000	m
Span, x / effective depth, $d_{x,s}$ ratio	**35.7**	
Basic span / effective depth ratio criteria (20 precast or single span; 23 edge;	23.0	
Multiplier $C_{1,\text{span more or less than 10m}}$ — Include	1.00	
Modification factor for tension C_2		
$m_x/bd_{x,s}^2$	0.73	N/mm^2
$f_s = \frac{2 f_y A_{s\ req}}{3 A_{s\ prov}} \times \frac{1}{\beta_b}$ (β_b=1.2 unless precast or single span)	160	N/mm^2
Modification $0.55 + \frac{(477 - f_s)}{120\left(0.9 + \frac{M}{bd^2}\right)} \le 2.0$	2.00	
Modified span / effective depth ratio criteria	**46.0**	
Deflection utilisation	**78%**	**OK**

Span in y

Note that the deflection check is performed only for the shorter direction.

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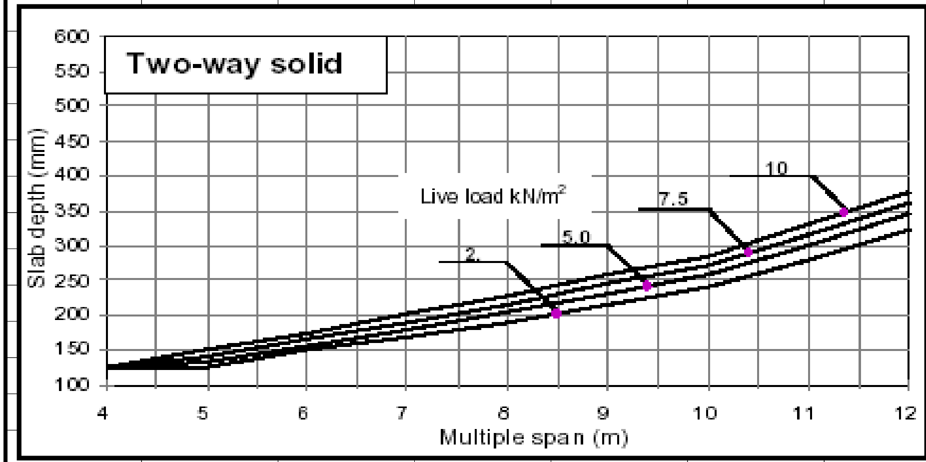
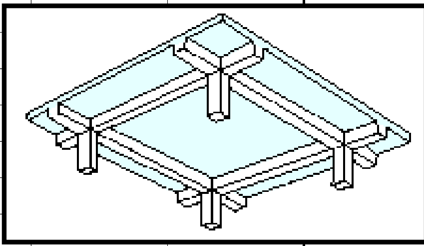
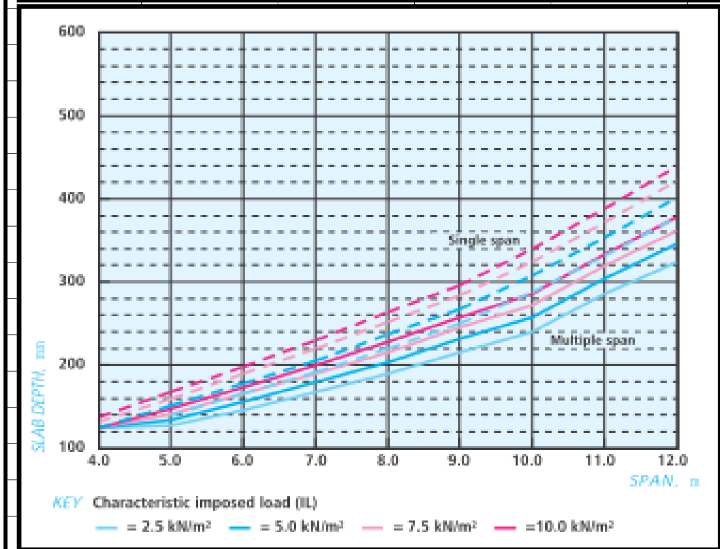
Scheme Design







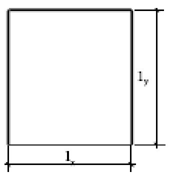
SLABS

Bending[3]

Simply supported on all sides:

$l_y > 1.5l_x$ then one-way spanning, else $M = \frac{W_x l_y}{24}$ kNm/m

Design for bending as for beams (in 2 directions)



Continuous one-way spanning:

Bending moments and shear forces for one-way slabs

	End support	End span	Penultimate support	Interior spans	Interior supports
Moment	0	0.086 Fl	-0.086 Fl	0.063 Fl	-0.063 Fl
Shear	0.4 F	-	0.6 F	-	0.5 F

Beam Section Input Description

A. Beam

	Depth	Width	Sag Section
Continuous	*slab + downstand*	b_w	*T - continuous*
Precast	*downstand*	b_w	*Rect - continuous*

B. Beam at Edge of Slab Span

	Depth	Width	Sag Section
Continuous	*slab + downstand*	b_w	*L - continuous*
Precast	*downstand*	b_w	*Rect - continuous*

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Typical Initial Span / Effective Depth Ratios

Table 3 Span/effective depth ratios for initial design of slabs

	One-way spanning			Two-way spanning		Flat slab
Imposed load kN/m²	simply supported	continuous	cantilever	simply supported	continuous	
5.0	23	30	11	30	39	28
10.0	21	27	10	27	35	25

Flat slab design should be based on the longer span dimension. For exterior panels, 85% of the ratios quoted in Table 3 should be used.

For ribbed slabs, 85% of the ratios quoted in Table 3 should be used.

Span-to-depth ratios for two-way spanning slabs

span is in the range 4 to 12 m.

Imposed load, Q_k (kN/m²)	1:1 panel		2:1 panel (based on shorter span)	
	Single span	Multiple span	Single span	Multiple span
2.5	34	39	30	34
5.0	32	37	28	32
7.5	30	35	26	30
10.0	28	34	25	29

Table 1:
Span/depth ratios for *insitu* concrete slabs *(from Reynolds's Reinforced Concrete Designer's Handbook)*

Slab type	5 kN/m² Imposed load	10 kN/m² Imposed load
Simply supported one-way	27	24
Simply supported two-way	30	27
Continuous one-way	34	30
Continuous two-way	44	40
Cantilever	11	10
Flat slab	30	27

Two Way Spanning Ribbed Slab (Waffle Slab)

*1. The two way spanning ribbed slab is beneficial for its **lighter weight** compared to the equivalent two way spanning solid slab;*

*2. The **dimensions** of the two way spanning ribbed slab is as per the one way spanning ribbed slab;*

*3. The **design** of the two way spanning ribbed slab is as per the one way spanning ribbed slab with design moment and shear coefficients as per the two way spanning solid slab;*

*4. The **minimum steel reinforcement** is as per the one way spanning ribbed slab;*