Design of slab

Trial depth:

As a starting point the depth of the slab will be set as 200 mm.

General AS3600:2018 Cl 9.4.1

The deflection of a slab shall be determined in accordance with Clause 9.4.2 or Clause 9.4.3.

Alternatively, for reinforced slabs, the effective span-to-depth ratio of the slab shall conform with Clause 9.4.4.

For a slab containing steel fibers in addition to conventional reinforcement or tendons, the deflection shall be determined in accordace with Clause 16.4.7.3.

Live load is greater than dead load, therefore Clause 9.4.4 deemed to comply deflection check is not applicable, use Clause 9.4.3.

Slab deflection by simplified calculation AS3600:2018 Cl 9.4.3

The deflection of a slab subject to uniformly distributed loads shall be calcualted in accordance with Clause 8.5.3 on the basis of an equivalent beam taken as follows:

(a) For a one-way slab, a prismatic beam of unit width.

(b) For a rectangular slab supported on four sides, a prismatic beam of unit width through the centre of the slab, spanning in the short direction L_x, with the same conditions of continuity as the slab in that direction and with the load distributedso that the proportion of load carried by the beam is given by:

$$L_y^4/(\alpha L_x^4 + L_y^4)$$

where α is given in Table 9.4.3 for the appropriate slab-edge condition.

(c) For a two-way flat slab having multiple spans (for deflections on the column lines or midway between the supports), the column strips of the idealised frame described in Clause 6.9.

Table 9.4.3

	Edge condition	Coefficient (α)
1	Four edges continuous	1
2	One short edge discontinuous	0.5
3	One long edge discontinuous	2
4	Two short edges discontinuous	0.2
5	Two long edges discontinuous	5
6	Two adjacent edges discontinuous	1
7	Three edges discontinuous (one long edge continuous)	0.4
8	Three edges discontinuous (one short edge continuous)	2.5
9	Four edges discontinuous	1

Calculations

Lx = 2300mm

Ly = 2300mm

G = 16 KPa
Q = 5 KPa

$(1.0 + k_{cs})G + (\psi_s + k_{cs}\psi_l)Q$ =26.7 KN/m

For case 1

$\alpha = 1.0$

$L_y^4/(\alpha L_x^4 + L_y^4)$ =0.5

Load on unit width beam = 9.75KN/m

For case 2

$\alpha = 0.5$

$L_y^4/(\alpha L_x^4 + L_y^4)$ =0.67

Load on unit width beam = 13.0KN/m

For case 3

$\alpha = 2.0$

$L_y^4/(\alpha L_x^4 + L_y^4)$ =0.33

Load on unit width beam = 6.5KN/m

For case 4

$\alpha = 0.2$

$L_y^4/(\alpha L_x^4 + L_y^4)$ =0.83

Load on unit width beam = 16.25KN/m

For case 5

$\alpha = 5.0$

$L_y^4/(\alpha L_x^4 + L_y^4)$ =0.17

Load on unit width beam = 3.25KN/m

For case 6

$\alpha = 1.0$

$L_y^4/(\alpha L_x^4 + L_y^4)$ =0.5

Load on unit width beam = 9.75KN/m

For case 7

$\alpha = 0.4$

$L_y^4/(\alpha L_x^4 + L_y^4)$ =0.71

Load on unit width beam = 13.93KN/m

For case 8

$\alpha = 2.5$

$L_y^4/(\alpha L_x^4 + L_y^4)$ =0.29

Load on unit width beam = 5.57KN/m

For case 9

$\alpha = 1.0$

$L_y^4/(\alpha L_x^4 + L_y^4)$ =0.5

Load on unit width beam = 9.75KN/m

Beam deflection by simplified calculation AS3600:2018 Cl 8.5.3

Short-term deflection AS3600:2018 Cl 8.5.3.1

The short-term deflection due to external loads and prestressing, which occur immediately on their application, shall be calculated using the value of E_{cj} determined in accordance with Clause 3.1.2 and the value of the effective second moment of area of the member (I_{ef}).This value of I_{ef} shall be determined by rational calculation. Alternatively, I_{ef} may be determined at the nominated cross-sections as follows:

(a) For a simply suppported span, the value at midspan.

(b) In a continuous beam:

(i) for an interior span, half the midspanvalue plus one quarter of each support value; or

(ii) for an end span, half the midspan value plus half the value at the continuous support.

(c) For a cantilever, the value at the support.

For the purposes of the above determinations, the value of I_{ef} at each of the cross-sections nominated in Items (a) to (c) above is given by:

$I_{ef} = \frac{I_{cr}}{1-\left(1-\frac{I_{cr}}{I}\right)\left(\frac{M_{cr.t}}{M_s^*}\right)^2} \leq I_{ef.max}$

where

I$_{ef.max}$ = maximum effective second moment of area and is taken as I, for reinforced sections when $p = A_{st}/bd \geq 0.005$ for prestressed sections

$= 0.6I$, for reinforced sections when $p = A_{st}/bd < 0.005$

b $= m$ width of the cross-section at the compression face

M_s^* = maximum bending moment at the section, based on the short-term serviceability load or the construction load

$M_{cr.t} = Z(f'_{ct.f} - \sigma_{cs} + P/A_g) + Pe \geq 0$

Z = section modulus of the uncracked section, referred to the extreme fibre at which cracking occurs

$f'_{ct.f}$ = characteristic flexural tensile strength of concrete

σ_{cs} = maximum shrinkage-induced tensile stress on the uncracked section at the extreme fibre at which cracking occurs. In the absence of more refined calculation, the value of σ_{cs} that accounts for the restraint provided by the steel reinforcement may be taken as:

$= \frac{2.5p_w - 0.8p_{cw}}{1+50P_w} E_s \varepsilon_{cs}$

Long-term deflection AS3600:2018 Cl 8.5.3.2

For reinforced and prestressed beams, that part of the deflection that occurs after the short term deflection shall be calcualted as the sum of:

(a) the shrinkage component of the long term deflection, determined from the design shrinkage strain of concrete (ε_{cs}) (see Clause 3.1.7) and the principles of mechanics; and

(b) the additional long-term creep deflections, determined from the design creep coefficient of concrete(φ_{cc}) (see Clause 3.1.8) and the principles of mechanics.

In the absence of more accurate calculations, the additional long-term deflection of a reinforced beam due to creep and shrinkage may be estimated by multiplying the short term-term deflection caused by the sustained loads (obtained using the final long-term shrinkage strain in the estimate of $M_{cr.t}$) by a multiplier, K_{cs}, given by:

$k_{cs} = [2 - 1.2(A_{sc}/A_{st})] \geq 0.8$

where A_{sc} is the area of steel in the compressive zone of the cracked section between the neutral axis at service loads and the extreme concrete compressive fiber and A_{sc}/A_{st} is taken at midspan, for a simply supported or continuous beam and at the support, for a cantilever beam.Long term deflection:

$\Delta_{total} = \Delta_s + k_{cs}\Delta_{s.sus}$

where

$\Delta s = \frac{L_{ox}^2}{96E_c I_{ef.av}}(M_{L.s} + 10M_{M.s} + M_{R.s})$

$\Delta_{s.sus} = \frac{w_{long}}{w_{short}}\Delta_s$

Calculations

Cases to check: [1, 2, 3, 4, 5, 6, 7, 8, 9]

Try SL92 mesh top and bottom

Assume reinforcement is uniform across slab.

The value of dn is28.971917758417224

Slab Properties

Concrete cover	=	70	mm
Total slab depth	=	200	mm
Equivalent area of steel A_{st}	=	2000	mm^2
Breadth, b	=	1000	mm
Depth to centroid of tension reinforcement, d	=	85	mm
Depth to the neutral axis, c	=	29	mm
Cracked second moment of area, I_{cr}	=	55134477	mm^4
Gross second moment of area, I_g	=	666666667	mm^4
Concrete flexural strength, $f'_{ct.f}$	=	3.0	MPa
Concrete modulus of elasticity, E_c	=	26700.0	MPa
Steel modulus of elasticity, E_s	=	200000	MPa

For case 1

At the left support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,L}$ = 5 KNm
$I_{ef,L}$ = 100036892 mm^4

At the midpoint support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,M}$ = 1 KNm
$I_{ef,M}$ = 666666667 mm^4

At the right support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,R}$ = 5 KNm
$I_{ef,R}$ = 100036892 mm^4

Span Lx is continuous, therefore I_{ef} = half the midspan value plus one quarter of each support

$I_{ef} = 0.5I_{ef,M} + 0.25I_{ef,L} + 0.25I_{ef,R}$ =383351779 mm^4

Δ_s =0.014 mm

$w_{long} = G + \psi_l Q$ =18 KN/m
$w_{short} = G + \psi_s Q$ = 20 KN/m

$\Delta_{s.sus}$ = 0.01 mm

Δ_{total} = 0.03 mm

For case 2

At the left support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,L}$ = 7 KNm
$I_{ef,L}$ = 73756814 mm^4

At the midpoint support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,M}$ = 2 KNm
$I_{ef,M}$ = 666666667 mm^4

At the right support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,R}$ = 7 KNm
$I_{ef,R}$ = 73756814 mm^4

Span Lx is continuous, therefore I_{ef} = half the midspan value plus one quarter of each support

$I_{ef} = 0.5 I_{ef,M} + 0.25 I_{ef,L} + 0.25 I_{ef,R}$ =370211740 mm^4

Δ_s =0.019 mm

$w_{long} = G + \psi_l Q$ =18 KN/m
$w_{short} = G + \psi_s Q$ = 20 KN/m

$\Delta_{s.sus}$ = 0.01 mm

Δ_{total} = 0.04 mm

For case 3

At the left support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,L}$ = 3 KNm
$I_{ef,L}$ = 666666667 mm^4

At the midpoint support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,M}$ = 2 KNm
$I_{ef,M}$ = 666666667 mm^4

At the right support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,R}$ = 1 KNm
$I_{ef,R}$ = 666666667 mm^4

Span Lx is an edge span, therefore I_{ef} = half the midspan value plus half the value at the continuous support.

$I_{ef} = 0.5I_{ef,M} + 0.5I_{ef,L}$ =666666667 mm^4

Δ_s =0.049 mm

$w_{long} = G + \psi_l Q$ =18 KN/m
$w_{short} = G + \psi_s Q$ = 20 KN/m

$\Delta_{s.sus}$ = 0.02 mm

Δ_{total} = 0.08 mm

For case 4

At the left support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,L}$ = 9 KNm
$I_{ef,L}$ = 65760686 mm^4

At the midpoint support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,M}$ = 2 KNm
$I_{ef,M}$ = 666666667 mm^4

At the right support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,R}$ = 9 KNm
$I_{ef,R}$ = 65760686 mm^4

Span Lx is continuous, therefore I_{ef} = half the midspan value plus one quarter of each support

$I_{ef} = 0.5I_{ef,M} + 0.25I_{ef,L} + 0.25I_{ef,R}$ =366213676 mm^4

Δ_s =0.024 mm

$w_{long} = G + \psi_l Q$ =18 KN/m
$w_{short} = G + \psi_s Q$ = 20 KN/m

$\Delta_{s.sus}$ = 0.02 mm

Δ_{total} = 0.06 mm

For case 5

At the left support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,L}$ = 1 KNm
$I_{ef,L}$ = 666666667 mm^4

At the midpoint support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,M}$ = 2 KNm

$I_{ef,M}$ = 666666667 mm^4

At the right support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,R}$ = 1 KNm
$I_{ef,R}$ = 666666667 mm^4

Span Lx is simply supported, therefore I_{ef} = the value at midspan

$I_{ef} = I_{ef,M}$ =666666667 mm^4

Δ_s =0.063 mm

$w_{long} = G + \psi_l Q$ =18 KN/m
$w_{short} = G + \psi_s Q$ = 20 KN/m

$\Delta_{s.sus}$ = 0.01 mm

Δ_{total} = 0.08 mm

For case 6

At the left support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,L}$ = 5 KNm
$I_{ef,L}$ = 100036892 mm^4

At the midpoint support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,M}$ = 3 KNm
$I_{ef,M}$ = 666666667 mm^4

At the right support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,R}$ = 2 KNm
$I_{ef,R}$ = 666666667 mm^4

Span Lx is an edge span, therefore I_{ef} = half the midspan value plus half the value at the continuous support.

$I_{ef} = 0.5I_{ef,M} + 0.5I_{ef,L}$ =383351779 mm^4

Δ_s =0.129 mm

$w_{long} = G + \psi_l Q$ =18 KN/m
$w_{short} = G + \psi_s Q$ = 20 KN/m

$\Delta_{s.sus}$ = 0.06 mm

Δ_{total} = 0.25 mm

For case 7

At the left support:

$M_{ct.t} = 4$ KNm
$M^*_{s,L} = 7$ KNm
$I_{ef,L} = 70679853\ mm^4$

At the midpoint support:

$M_{ct.t} = 4$ KNm
$M^*_{s,M} = 4$ KNm
$I_{ef,M} = 145381726\ mm^4$

At the right support:

$M_{ct.t} = 4$ KNm
$M^*_{s,R} = 2$ KNm
$I_{ef,R} = 666666667\ mm^4$

Span Lx is an edge span, therefore I_{ef} = half the midspan value plus half the value at the continuous support.

$I_{ef} = 0.5I_{ef,M} + 0.5I_{ef,L}$ =108030789 mm^4

Δ_s =0.653 mm

$w_{long} = G + \psi_l Q$ =18 KN/m
$w_{short} = G + \psi_s Q$ = 20 KN/m

$\Delta_{s.sus}$ = 0.43 mm

Δ_{total} = 1.51 mm

For case 8

At the left support:

$M_{ct.t} = 4$ KNm
$M^*_{s,L} = 1$ KNm
$I_{ef,L} = 666666667\ mm^4$

At the midpoint support:

$M_{ct.t} = 4$ KNm
$M^*_{s,M} = 4$ KNm
$I_{ef,M} = 458547466\ mm^4$

At the right support:

$M_{ct.t} = 4$ KNm
$M^*_{s,R} = 1$ KNm
$I_{ef,R} = 666666667\ mm^4$

Span Lx is simply supported, therefore I_{ef} = the value at midspan

$I_{ef} = I_{ef,M}$ =458547466 mm^4

Δ_s =0.158 mm

$w_{long} = G + \psi_l Q$ =18 KN/m
$w_{short} = G + \psi_s Q$ = 20 KN/m

$\Delta_{s.sus}$ = 0.04 mm

Δ_{total} = 0.24 mm

For case 9

At the left support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,L}$ = 2 KNm
$I_{ef,L}$ = 666666667 mm^4

At the midpoint support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,M}$ = 6 KNm
$I_{ef,M}$ = 77356694 mm^4

At the right support:

$M_{ct.t}$ = 4 KNm
$M^*_{s,R}$ = 2 KNm
$I_{ef,R}$ = 666666667 mm^4

Span Lx is simply supported, therefore I_{ef} = the value at midspan

$I_{ef} = I_{ef,M}$ =77356694 mm^4

Δ_s =1.634 mm

$w_{long} = G + \psi_l Q$ =18 KN/m
$w_{short} = G + \psi_s Q$ = 20 KN/m

$\Delta_{s.sus}$ = 0.75 mm

Δ_{total} = 3.14 mm

Summary of deflections			
1	0.03	mm	OK
2	0.04	mm	OK
3	0.08	mm	OK
4	0.06	mm	OK
5	0.08	mm	OK
6	0.25	mm	OK
7	1.51	mm	OK
8	0.24	mm	OK
9	3.14	mm	OK

Strength of Slabs in Bending AS3600:2018 Cl 9.1

General AS3600:2018 Cl 9.1.1

The strength of a slab in bending shall be determined in accordance with Clauses 8.1.1 to 8.1.8, except that for a two-way reinforced slabs, the minimum strength requirements of Clause 8.1.6.1 shall be determined to be satisfied by providing tensile reinforcement such that A_{st}/bd is not less than the following in each direction:

(a) Slabs supported by columns at their corners $0.24(D/d)^2 f'_{ct.f}/f_{sy}$

(b) Slabs supported by beams or walls on four sides $0.19(D/d)^2 f'_{ct.f}/f_{sy}$

Strength of Beams in Bending AS3600:2018 Cl 8.1

Basis of strength calculations AS3600:2018 Cl 8.1.2

Rectangular stress block AS3600:2018 Cl 8.1.3

Calculations

Determine bending capacity of section (ϕM_n):

ϕM_n =42.6 KNm

Determine bending moment demands:

As reo is symmetrical top and bottom, ϕM_n applies to positive and negative bending
$M_x^* = \beta_x F_d L_x^2$

$M_y^* = \beta_y F_d L_x^2$

where F_d is the uniformly distributed design load per unit area factored for strength, and β_x and β_y are given in:

(i) Table 6.10.3.2(A) for slabs with Ductility Class N reinforcement as the main flexural reinforcement

(ii) Table 6.10.3.2(B) for slabs with Ductility Class N reinforcement or Ductility Class L mesh as the main flexural reinforcement, no moment redistribution can be accommodated at either the servicibility or strength limit states

The moments, so calcualted, shall apply over a central region of the slab equal to three quarters of L_x and L_y respectively. Outside of this region, the minimum requirement for strength shall be deemed to conform with the minimum strength requirement of Clause 9.1.1.

(b) The negative bending moments at a continuous edge shall be taken as:

(i) 1.33 times the midspan values in the direction considered, when they are taken from Table 6.10.3.2(A)

(ii) α_x or α_y times the midspan values in the direction considered when they are taken from Table 6.10.3.2(B)

0.1 Table 6.10.3.2(B)

0.2 Bending moment coefficients for rectangular slabs supported on four sides (ductility class N or ductility class L reinforcement)

| Edge condition | Short span coefficients (β_{x} and α_{x} | Long span coefficients (eta_y and $lpha_y$) for all values of

0.3 Calculations

For case 1.

$M_x^* = 3.0$ KNm

$M_y^* = 2.8$ KNm

$M_{x,negative}^* = 6.9$ KNm

$M_{y,negative}^* = 7.6$ KNm

For case 2.

$M_x^* = 3.8$ KNm

$M_y^* = 3.4$ KNm

$M_{x,negative}^* = 8.4$ KNm

$M_{y,negative}^* = 7.8$ KNm

For case 3.

$M_x^* = 3.4$ KNm

$M_y^* = 4.0$ KNm

$M_{x,negative}^* = 7.5$ KNm

$M_{y,negative}^* = 9.7$ KNm

For case 4.

$M_x^* = 4.5$ KNm

$M_y^* = 3.4$ KNm

$M_{x,negative}^* = 9.4$ KNm

$M_{y,negative}^* = 0.0$ KNm

For case 5.

$M_x^* = 3.4$ KNm

$M_y^* = 5.5$ KNm

$M_{x,negative}^* = 0.0$ KNm

$M_{y,negative}^* = 12.7$ KNm

For case 6.

$M_x^* = 4.4$ KNm

$M_y^* = 4.8$ KNm

$M_{x,negative}^* = 9.3$ KNm

$M_{y,negative}^* = 10.2$ KNm

For case 7.

$M_x^* = 5.5$ KNm

$M_y^* = 4.9$ KNm

$M_{x,negative}^* = 11.2$ KNm

$M_{y,negative}^* = 0.0$ KNm

For case 8.

$M_x^* = 4.7$ KNm

$M_y^* = 6.5$ KNm

$M_{x,negative}^* = 0.0$ KNm

$M_{y,negative}^* = 13.8$ KNm

For case 9.

$M_x^* = 6.2$ KNm

$M_y^* = 6.9$ KNm

$M_{x,negative}^* = 0.0$ KNm

$M_{y,negative}^* = 0.0$ KNm