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DESIGN OF SLABS : One-Way Slab

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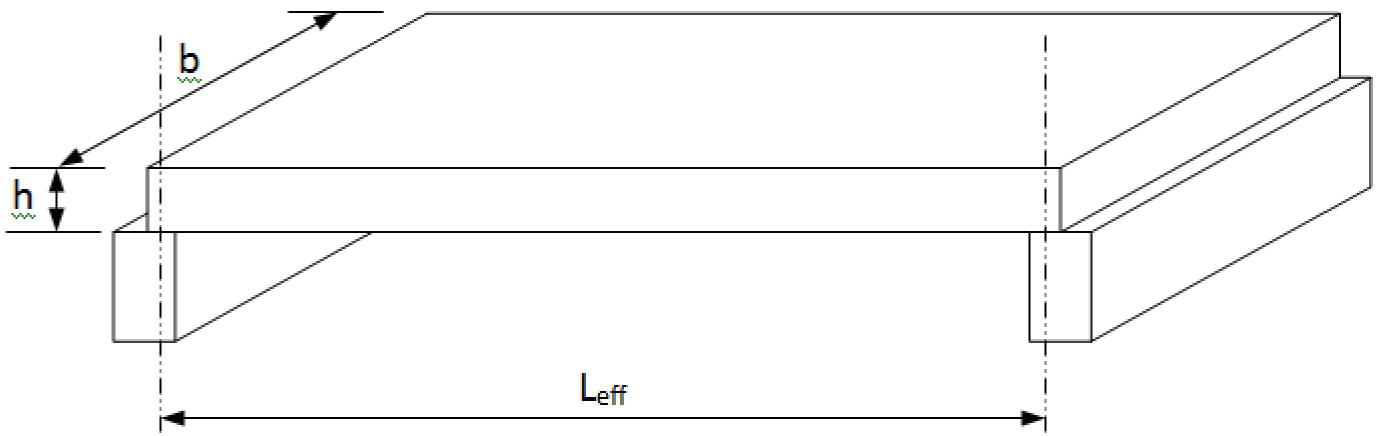
Design 1

Simply Supported One Way Slab

A rectangular reinforced concrete slab is simply supported on two masonry walls 250mm thick and 4.0m apart (clear distance). The slab has to carry a distributed permanent action of 1.0kN/m^2 (excluding slab self-weight) and a variable action of 3.0kN/m^2. The materials to be used are grade C30 concrete and grade 500 reinforcement. The slab is outside building which subjected to 1 hour fire resistance and design for 50 years design life. Design the slab.



1.0 SPECIFICATION

Effective span, L_{eff}	= 4.25m
Characteristic actions:	
Permanent, g_k	= 1.0kN/m^2 (excluding self-weight)
Variable, q_k	= 3.0kN/m^2
Design life	= 50 Years
Fire resistance	= R60
Exposure classes	= XC3
Materials:	
Characteristic strength of concrete, f_{ck}	= 30N/mm^2
Characteristic strength of steel, f_{yk}	= 500N/mm^2
Unit weight of reinforced concrete	= 25kN/m^3
Assumed: $Ø_{bar}$	= 12mm

Table 5.8: Minimum dimensions and axis distances for reinforced and prestressed concrete simply supported one-way and two-way solid slabs

Standard fire resistance	Minimum dimensions (mm)			
	slab thickness h_s (mm)	axis-distance *a*		
		one way	two way: $l_y/l_x \leq 1,5$	two way: $1,5 < l_y/l_x \leq 2$
1	2	3	4	5
REI 30	60	10*	10*	10*
REI 60	80	20	10*	15*
REI 90	100	30	15*	20
REI 120	120	40	20	25
REI 180	150	55	30	40
REI 240	175	65	40	50

l_x and l_y are the spans of a two-way slab (two directions at right angles) where l_y is the longer span.

For prestressed slabs the increase of axis distance according to 5.2(5) should be noted.

The axis distance *a* in Column 4 and 5 for two way slabs relate to slabs supported at all four edges. Otherwise, they should be treated as one-way spanning slab.

* Normally the cover required by EN 1992-1-1 will control.

2.0 SLAB THICKNESS

Min. thickness for fire resistance = 80mm

Estimated thickness for deflection control, h = L/26

= 163mm

Use, h = 175mm

Thickness ≈ L/20 – L/30
Around 125mm – 200mm

3.0 DURABILITY, FIRE AND BOND REQUIREMENTS

Min. concrete cover regard to bond, $C_{min,b}$ = 12mm
Min.concrete cover regard to durability, $C_{min,\ dur}$ = 20
Min. required axis distance for R60, a = 20mm

Min. concrete cover regard to fire
$C_{min,fire} = a - Ø_{bar}/2$ = 20-(12/2)
= 14mm

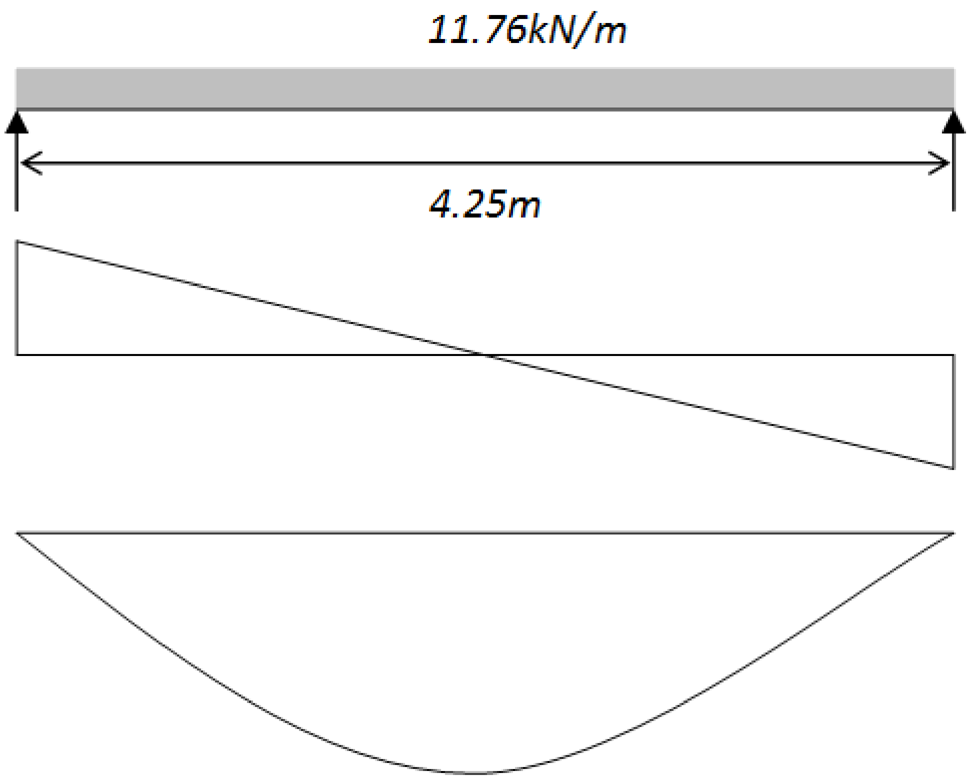
Allowance in design for deviation, ΔCdev = 10mm

Nominal cover,
$C_{nom} = C_{min} + \Delta C_{dev}$ = 20+10
= 30mm

$\therefore C_{nom}$=30mm

4.0 LOADING AND ANALYSIS

Slab self-weight	= 0.175x25
	= 4.38kN/m^2
Permanent load (excluding self-weight)	= 1.0kN/m^2
Characteristic permanent action, G_k	= 5.38kN/m^2
Characteristic variable action, Q_k	= 3.00kN/m^2
Design action, n_d	= $1.35G_k+1.5Q_k$
	= 1.35(5.38) + 1.5(3.00)
	= 11.76kN/m^2
Consider 1m width, $W_d = n_d x1m$	= 11.76kN/m



Shear Force,

$V = W_d L/2$

$= 25.0kN$

Bending Moment,

$M = W_d L^2/8$

$= 26.5kNm$

5.0 MAIN REINFORCEMENT

Effective depth:

$d = h - C_{nom} - Ø_{bar}/2$ $= 175-30-(12/2)$

$= 139mm$

Design bending moment, M_{Ed} $= 26.5kN/m$

$K = M_{Ed}/bd^2f_{ck}$ $= 26.5x10^6/(1000x139^2x30)$

$= 0.046 < K_{bal}=0.167$

∴ **Compression reinforcement is not required**

$z = d[0.5+\sqrt{0.25 - K/1.134}]$ $= 0.96d \geq 0.95d$

Use 0.95d

$A_s = M/0.87f_{yk}z$ $= 27\times10^6/(0.87\times500\times0.95\times139)$
$= 462mm^2/m$

Main bar: H12-225 ($503mm^2/m$)

Min. and max. reinforcement area,

$A_{s,min} = 0.26(f_{ctm}/f_{yk})bd$ $= 0.26\times(2.90/500)bd$
$= 0.0015bd > 0.0013bd$

Use 0.0015bd $= 0.0015\times1000\times139$
$= 209mm^2/m$

$A_{s,max} = 0.04A_c = 0.04bh$ $= 0.04\times1000\times175$
$= 7000mm^2/m$

Secondary bar: H12-450 ($251mm^2/m$)

$$\frac{A_{s,req}}{1000} = \frac{\pi D^2/4}{S}$$

$$A_{s,prov} = \frac{\left(\pi D^2/4\right)1000}{S_{prov}}$$

6.0 SHEAR REINFORCEMENT

Design shear force, V_{Ed} = 25.0kN

Design shear resistance,

$k = 1+(200/d)^{1/2} \leq 2.0$ $= 1+(200/139)^{1/2}$

$= 2.20 \geq 2.0$

$\rho^1 = A_{s1}/bd \leq 0.02$ $= 503/(1000x139)$

$= 0.0036 \leq 0.02$

$V_{Rd,c} = [0.12k(100\rho^1 f_{ck})^{1/3}]bd$ $= [0.12x2.0(100x0.0036x30)^{1/3}]x1000x139$

$= 73853N = 73.9kN$

$V_{min} = [0.35k^{3/2}f_{ck}^{1/2}]bd$ $= [0.0035x2.0^{3/2}x30^{1/2}]x1000x139$

$= 75368N = 75.4kN$

$V_{Rd,c}$; V_{min} > V_{Ed} (OK)

7.0 DEFLECTION

Percentage of required tension reinforcement,

$\rho = A_{s,req}/bd$ $= 462/(1000x139)$

$= 0.0033$

Reference reinforcement ratio,

$\rho_0 = (f_{ck})^{1/2} x10^{-3}$ $= (30)^{1/2} x10^{-3}$

$= 0.0055$

Percentage of required compression reinforcement

$\rho' = A_{s',req}/bd$ $= 0/(1000x139)$

$= 0.000$

Factor for structural system,

K = 1.0 $\rho < \rho_0$

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

= 1.0(11+13.5+9.13)
= 33.7

Modification factor for span less than 7m = 1.0

Modification factor for steel area provided
= $A_{s,prov}/A_{s,req}$
= 503/462
= 1.09 $<$ 1.5

Therefore allowable span-effective depth ratio
= $(l/d)_{allowable}$
= 33.7x1.0x1.09
= 36.63

Actual span-effective depth
= $(l/d)_{actual}$
= 4250/139
= 30.6 $<$ $(l/d)_{allowable}$ (OK)

8.0 CRACKING

$h = 175mm < 200mm$

Main bar,

$S_{max,slabs} = 3h$ or $400mm$ $= 525mm > 400mm$

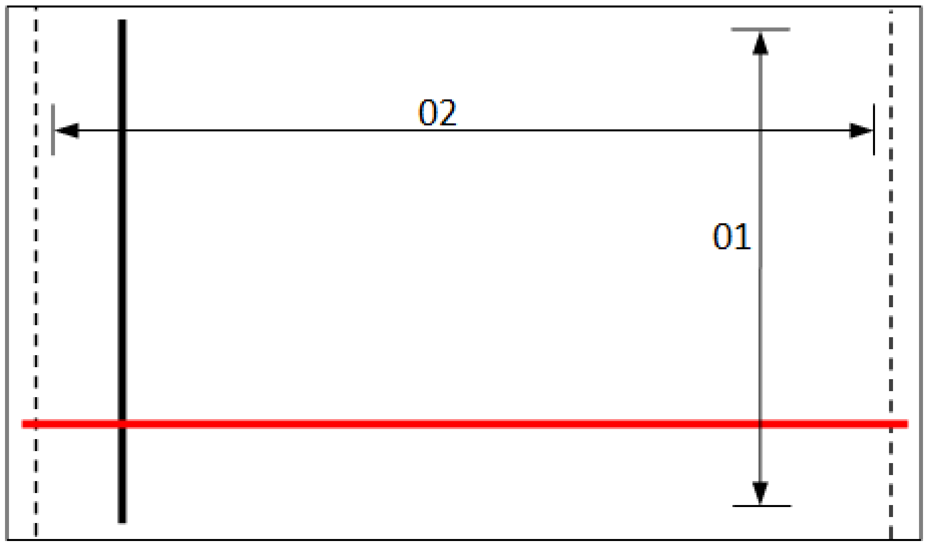
Max. bar spacing $= 225mm \leq S_{max,slab} = 400mm$ (OK)

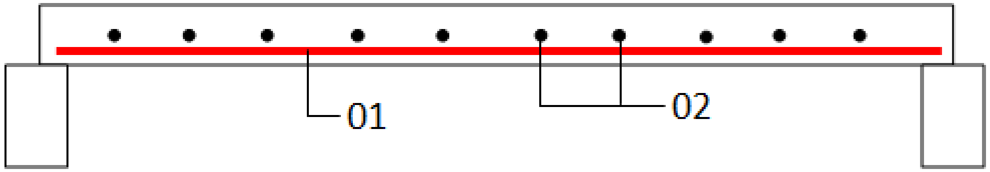
Secondary bar,

$S_{max,slabs} = 3.5h$ or $450mm$ $= 613mm > 450mm$

Max. bar spacing $= 450mm \leq S_{max,slab} = 450mm$ (OK)

9.0 DETAILING



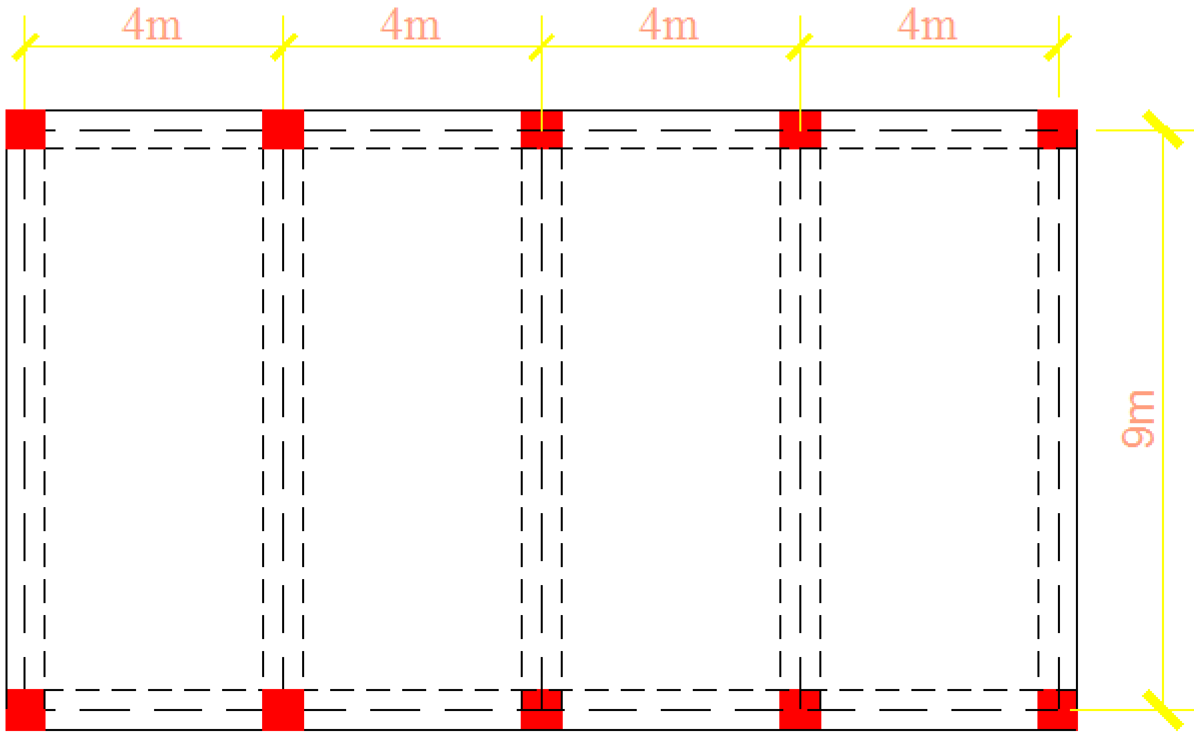


Reinforcement:
01: H12 – 225
02: H12 – 450

Design 2

Continuous One Way Slab

Design a continuous slab for a hall of internal dimension 24m x 9m. The slab is supported on beams of size 200mm x 450mm spaced at 4.0m centers as shown in the figure below. The variable action on slab may be taken as 3.5kN/m^2 and the permanent action consist of floor finish and services of 1.0kN/m^2. The materials to be used are grade C25 concrete and grade 500 reinforcement. The slab is inside buildings subjected to 1.5 hours fire resistance and 50 years design life.



1.0 SPECIFICATION

Long span, L_y = 9000mm	
Short span, L_x = 4000mm	L_y/L_x = 2.25 > 2.0 (One-way slab)
Effective length, L_{eff}	= 4000mm
Characteristic actions:	
Permanent, g_k	= 1.0kN/m^2 (excluding self-weight)
Variable, q_k	= 3.5kN/m^2
Design life	= 50 Years
Fire resistance	= R90
Exposure classes	= XC1
Materials:	
Characteristic strength of concrete, f_{ck}	= 25N/mm^2
Characteristic strength of steel, f_{yk}	= 500N/mm^2
Unit weight of reinforced concrete	= 25kN/m^3
Assumed: $Ø_{bar}$	= 10mm

2.0 SLAB THICKNESS

Min. thickness for fire resistance	= 100mm
Estimated thickness for deflection control, h	= L/30
	= 133mm

Use, h = 150mm

3.0 DURABILITY, FIRE AND BOND REQUIREMENTS

Min. concrete cover regard to bond, $C_{min,b}$ = 10mm

Min. concrete cover regard to durability, $C_{min,\ dur}$ = 15

Min. required axis distance for R90, a = 20mm

Min. concrete cover regard to fire

$C_{min,fire} = a - Ø_{bar}/2$ = 20-(10/2) (30mm for RE90)

= 15mm

Allowance in design for deviation, ΔC_{dev} = 10mm

Nominal cover,

$C_{nom} = C_{min} + \Delta C_{dev}$ = 15+10

= 25mm

$\therefore C_{nom} = 30mm$

4.0 LOADING AND ANALYSIS

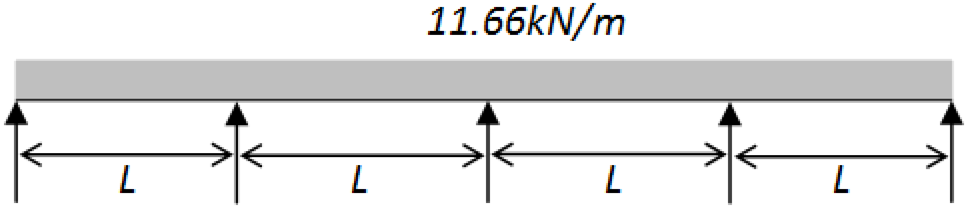
Slab self-weight	= 0.150x25
	= 3.75kN/m^2
Permanent load (excluding self-weight)	= 1.0kN/m^2
Characteristic permanent action, G_k	= 4.75kN/m^2
Characteristic variable action, Q_k	= 3.50kN/m^2
Design action, W_d	= $1.35G_k+1.5Q_k$
	= 1.35(4.75) + 1.5(3.50)
	= 11.66kN/m^2
Continuous one-way slab	
Area of bay	= 4x9x4
	= 144m^2 > 30m^2
Q_k/G_k	= 3.50/4.75
	= 0.74 < 1.25

$Q_k < 5.0kN/m^2$

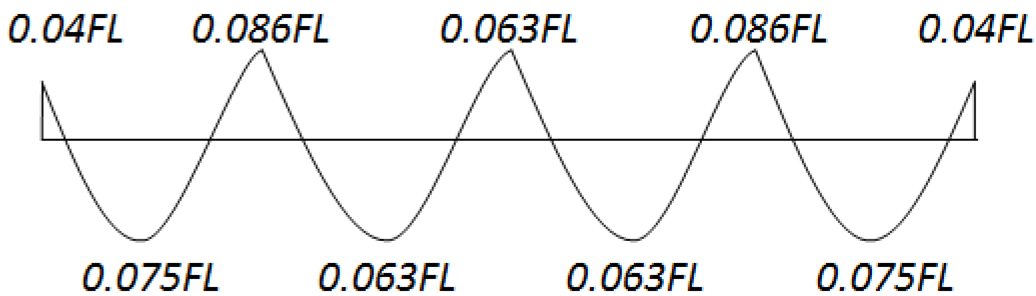
∴ use Table 3.14 BS8110: Part 1: 1997 to determine the bending moment and shear forces

Table 3.12 BS8110: 1997 (Ultimate moment and shear coefficients in continuous one way slab)

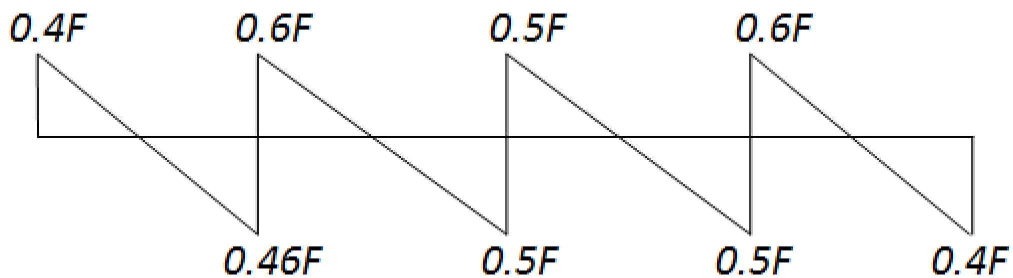
	End support condition						
	Pinned		Continuous				
	Outer support	Near middle of end span	End support	End span	At 1st interior support	At middle of interior span	At interior support
Moment	0	0.086FL	-0.04FL	0.075FL	0.086FL	0.063FL	0.063FL
Shear	0.4F	-	0.46F	-	0.6FL	-	0.5FL
L = effective span F = total ultimate load = $1.35G_k + 1.5Q_k$							



Moment:



Shear:



$F = W_d L_x = 11.7x4 = 46.7kN$

5.0 MAIN REINFORCEMENT

Effective depth:

$d = h - C_{nom} - Ø_{bar}/2$ $= 150-25-(10/2)$

$= 120mm$

<u>At first interior support</u>:

$M_{Ed} = 0.086FL$ $= 0.086x46.7x4.0$

$= 16kNm/m$

$K = M_{Ed}/bd^2f_{ck}$ $= 16x10^6/(1000x120^2x25)$

$= 0.0045 < K_{bal} = 0.167$

∴ Compression reinforcement is not required

$z = d[0.5+\sqrt{0.25 - K/1.134}]$ $= 0.96d \geq 0.95d$

$As = M/0.87f_{yk}z$ $= 16x10^6/(0.87x500x0.95x120)$

$= 324mm^2/m$

Use H10-255 (top)
($349mm^2/m$)

Near middle of end span:

$M_{Ed} = 0.075FL$ $= 0.075 x 46.7 x 4.0$

$= 14 kNm/m$

$As = M/0.87 f_{yk} z$ $= 14x10^6/(0.87x500x0.95x120)$

$= 282 mm^2/m$

Use H10-275 (bot)
($286 mm^2/m$)

At interior support and interior span:

$M_{Ed} = 0.063FL$ $= 0.063 x 46.7 x 4.0$

$= 11.8 kNm/m$

$As = M/0.87 f_{yk} z$ $= 11.8x10^6/(0.87x500x0.95x120)$

$= 237 mm^2/m$

Use H10-300 (bot)
($262 mm^2/m$)

At interior support and interior span:

$M_{Ed} = 0.04FL$ $= 0.04x46.7x4.0$

$= 7.5kNm/m$

$As = M/0.87f_{yk}z$ $= 7.5x10^6/(0.87x500x0.95x120)$

$= 151mm^2/m$

Use H10-400 (bot) ($196mm^2/m$)

Min. and max. reinforcement area,

$A_{s,min} = 0.26(f_{ctm}/f_{yk})bd$ $= 0.26x(2.56/500)bd$

Use 0.0013bd $= 0.0013bd > 0.0013bd$

$= 0.0013x1000x120$

$= 160mm^2/m$

$A_{s,max} = 0.04A_c = 0.04bh$ $= 0.04x1000x150$

$= 6000mm^2/m$

Secondary bar: H10-425 ($185mm^2/m$)

6.0 SHEAR

Max. design shear force, V_{Ed} $= 0.6F$
$= 28.0kN$

Design shear resistance,
$k = 1+(200/d)^{1/2} \leq 2.0$ $= 1+(200/120)^{1/2}$
$= 2.29 \geq 2.0$

$\rho^1 = A_{s1}/bd \leq 0.02$ $= 286/(1000x120)$
$= 0.0024 \leq 0.02$

$V_{Rd,c} = [0.12k(100\rho^1 f_{ck})^{1/3}]bd$ $= [0.12x2.0(100x0.0024x25)^{1/3}]x1000x120$
$= 52190N = 52.2kN$

$V_{min} = [0.35k^{3/2} f_{ck}^{1/2}]bd$ $= [0.0035x2.0^{3/2}x25^{1/2}]x1000x120$
$= 59397N = 59.4kN$

$V_{Rd,c}$; $V_{min} > V_{Ed}$ (OK)

7.0 DEFLECTION

Percentage of required tension reinforcement,

$\rho = A_{s,req}/bd$ = 282/(1000x120)

= 0.0024

Reference reinforcement ratio,

$\rho_0 = (f_{yk})^{1/2} \times 10^{-3}$ = $(25)^{1/2} \times 10^{-3}$

= 0.0050

Percentage of required compression reinforcement = 0/(1000x139)

$\rho' = A_{s',req}/bd$ = 0.000

Factor for structural system,

K = 1.3

$\rho < \rho_0$

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

= 1.3(11+15.9+19.12)
= 59.9

Modification factor for span less than 7m = 1.0

Modification factor for steel area provided = $A_{s,prov}/A_{s,req}$
= 286/282
= 1.01 $\leq$ 1.5

Therefore allowable span-effective depth ratio = $(l/d)_{allowable}$
= 59.5x1.0x1.01
= 60.61

Actual span-effective depth = $(l/d)_{actual}$
= 4000/120
= 33.3 $<$ $(l/d)_{allowable}$
(OK)

8.0 CRACKING

$h = 150mm < 200mm$

Main bar,

$S_{max,slabs} = 3h$ or $400mm$ $= 450mm > 400mm$

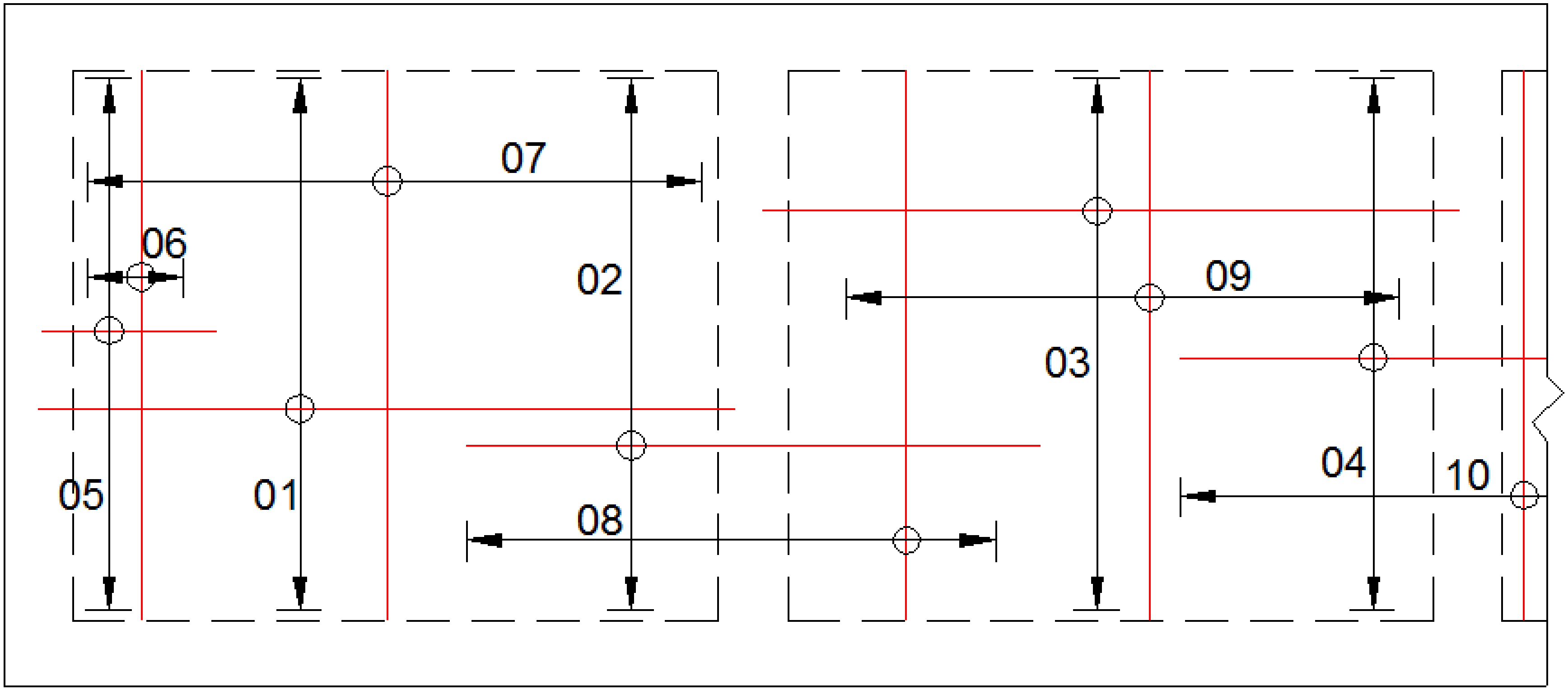
Max. bar spacing $= 400mm \leq S_{max,slab} = 450mm$ (OK)

Secondary bar,

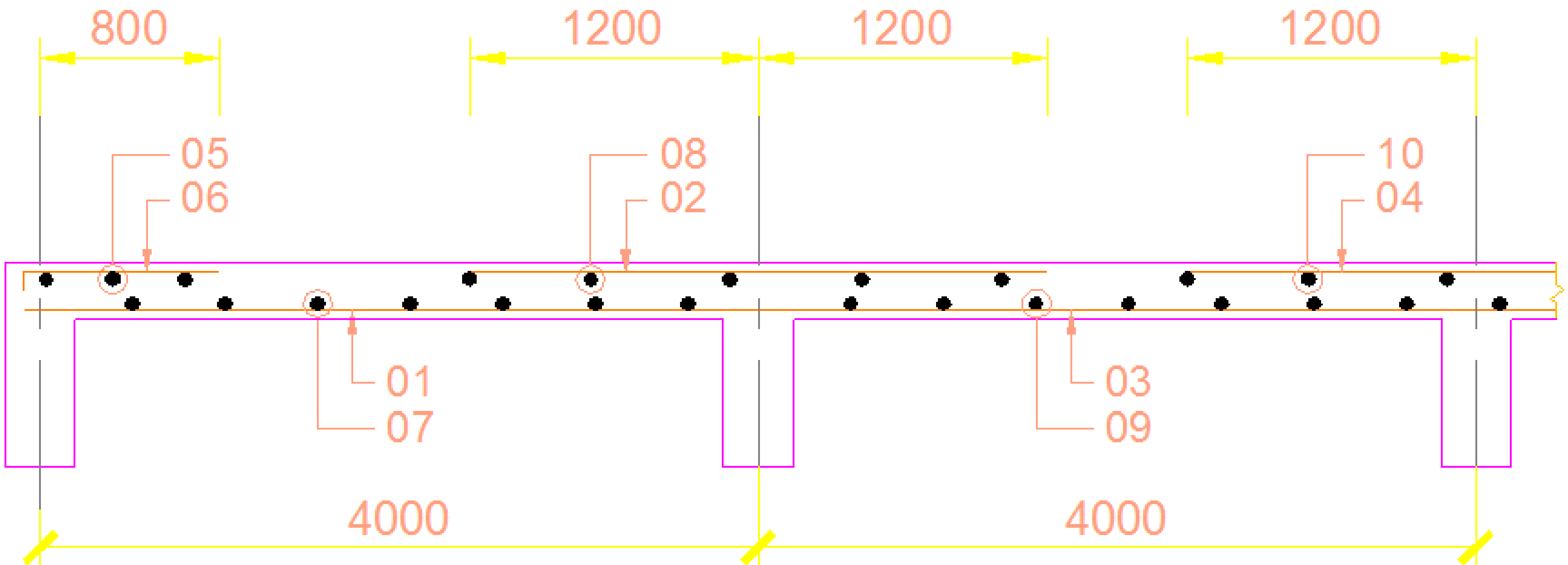
$S_{max,slabs} = 3.5h$ or $450mm$ $= 525mm > 450mm$

Max. bar spacing $= 425mm \leq S_{max,slab} = 450mm$ (OK)

9.0 DETAILING



PLAN



SECTION

Reinforcement:

01 : H10 – 275 (bot)
02 : H10 – 225 (top)
03 : H10 – 300 (bot)
04 : H10 – 300 (top)
05 : H10 – 400 (top)
06 : H10 – 425 (top)
07 : H10 – 425 (bot)
08 : H10 – 425 (top)
09: H10 – 425 (bot)
10 : H10 – 425 (top)