Structural design calculations Of bearing wall houses

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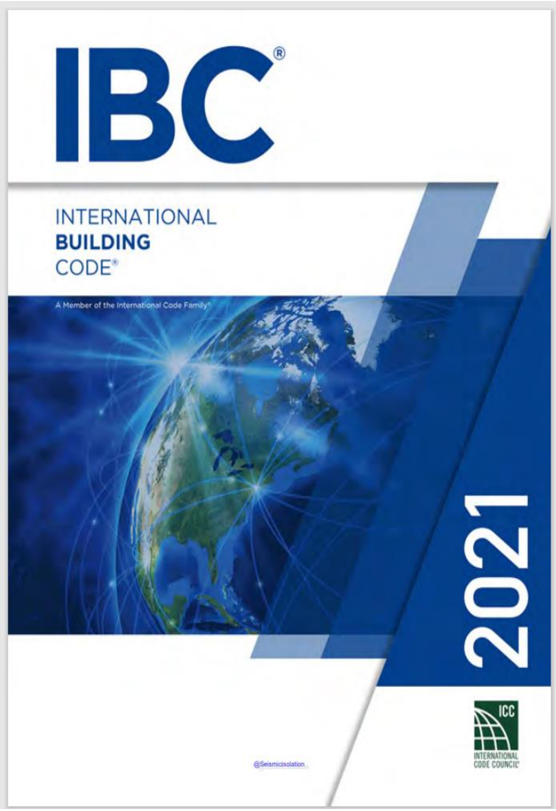
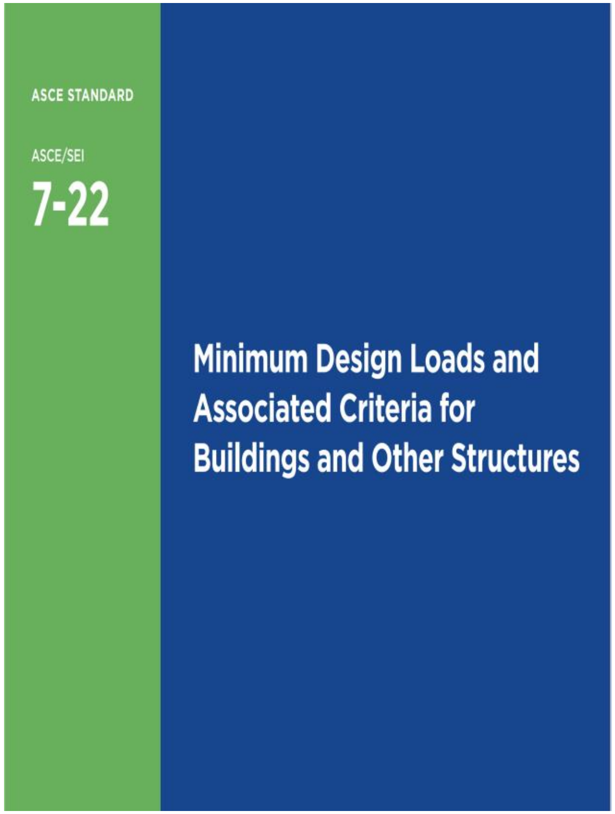
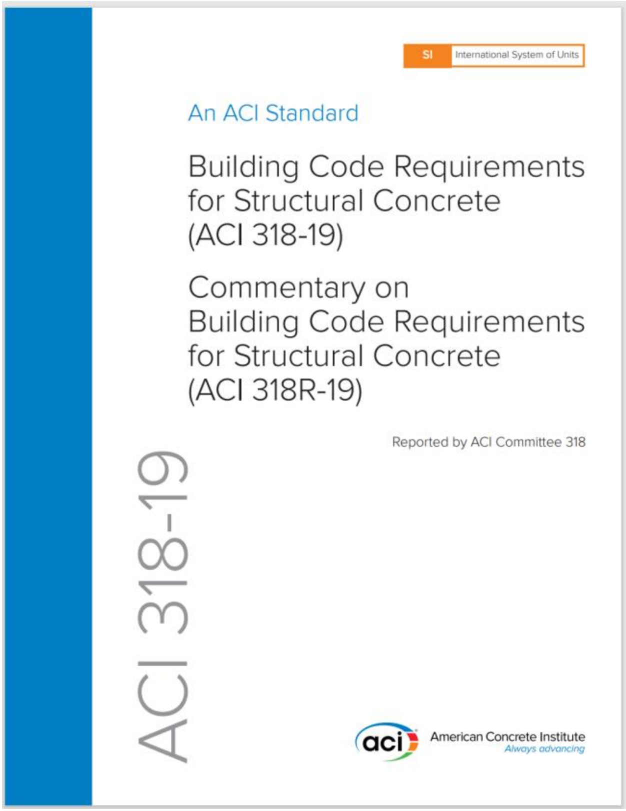
Required structural design data:

1. Architectural design drawings; Plan and sections.
2. Applied loads; see IBC chapter 16 or ASCE chapter 4 or ….
3. Material properties; concrete compressive strength, steel yield strength
4. Wall type and materials; thickness and unit weight.
5. Roof finishing materials and its function; without water proofing or using water proofing materials, ….
6. Ground and first floor finishing materials; ceramic tile or marble or other finishing material above layer of screed.
7. Type of false ceiling.
8. Type of interior and exterior wall finishing materials
9. Soil properties; bearing capacity, soil category,….

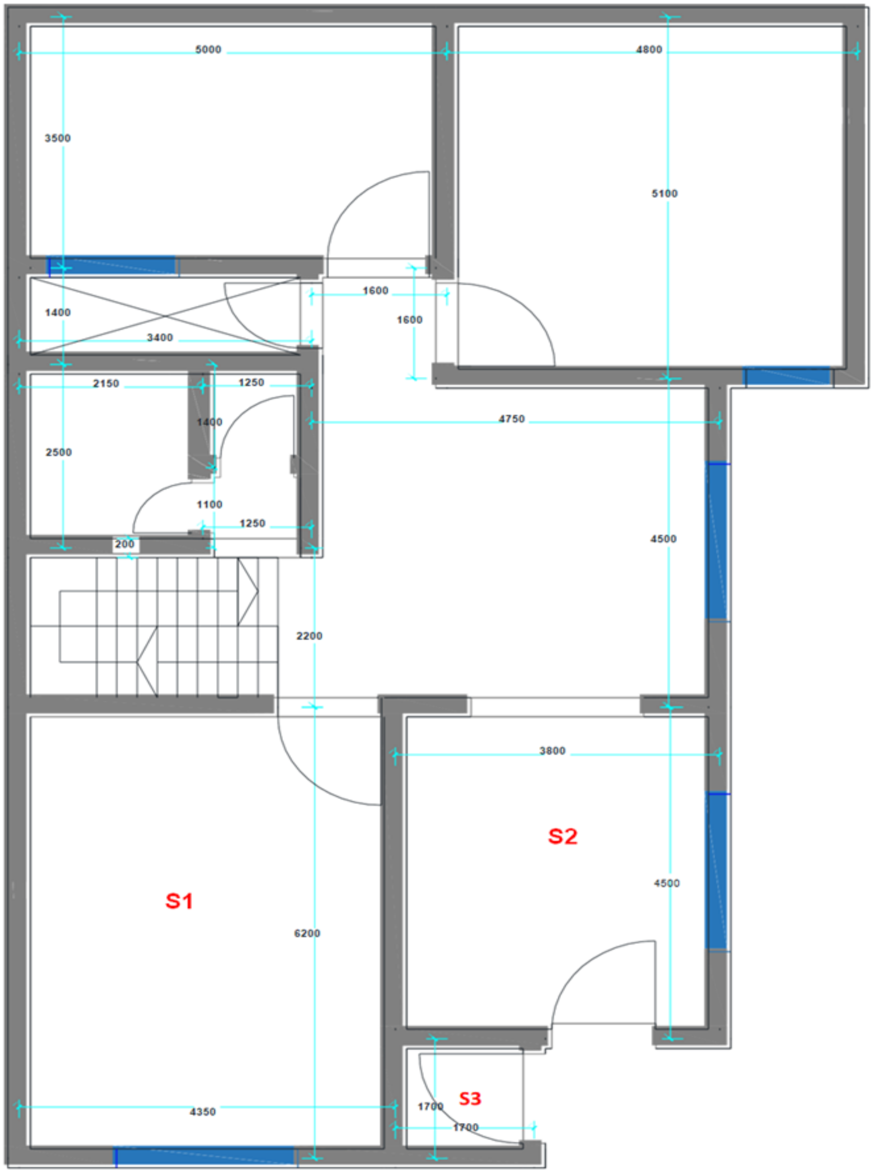
Codes of practice







Required to design of one story bearing wall house shown below according to ACI code and use 20cm normal concrete block walls.



Plan of the house

Structural design calculation (House)

1. Load calculations:

- Thickness of the slab (t) ;
- Maximum panel size 6200x4350mm (6.0x4.15m clear distance).
- The slab system is two-way slab.
- $t_{min.} = \frac{Ln}{30} = \frac{6000}{30}$ = 200mm=20cm , **(if considered slab without drop beams).**
- **If considered slab with drop beams :**

$$t_{slab(\min.)} = \frac{\ell_n (0.8 + \frac{f_y}{1400})}{36 + 9\beta} ;$$

$\ell_n(\ell_b)$= clear span in long direction

ℓ_b =clear slab span in long direction=6m; ℓ_a =clear slab span in short direction=4.15m ;

$\beta = \ell_b / \ell_a$ =6/4.15 = 1.446 ;

$$t_{slab(\min.)} = \frac{\ell_n (0.8 + \frac{f_y}{1400})}{36 + 9\beta}$$ → Use **t= 15cm** for all rooms.

a. Dead load :

- Weight of the slab=0.15*24=3.6 kN/m^2
- Weight of the plastering =0.3 kN/m^2
- Weight of roofing system=3 kN/m^2

  (Water proof + Isolated material + 7cm concrete + BRC)
- $W_{D.L}$=3.6+0.3+3=6.9 kN/m^2

Table 8.3.1.1—Minimum thickness of nonprestressed two-way slabs without interior beams (mm)[1]

	Without drop panels[3]			With drop panels[3]		
	Exterior panels			Exterior panels		
f_y, MPa[2]	Without edge beams	With edge beams[4]	Interior panels	Without edge beams	With edge beams[4]	Interior panels
280	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$	$\ell_n/36$	$\ell_n/40$	$\ell_n/40$
420	$\ell_n/30$	$\ell_n/33$	$\ell_n/33$	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$
550	$\ell_n/27$	$\ell_n/30$	$\ell_n/30$	$\ell_n/30$	$\ell_n/33$	$\ell_n/33$

[1]ℓ_n is the clear span in the long direction, measured face-to-face of supports (mm).

[2]For f_y between the values given in the table, minimum thickness shall be calculated by linear interpolation.

[3]Drop panels as given in 8.2.4.

[4]Slabs with beams between columns along exterior edges. Exterior panels shall be considered to be without edge beams if α_f is less than 0.8.

Table 8.3.1.2—Minimum thickness of nonprestressed two-way slabs with beams spanning between supports on all sides

α_{fm}[1]	Minimum h, mm		
$\alpha_{fm} \leq 0.2$	8.3.1.1 applies		(a)
$0.2 < \alpha_{fm} \leq 2.0$	Greater of:	$\dfrac{\ell_n\left(0.8+\dfrac{f_y}{1400}\right)}{36+5\beta(\alpha_{fm}-0.2)}$	(b)[1],[2]
		125	(c)
$\alpha_{fm} > 2.0$	Greater of:	$\dfrac{\ell_n\left(0.8+\dfrac{f_y}{1400}\right)}{36+9\beta}$	(d)
		90	(e)

[1]α_{fm} is the average value of α_f for all beams on edges of a panel.

[2]ℓ_n is the clear span in the long direction, measured face-to-face of beams (mm).

[3]β is the ratio of clear spans in long to short directions of slab.

b. Live load :

- Assume live load of about 2 kN/m^2

$W_u=1.2W_{D.L}+1.6W_{L.L}=1.2*6.9+1.6*2=11.5\ KN/m^2$ → Say $W_u=12\ KN/m^2$

2. Design of the slab by YLT: Using yield line theory to find negative and positive moments.

$\sum w\delta = 12*[0.5*4.35*2.175*\frac{\delta}{3}*2 + 0.5*2.175^2*\frac{\delta}{3}*4 + 1.85*2.175*\frac{\delta}{2}*2] \approx 124\,\delta$

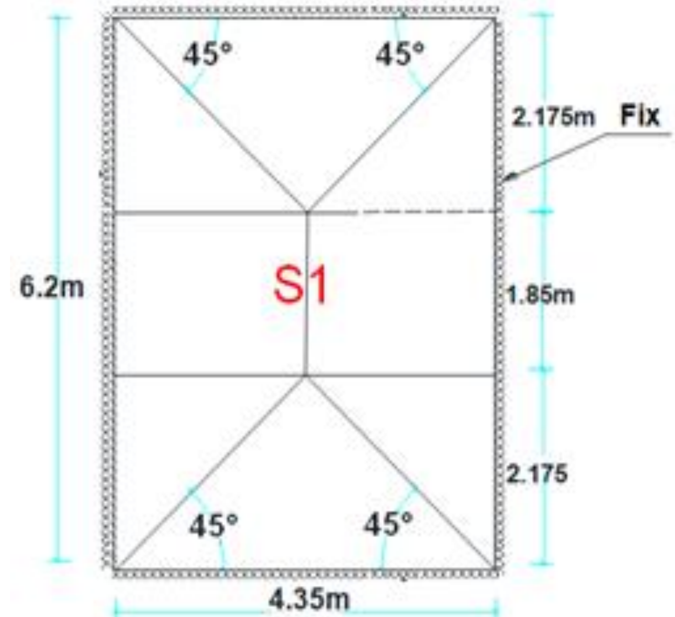
$\sum Mo=(mp+mn)*[4.35*\frac{\delta}{2.175} + 6.2*\frac{\delta}{2.175}]*2$

Assume (mn=2mp)

$\sum Mo = 29.1\ mp\ \delta$

$\sum w\delta = \sum Mo$ → $124\,\delta = 29.1\ mp\ \delta$ → mp=4.3 kN.m/m

mn=2 mp = 2*4.3=8.6 kN.m/m



Design for $m_{neg.}$=8.6 kN.m/m

fc'=21MPa , fy=420MPa (grade 60) , b=1m , t=150mm , Φ10mm ,

d=150-20- =125mm

$$R=\frac{m_{neg.}}{0.9bd^2}=\frac{8.6*10^6}{0.9*1000*125^2} = 0.612\text{MPa}$$

$$m=\frac{f_y}{0.85f'_c}=\frac{420}{0.85*21}=23.53$$

$$\rho=\frac{1}{m}(1-\sqrt{1-\frac{2mR}{f_y}}) = \frac{1}{23.53}(1-\sqrt{1-\frac{2*23.53*0.612}{420}}) = 0.00148 < \rho\min.=0.0018$$

use $\rho=\rho\min.=0.0018$

As $_{min.}$= ρ b t = 0.0018*1000*125=225mm²/m → Φ10mm@250mm c/c.

As $_{provided}$= $\frac{71}{250}*1000$ =284mm²/m > As $_{min.}$= 225 mm²/m ok

Spacing =250mm < Smax. =2 t = 2*150=300mm for two-way slabs. ok

Notes:

- This amount of steel reinforcement (Φ10mm@250mm c/c.) to be used in both directions (top & bottom) for all rooms.
- Since the $(\mathbf{m}_{neg.})_{Max.}$ give ($\rho_{min.}$), no need to calculate for positive moment and for other directions.

3. Design of drop beam:

The main purpose behind using drop beams to reduce slab thickness, reduce deflection and distribute the load to the walls.

Normally minimum steel reinforcement to be provide.

$\rho_{min} = \frac{1.4}{fy} = \frac{1.4}{420} = 0.00334$ **or** $\frac{\sqrt{fc'}}{4\,fy} = \frac{\sqrt{21}}{4 * 420} = 0.00273$ → choose max.(ρ_{min} =0.00334)

$As_{min.} = \rho_{min}\ b\ h = 0.00334*200*350 \approx 234mm^2$

Use : 2Φ16mm@top (cont.)

2Φ16mm@bottom (cont.)

$As_{provide} = 2*201 = 402mm^2 > As_{min.} = 234mm^2$ ok

Notes:

- When the unit(house) repeated, 2Φ12mm can be provided instead of 2Φ16mm
  $As = 2*113 = 226mm^2 \approx As_{min.} = 234mm^2$
- Stirrups, Φ10mm/200mm c/c **or** Φ8mm/200mm c/c can be used.

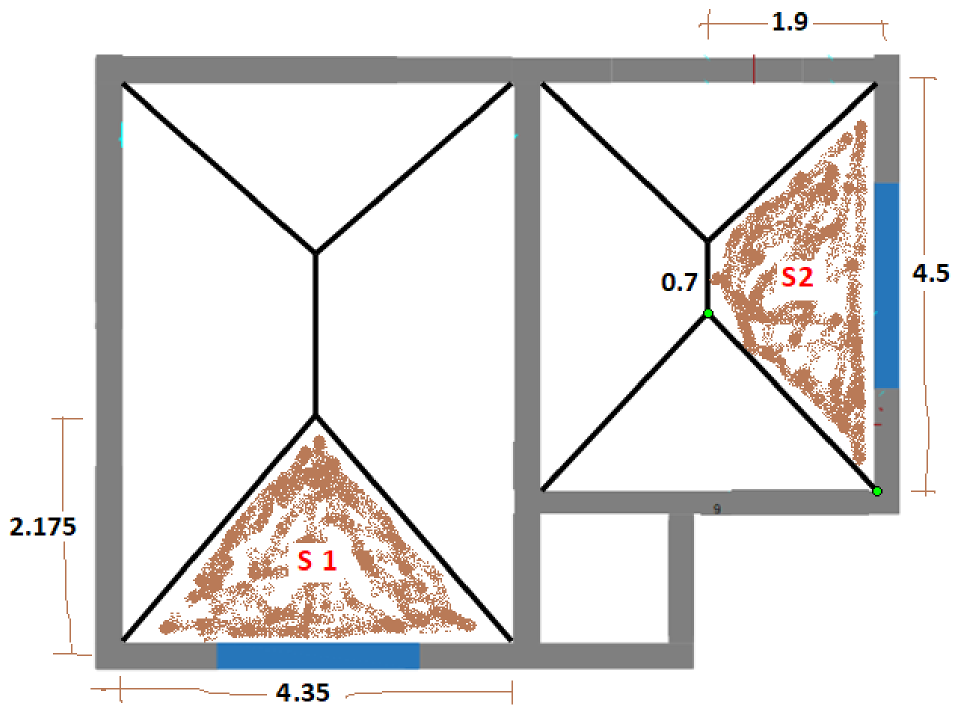
4. Design of tie beams above doors and windows:

For clear spans up to 2.5m

a. Weight above the tie beams≈(0.2*0.2*24*1.2)+(0.2*1.0*15*1.2)=**4.752**kN/m , say 5kN/m

b. 1. Load from S1 = [(0.5*2.175*4.35)*12]/4.35 =13.05 kN/m

2. Load from S2 =[(($\frac{0.7+4.5}{2}$)*1.9)*12]/4.5 =**13.2kN/m** Choose max. load from **S2**



c. Load from parapet: → Take:(height=1.4m , width=0.15m & γ=15kN/m^3)

=[(1.4*0.15)*15]*1.2 = **3.78** kN/m

Total loads = 13.2 + 3.78 + 4.752 = 21.732 kN/m

If considered (Ln≈2.5m) & simply supported.

$m_{pos.} = \frac{1}{8} Wu * Ln^2 = \frac{1}{8} * 21.732 * 2.5^2$ = 17 kN.m

b=200mm, h=200mm, Φ12mm, d=200 – 40 -10 - $\frac{12}{2}$ =144mm

$R = \frac{m_{pos.}}{0.9bd^2} = \frac{17*10^6}{0.9*200*144^2}$ =4.55MPa

$m = \frac{f_y}{0.85f'_c} = \frac{420}{0.85*21}$ =23.53

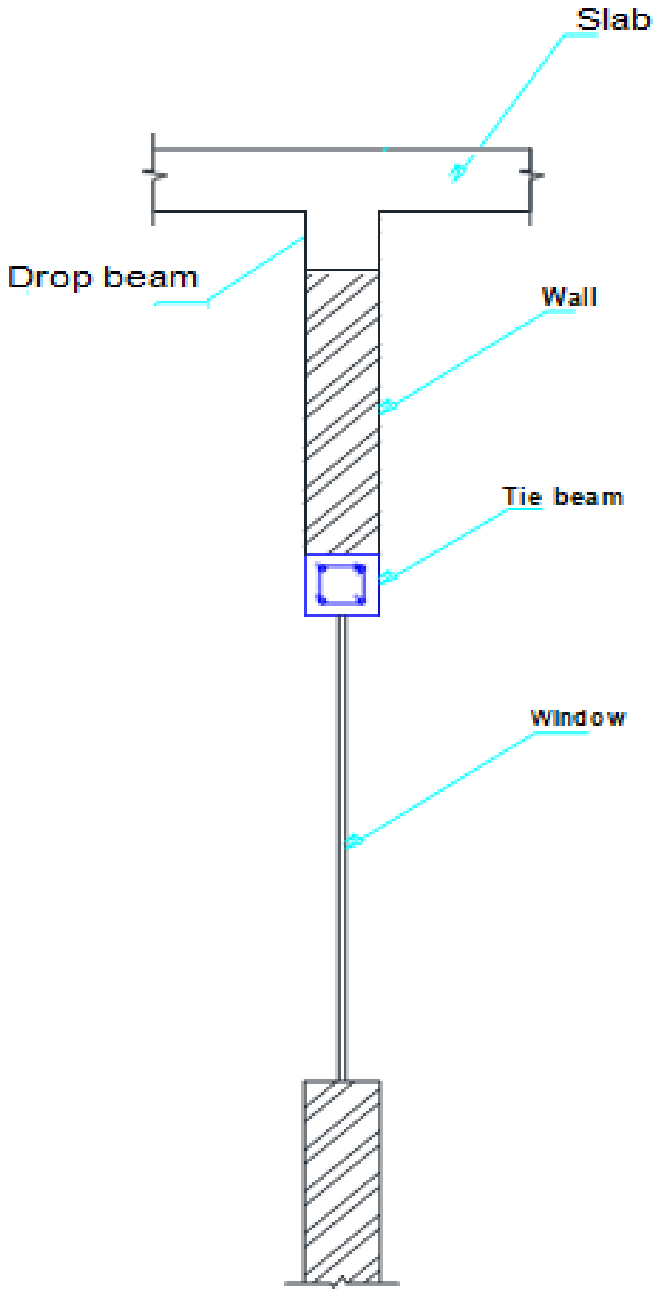
$\rho = \frac{1}{m}(1-\sqrt{1-\frac{2mR}{f_y}}) = \frac{1}{23.53}(1-\sqrt{1-\frac{2*23.53*4.55}{420}})$

$\rho =$ 0.01274 > $\rho \min. = 0.00334$

$As_{req.}$=0.01274*200*144=366.912mm^2

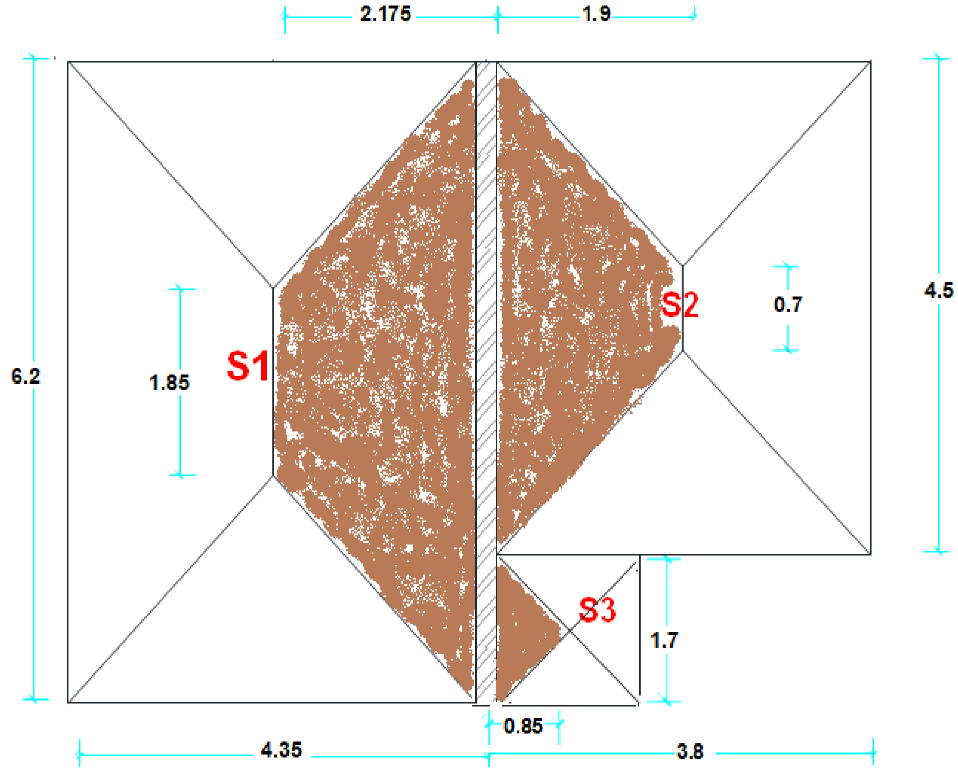
Use 2Φ16mm , As,provide =2*201=402 mm^2 > $As_{req..}$=366.912mm^2 ok

Stirrups: **Φ10mm@200mm c/c** **or** Φ8mm@200mm c/c .



5. Design of foundation:

Design an interior wall footing between S1 & (S2,S3) (most heavier wall).



Load from (**S1**)= $\frac{12*((\frac{1.85+6.2}{2})*2.175)}{6.2}$ =16.94 $\frac{kN}{m}$

Load from (**S2**)= $\frac{12*((\frac{0.7+4.5}{2})*1.9)}{4.5}$ =13.17 $\frac{kN}{m}$

Load from (**S3**)= $\frac{12(0.5*1.7*0.85)}{1.7}$ =5.1 $\frac{kN}{m}$

Load from Slabs = 16.94+13.17+5.1= 35.21 kN/m

Load from Slabs → Say 36 kN/m

Height of wall above DPC=3.5m & y=15kN/m^3

Load from wall above DPC = 0.2*3.5*15*1.2≈ 13 $\frac{kN}{m}$

Height of wall under DPC=1.0m , width of wall=0.4m & y=23kN/m^3

Load from wall under DPC = 0.4*1.0*23*1.2= 11 kN/m

For footing take (Width(B)=0.65m & thickness(t)=0.2m)

Footing Weight≈0.65*0.2*24*1.2 =4kN/m

Total loads = 36+13+11+4 = 64 kN/m

Unfactored load = 64/1.35 = 47.4 kN/m

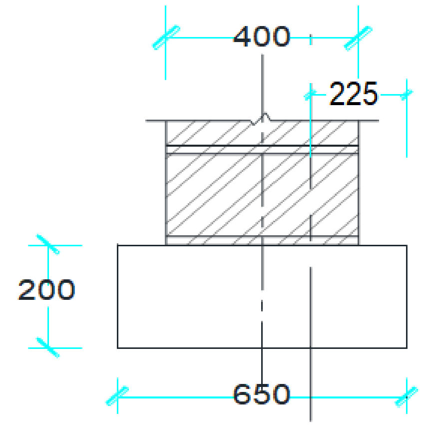
Assume bearing capacity, $q_{allowable}$=80kN/m^2 (or based on the soil investigation, to be provided by client)

Required width, B= 47.4/80 = 0.5925m → Use: B=0.65m

$q_{applied}$= 47.4/0.65 = 72.92 kN/m^2 < $q_{allowable}$=80 kN/m^2 ok

a. Design for bending, d=200-40-(12/2)=154mm

The critical section for maximum moment is located half away between the centerline and edge of the wall (i.e. @distance ((650/2)- (400/4)) = 225mm)



Considering (1m) long footing strip with (d=154mm).

Mu= $q_{applied} * (\frac{225}{2})^2\ 10^{-6}$ =0.923 kN.m

$$R = \frac{Mu}{0.9bd^2} = \frac{0.923*10^6}{0.9*1000*154^2} = 0.0432\text{MPa}$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85*21} = 23.53$$

$$\rho = \frac{1}{m}(1-\sqrt{1-\frac{2mR}{f_y}}) = \frac{1}{23.53}(1-\sqrt{1-\frac{2*23.53*0.0432}{420}}) = 0.0001031 < \rho\min. = 0.0018$$

Use (ρ = $\rho\min. = 0.0018$)

$As_{min.}$=0.0018*1000*200=360mm^2 → Use: **Φ12/250mm** **(Main reinforcement)**

Asprovide = $\frac{113}{250}$ * 1000 =452 mm^2 > $As_{min.}$=360mm^2 ok

Longitudinal reinforcement:

$As_{min.}$=0.00334*650*200= 434.2mm^2

Use: **4Φ12mm** **(secondary reinforcement)**

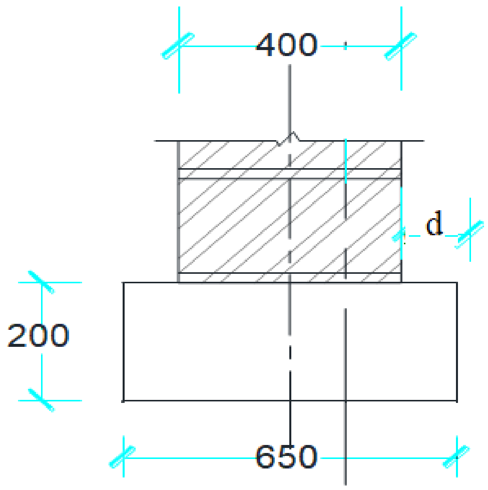
$As_{provided}$=4*113=452mm^2 > $As_{min.}$= 434.2mm^2 ok

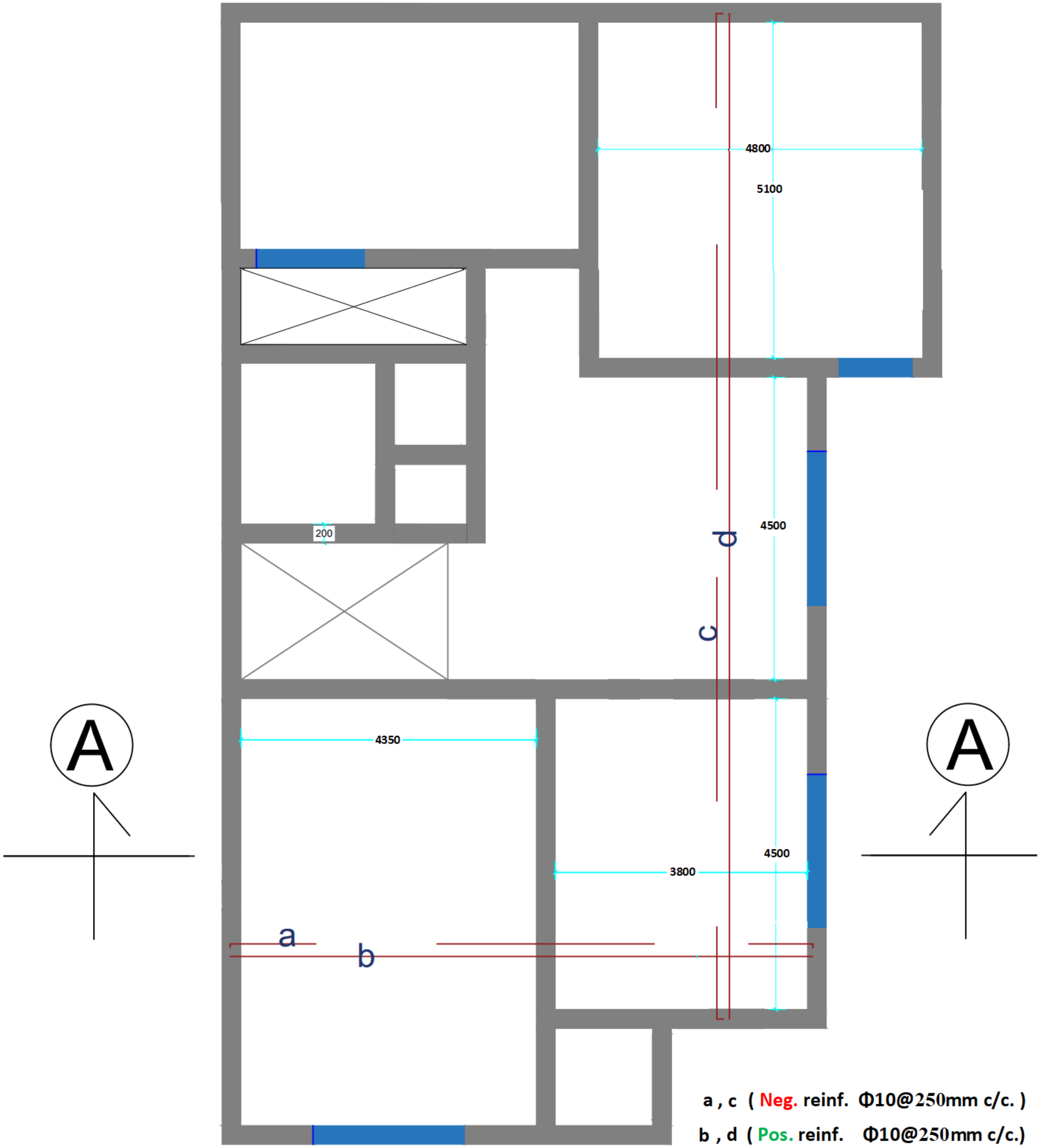
b. Design for shear

Critical section for shear is located @distance **d** away from the face of the wall.

$$V_u = q_{applied} * [(\frac{B-0.4}{2}) - d] = 72.92 * [(\frac{0.65-0.4}{2}) - 0.154] \approx -2.12 \text{ kN}$$

$$\Phi V_c = \frac{\Phi}{6} * \sqrt{fc'} * bd = \frac{0.75}{6} * \sqrt{21} * 650 * 0.154 \approx 57.34 \text{ kN} >> V_u \quad \text{ok.}$$

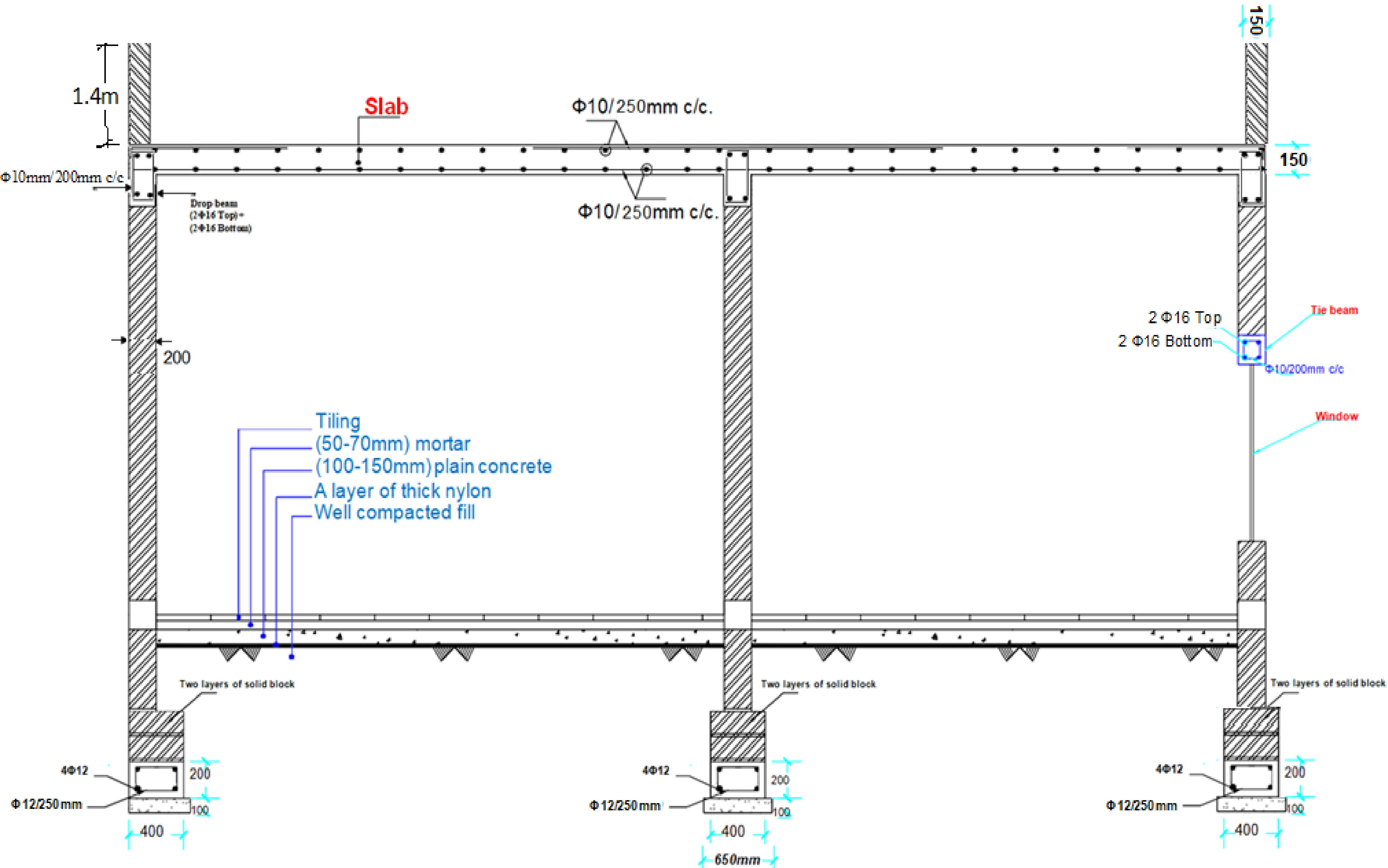




a , c (Neg. reinf. Φ10@250mm c/c.)

b , d (Pos. reinf. Φ10@250mm c/c.)

Slab reinf. details


150
1.4m
Slab
Φ10/250mm c/c.
150
Φ10mm/200mm c/c
Drop beam
(2Φ16 Top)+
(2Φ16 Bottom)
Φ10/250mm c/c.
200
2 Φ16 Top
2 Φ16 Bottom
Tie beam
Φ10/200mm c/c
Window
Tiling
(50-70mm) mortar
(100-150mm) plain concrete
A layer of thick nylon
Well compacted fill
Two layers of solid block
Two layers of solid block
Two layers of solid block
4Φ12
200
Φ12/250mm
100
400
4Φ12
200
Φ12/250mm
100
400
650mm
4Φ12
200
Φ12/250mm
100
400

Sec. A-A