Staircase

STAIR CASE

- **Definition**

- Stair cases are used for the purpose of giving access to different floors of a structure.

Parts of stair a case

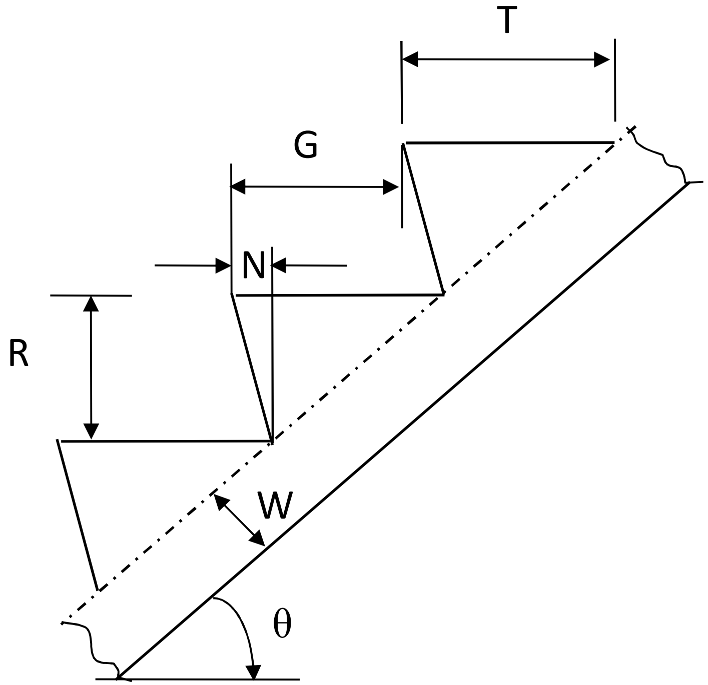


FIG.1 PARTS OF STAIR CASE

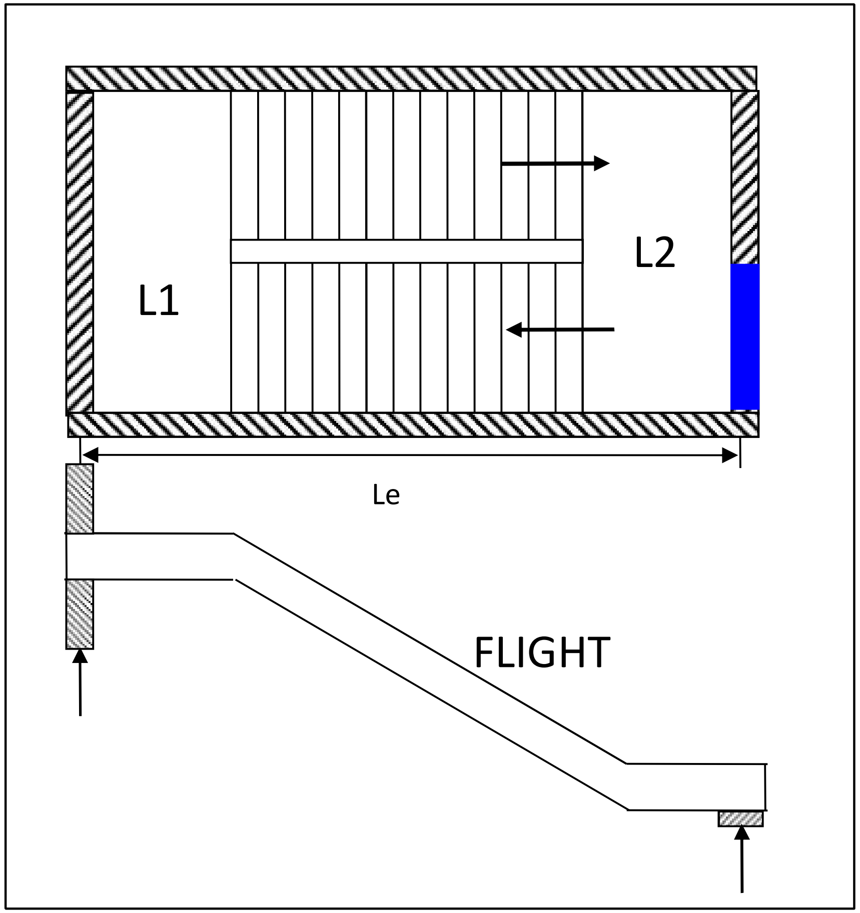
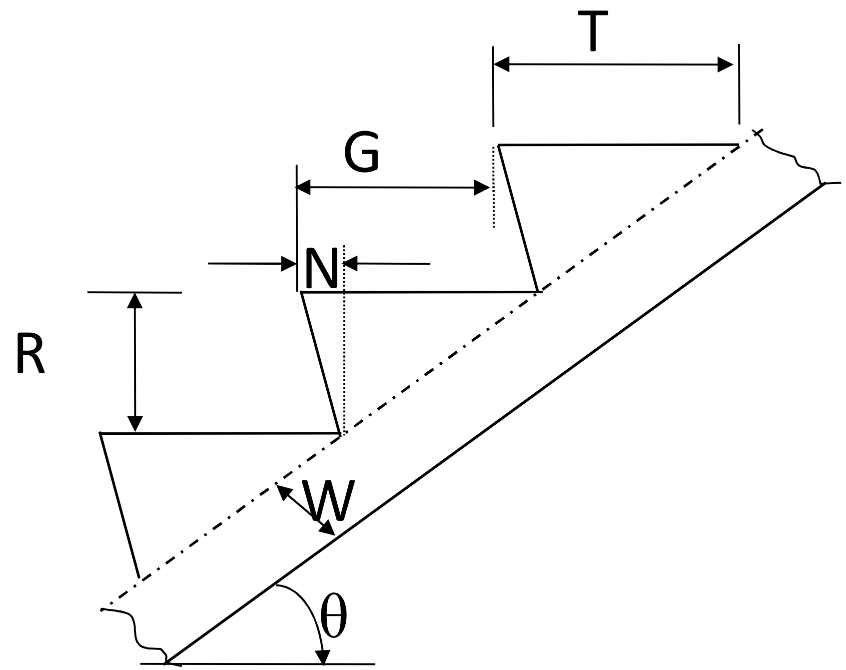


Fig. 2 DOG LEGGED STAIR CASE

Parts of stairs

- Flight and landing.

- Steps
- Rise-R
- Going-G=T-N
- Tread-T
- Nosing -N



Types of stair cases

- Based on shape

- Straight stairs
- Dog legged stairs
- Open well or open newel stairs
- Geometrical stairs such as spiral, circular, etc.
- Free standing stair cases

Some photos

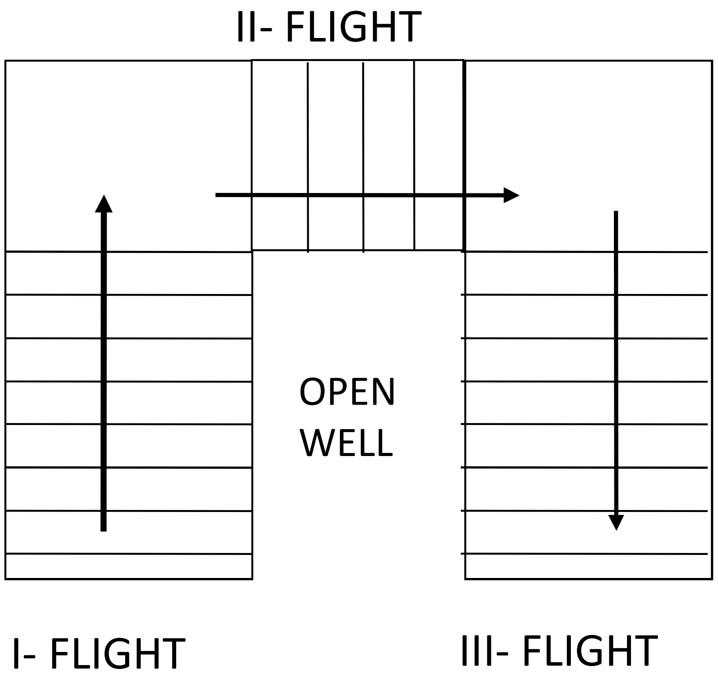
Straight SC

Dog legged SC

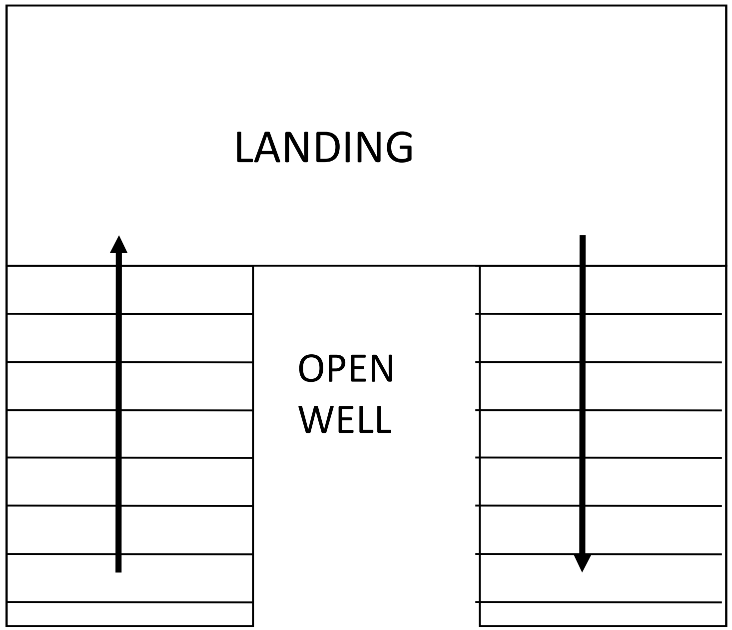
Geometric SC

Transversely spanning SC

Open Well or Newel stair cases

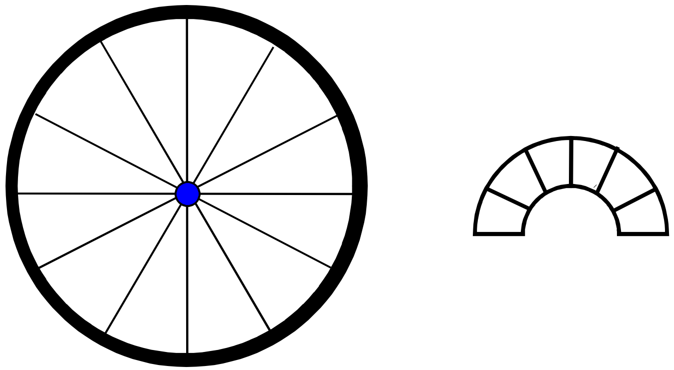


WITH INTERMEDIATE FLIGHT

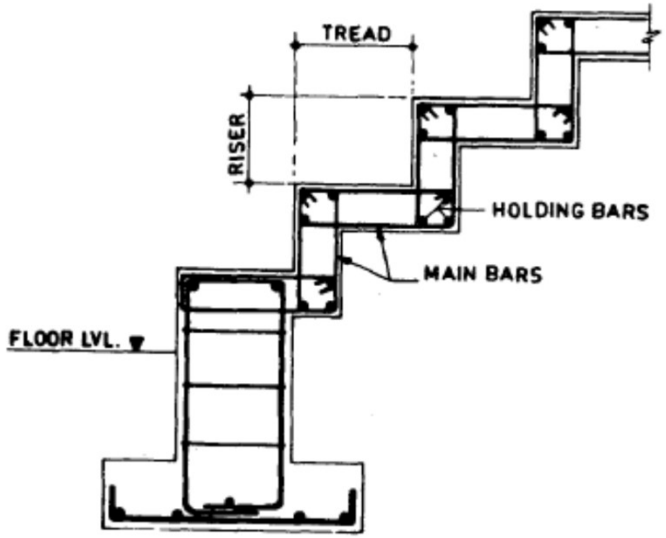


WITHOUT INTERMEDIATE FLIGHT

OTHER STAIRCASES



SPIRAL AND GEOMETRIC
STAIRCASES



RISER AND TREAD STAIRCASE

CLASSIFICATION

Based on type of span

- Horizontally spanning or transversely spanning SC

- Longitudinally spanning SC.

For details refer IS:456-2000 and SP-34.

Guide lines for fixing the dimensions

- Rise (R) : 150mm to 180mm
- Tread (T) : 220 mm to 250 mm- for residential buildings.

Rise (R) : 120 to 150 mm
Tread (T) : 250 mm to 300 mm – for public buildings

[T + 2R] : Between 500 mm to 650 mm

The width of the stair

- 0.8 m to 1 m for residential building and
- 1.8 m to 2 m for public building.

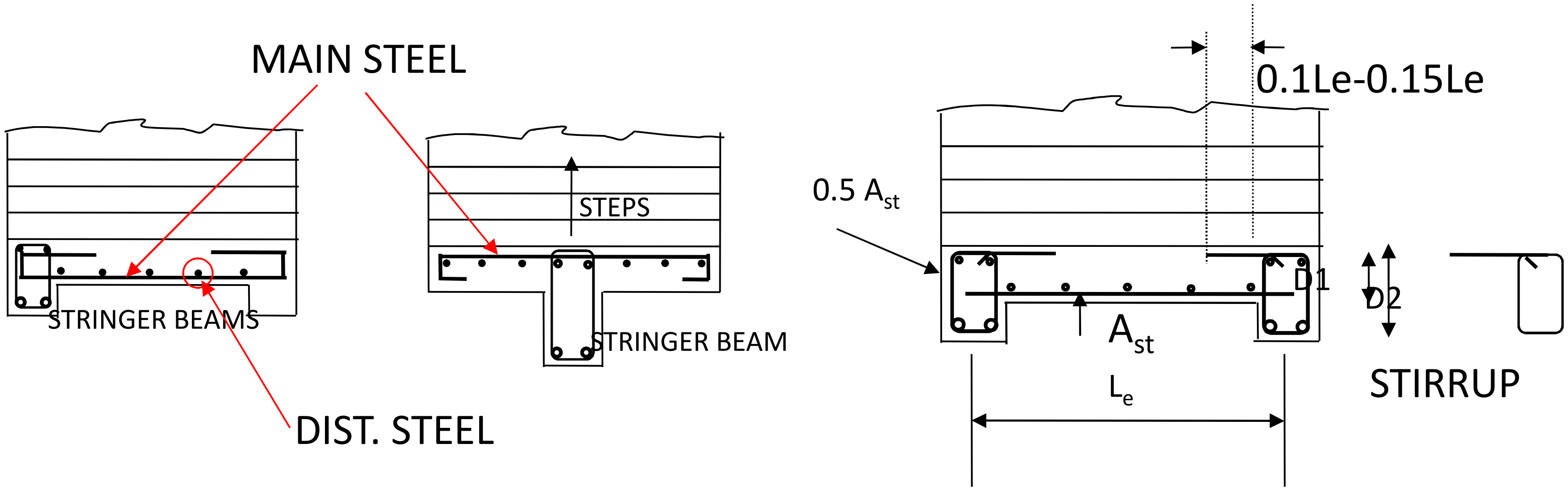
Guide lines for fixing the dimensions Contd…

- The width of the landing is equal to the width of stairs.
- The number of steps in each flight should not be greater than 12
- The pitch of the stair should not be more than 38 degrees.
- The head room measured vertically above any step or below the mid landing shall not be less than 2.1 m.

Design of stairs

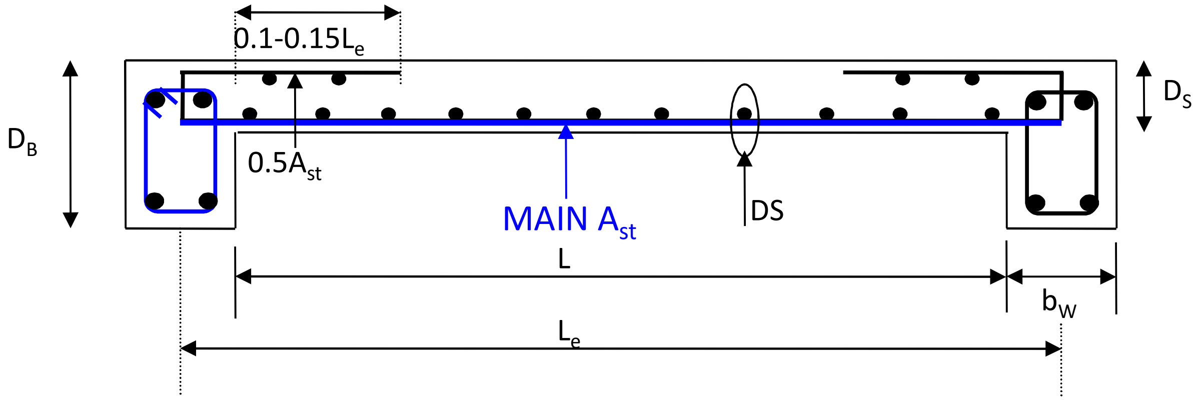
- Design for maximum bending moment and check for maximum shear force.
-
- The depth is to be fixed from deflection criteria.
- Stair case slab is designed as a conventional slab.
- All rules regarding the detailing are similar to that of slab.
-
- Enough development and anchorage lengths for steel should be provided.

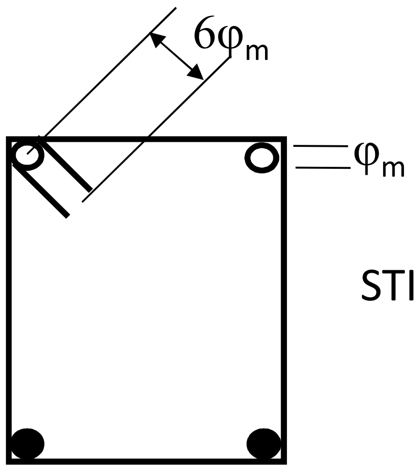
Transversally spanning stair case



Refer SP-34 for more details

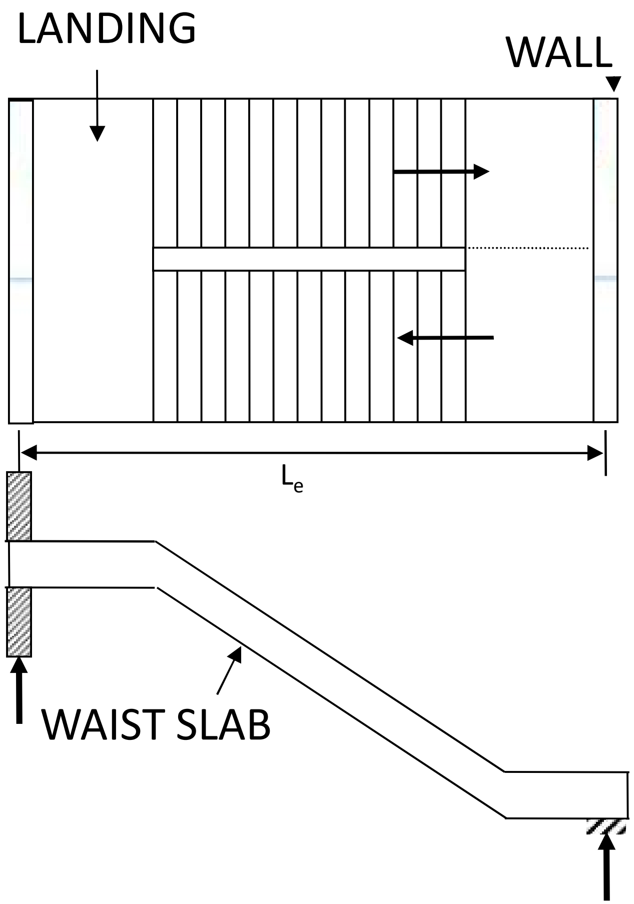
TRANSVERSLY SPANNING





STIRRUP DETAILS AND HOOK

STAIR CASE SUPPORTED ON SIDE BEAMS-
DETAILS

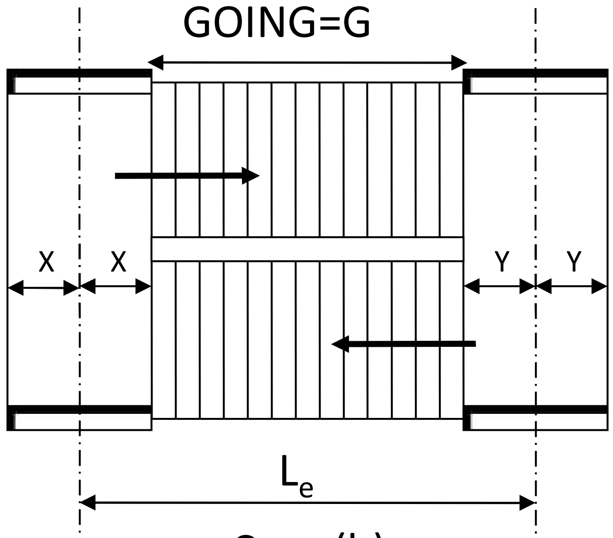


Case (a)

EFFECTIVE SPAN FOR LONGITUDINALLY SPANNING STAIRCASES

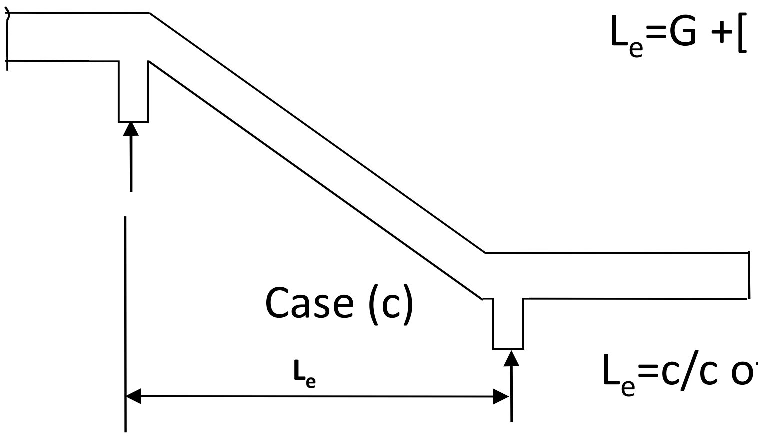
WAIST SLAB SUPPORTED AT THE ENDS OF LANDINGS

EFFECTIVE SPAN FOR LONGITUDINALLY SPANNING STAIRCASES



Case (b)

L_e=G +[X +Y], X ≤1m AND Y ≤1m



Case (c)

L_e=c/c of beams

Longitudinally spanning SC

- **Detailing**
- Steel at bottom longitudinally-tension
- Anchorage and development steel
- Distribution steel
- Row of chairs
- Nominal foundation for ground flight

Exercise contd.,

- Both flights are supported at the ends of
- landing on 230 mm wall.
- (Landing and flight spans in the same direction)
- The first flight starts from the plinth level
- Main steel for each flight = #12@120
- Distribution steel for each flight = #8@ 200
- Use M20 concrete and Fe 415 steel.

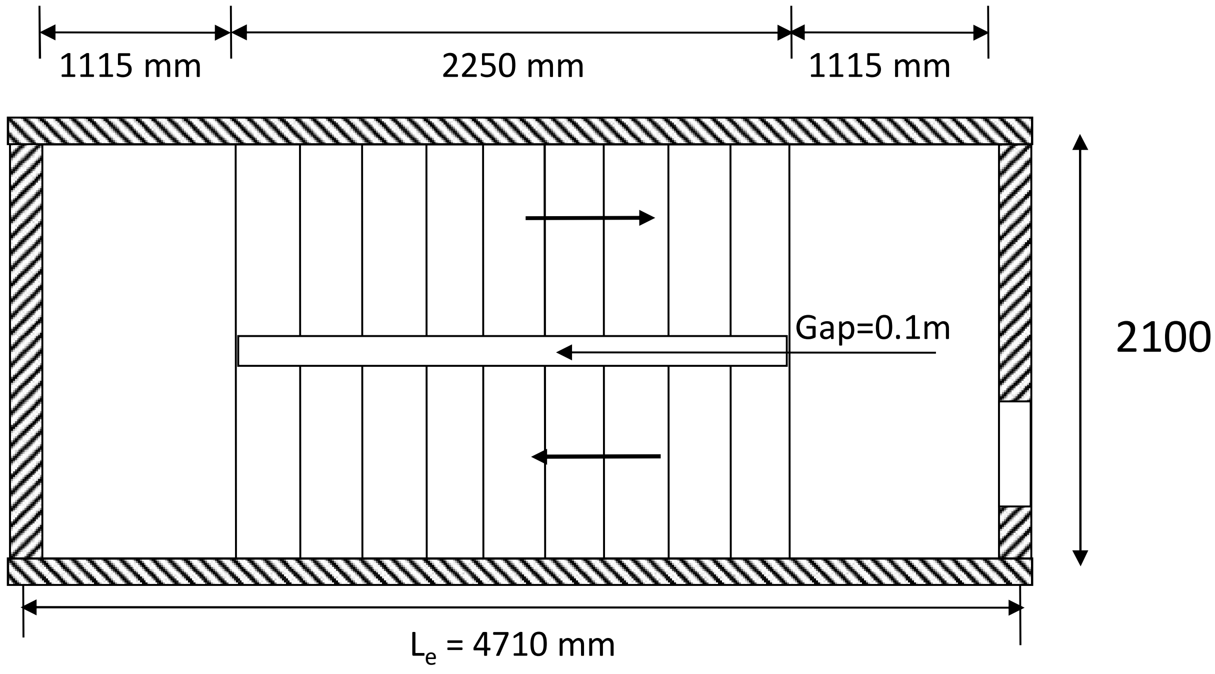
- Draw to a suitable scale
- The plan of stair case
- Sectional elevation of the Ground flight
- Sectional elevation of the First flight
- Bar bending schedule

Solution

- Dimensioning:
- R=160 mm, T= 250 mm
- Floor to floor height = 3200mm
- No of rises = 3200/R = 20. Each flight has 10 rises.
- No of treads per flight=10-1 =9
- Width of landing along flight
- = (4480-9x250)/2 = 1115mm.
- Going of flight=9x250 =2250mm
- Development length = 47ϕ= 47 x 12 = 564 mm

Exercise

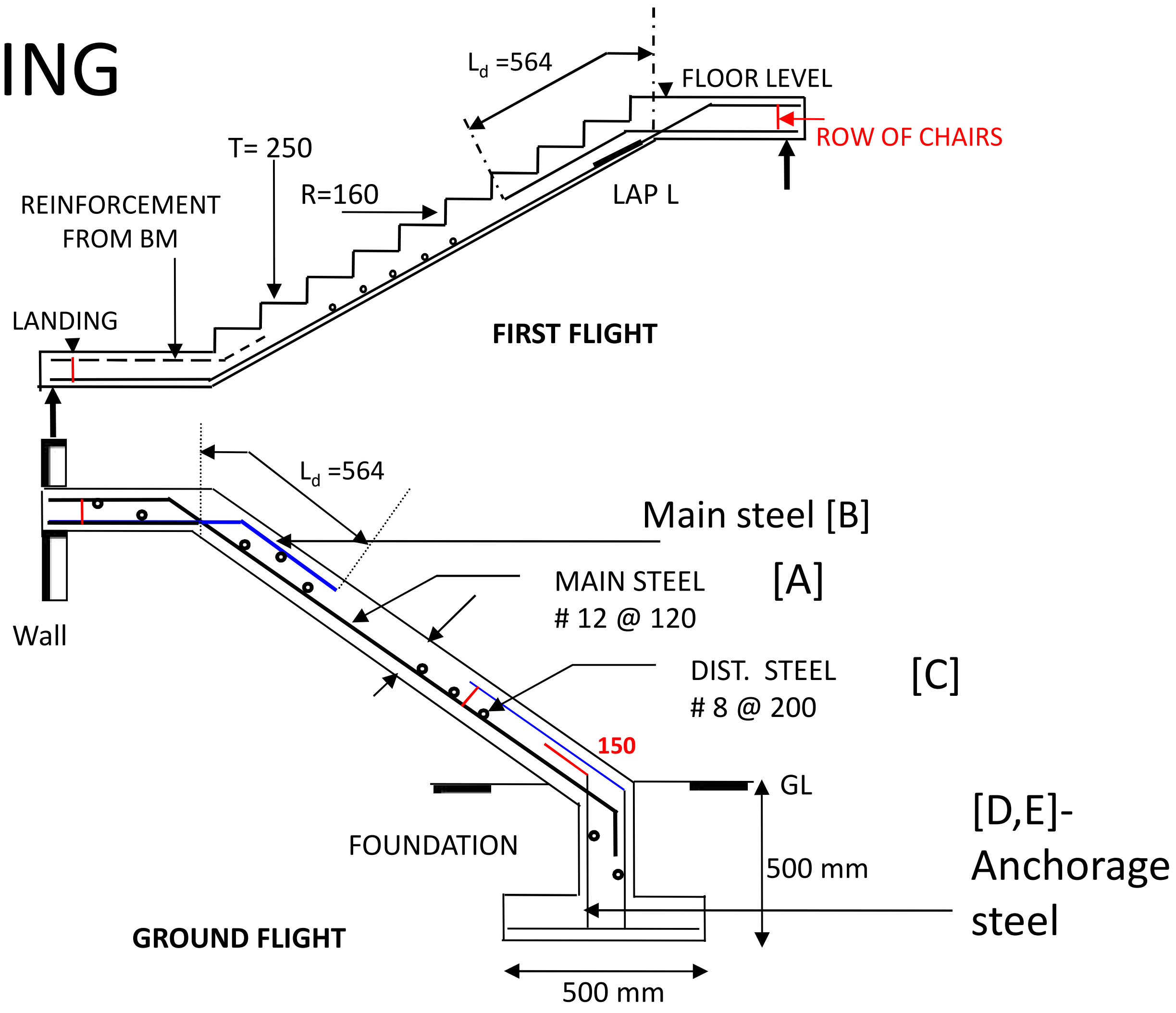
- Plan of stair case



PLAN

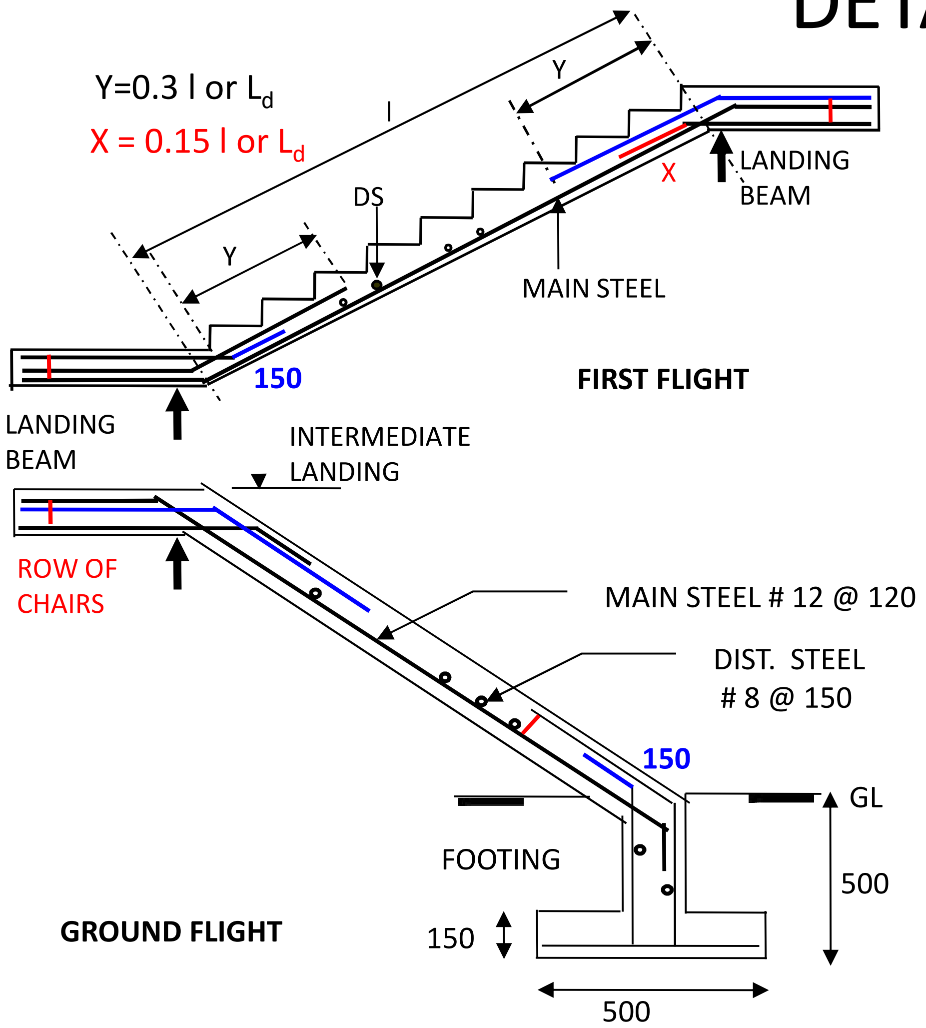
Clear dimension of stair case room=4.48 m x 2.1 m

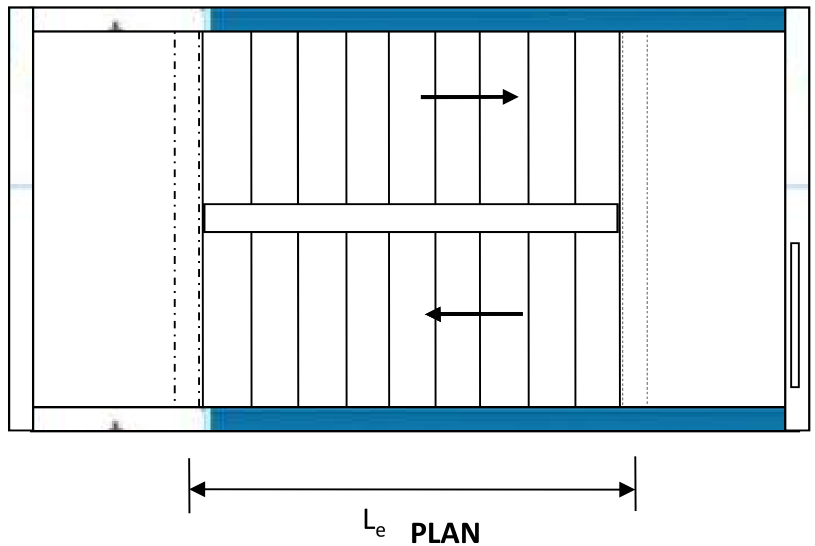
DETAILING



Landing and flight spans longitudinally

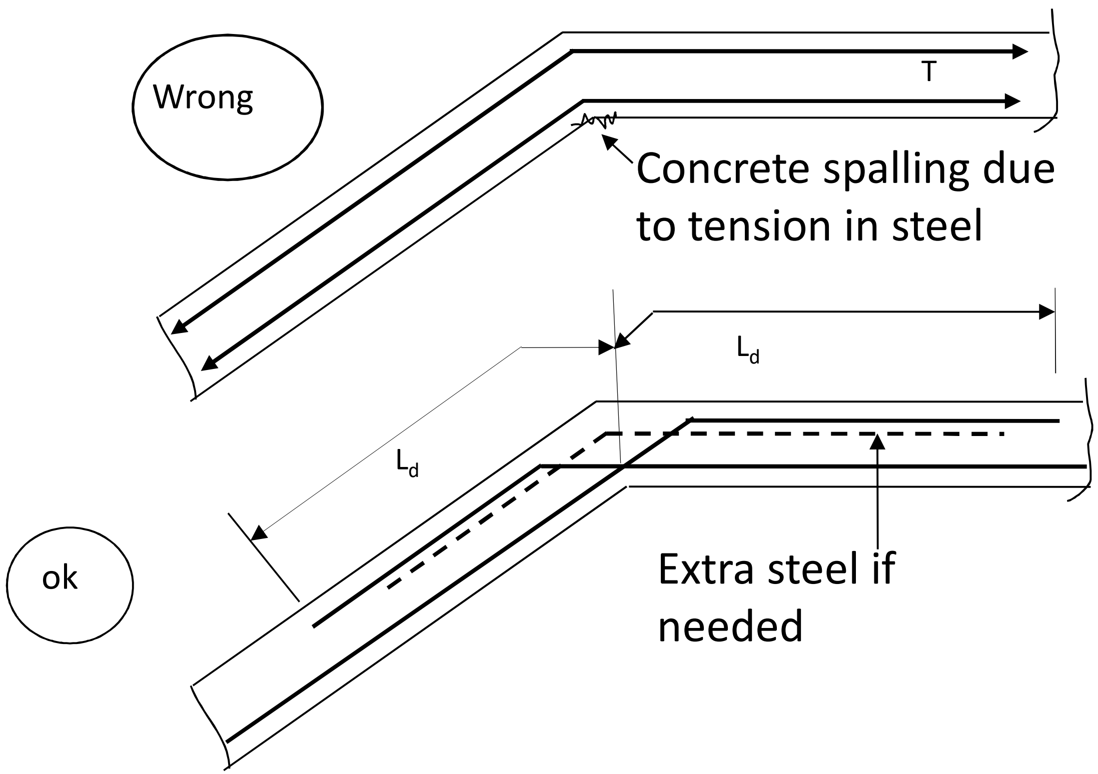
DETAILING



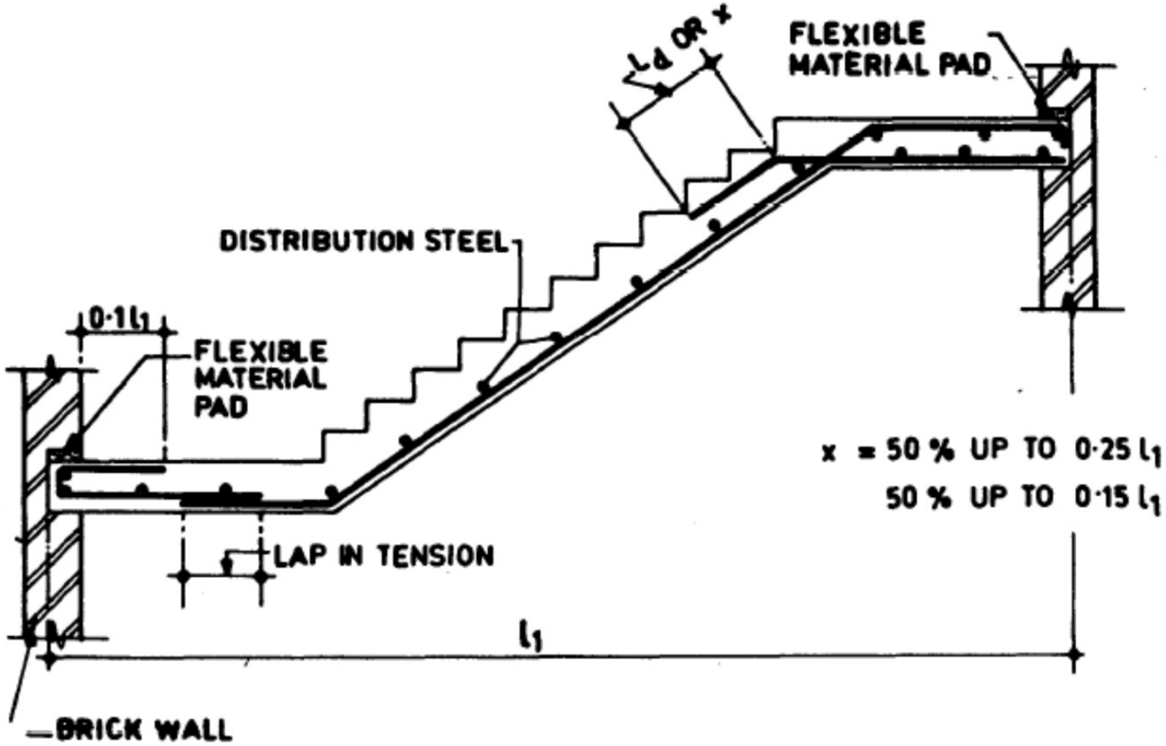


Flight spans longitudinally on landing beams

Details at the junction of flight and landing



STRAIGHT STAIR CASE



Refer SP-34 and learn the details

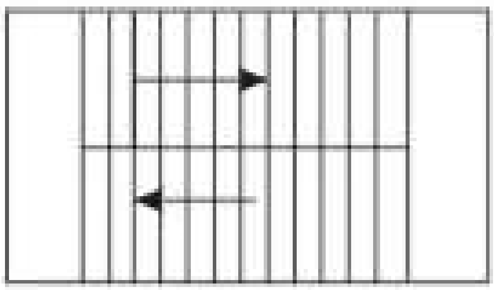
- Stair cases-
  - Types-
  - proportioning-
  - loads-
  - distribution of loads
  - stairs spanning horizontally
  - stairs spanning longitudinally
  - design of dog legged
  - tread- riser type stairs

Type of Stair cases

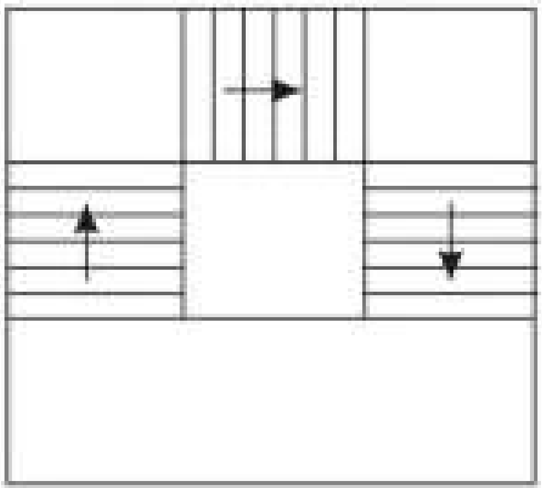
Based on Number of Flights

Dog – legged (Two Flights)

Open well (Three Flights)



Two flight staircase

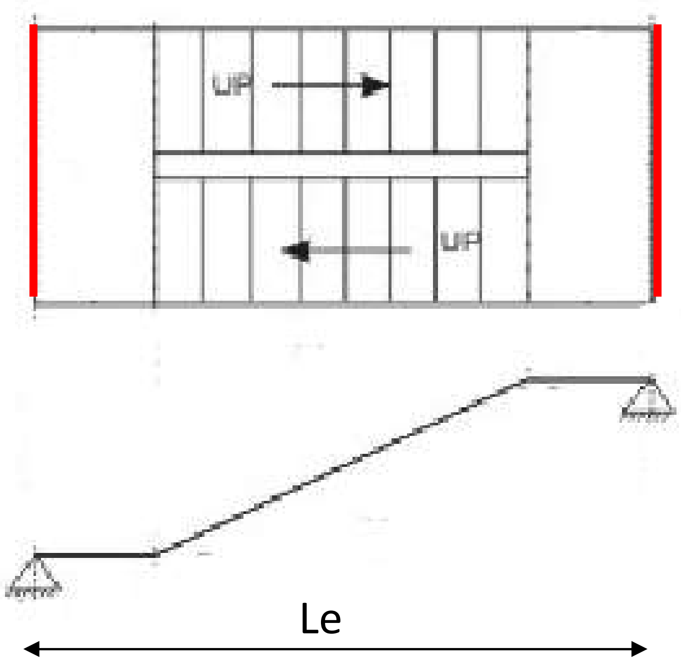


Open-well staircase

Based on Structural System

i) Spanning Longitudinally

Both landing and Going span in the same direction



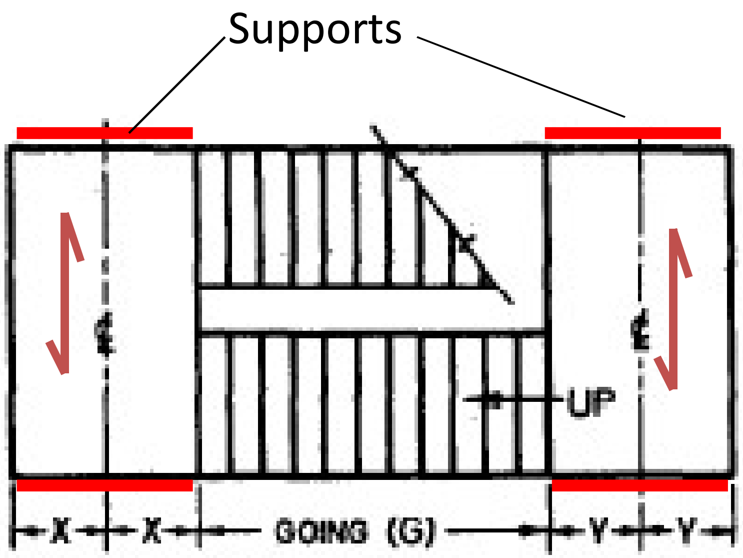
Effective Span (Le) CL 33.1.(c)

Le = C/C distance between supports

ii) Landings Spanning transverse to Going

Going is supported by landings

Effective Span Le   Cl 33.1 (b)



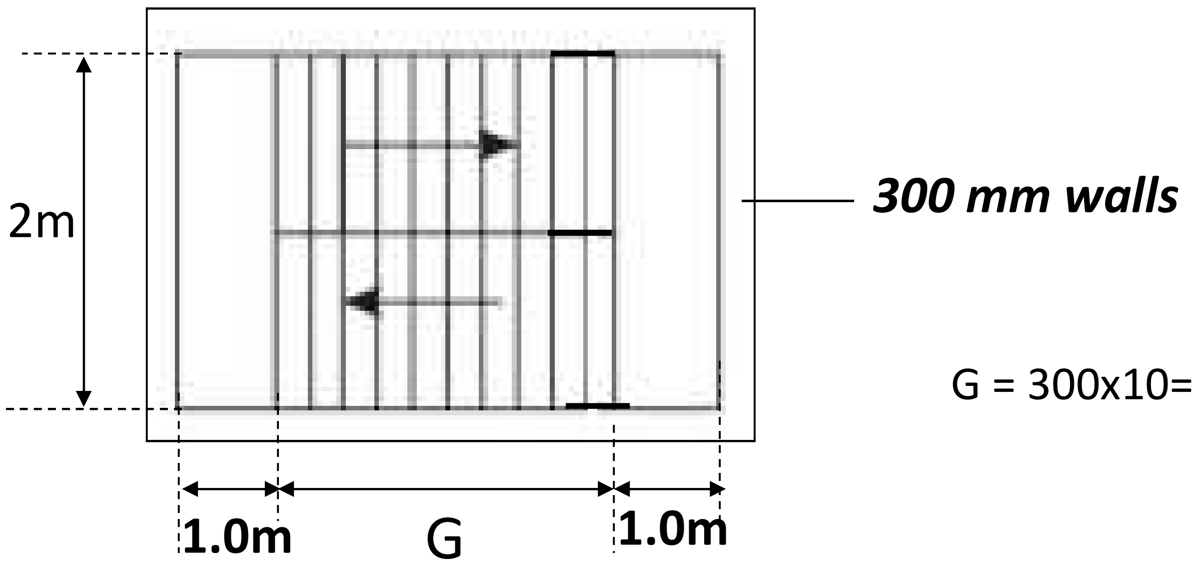
X	Y	SPAN IN METRES
<1 m	<1 m	G + X + Y
<1 m	≥1 m	G + X + 1
≥1 m	<1 m	G + Y + 1
≥1 m	≥1 m	G + 1 + 1

FIG. 17 EFFECTIVE SPAN FOR STAIRS SUPPORTED AT EACH END BY LANDINGS SPANNING PARALLEL WITH THE RISERS

Example 1

Design the Dog legged staircase if supported on walls 300 mm thick along landing slab at both ends.

Floor finish = 1 kN/m², Live load = 5 kN/m², riser R = 150 mm, tread T = 300 mm, M 20 and Fe 415.



G = 300x10=3000mm

Step 1: Effective Span (Le) of each flight

Stair case is spanning Longitudinally

Le = C/C distance between supports *CL 33.1.(c)*

Le = 3 + 1 x 2 + 0.3 = 5.3 m

Step 2: Trial Depth of Waist Slab

Le/d = 25 ; d = 5300/25 = 212 mm

Clear cover = 20mm; Dia of bars = 12mm

D = 212 + 20 + 6 = 238 mm

Adopt D = 230 mm; d = 204mm

Step 3: Loads (kN/m²)

Loads on going

$Cos(\theta) = 300/(300^2+150^2)^{0.5} = 0.894$

Self-weight of waist-slab = 25(0.23) / $Cos(\theta)$ = 6.43
Self-weight of steps = 24(0.15/2) = 1.8
Finishes = 1.0
Live loads = 5.0

Total = 14.3

Factored loads = 1.5(14.3) = 21.5 = 21.5 kN/m^2

Loads on Landing

Self-weight of waist-slab = 25(0.23) = 5.75

Finishes = 1.0

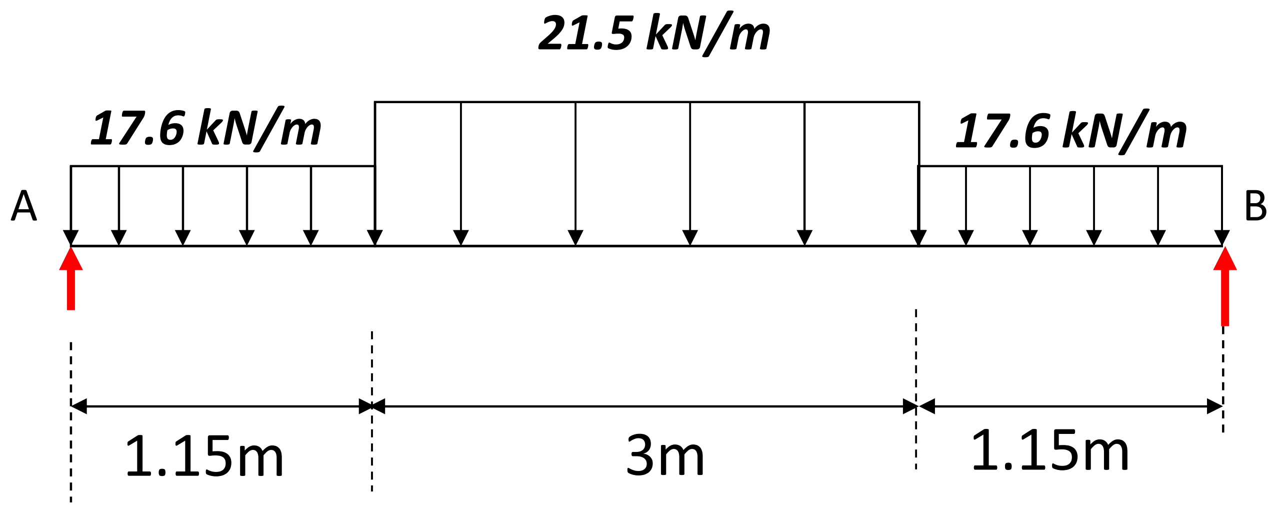
Live loads = 5.0

Total = 11.75

Factored loads = 1.5(11.75) = 17.6 kN/m^2

Step 4: Limit state of Collapse - Flexure

Consider 1m width of flight



Va = Vb = {(21.5x3) + (17.6x1.15)x2}/2 = 52.49 kN

<u>i) Mu(@mid span)</u>

=[52.49 x(1.15+1.5)]– [17.6x1.15x(1.5+(1.15/2))] – [21.5x1.5x1.5/2]

= 72.9 kNm per m width

ii) $Mu,lim = 0.36x0.48x(1-0.42x0.48)x1000x20x204^2$

$= 114.8$ kNm > Mu   Depth OK

iii) *Compute Ast per m width*

$72.9x10^6 = 0.87x415xAstx204x(1- 415xAst/(1000x204x20))$

$72.9x10^6 = 73654.2Ast – 7.49 Ast^2$

Ast = 1117 mm^2

iv) Ast. Minimum = 0.12 x1000x230/100 = 276 mm^2 < 1117mm^2

iv) Rebar Details

Main steel: Assume #12 bars

S = 1000x 113/1117 = 101 mm c/c < max spacing

Provide #12 @ 100 mm c/c

Distribution Steel: Assume #8 bars

S = 1000x50/276 = 181mm

Provide #8 @ 175 mm c/c

Step 5: Limit state of Collapse - Shear

V_u = 52.49kN

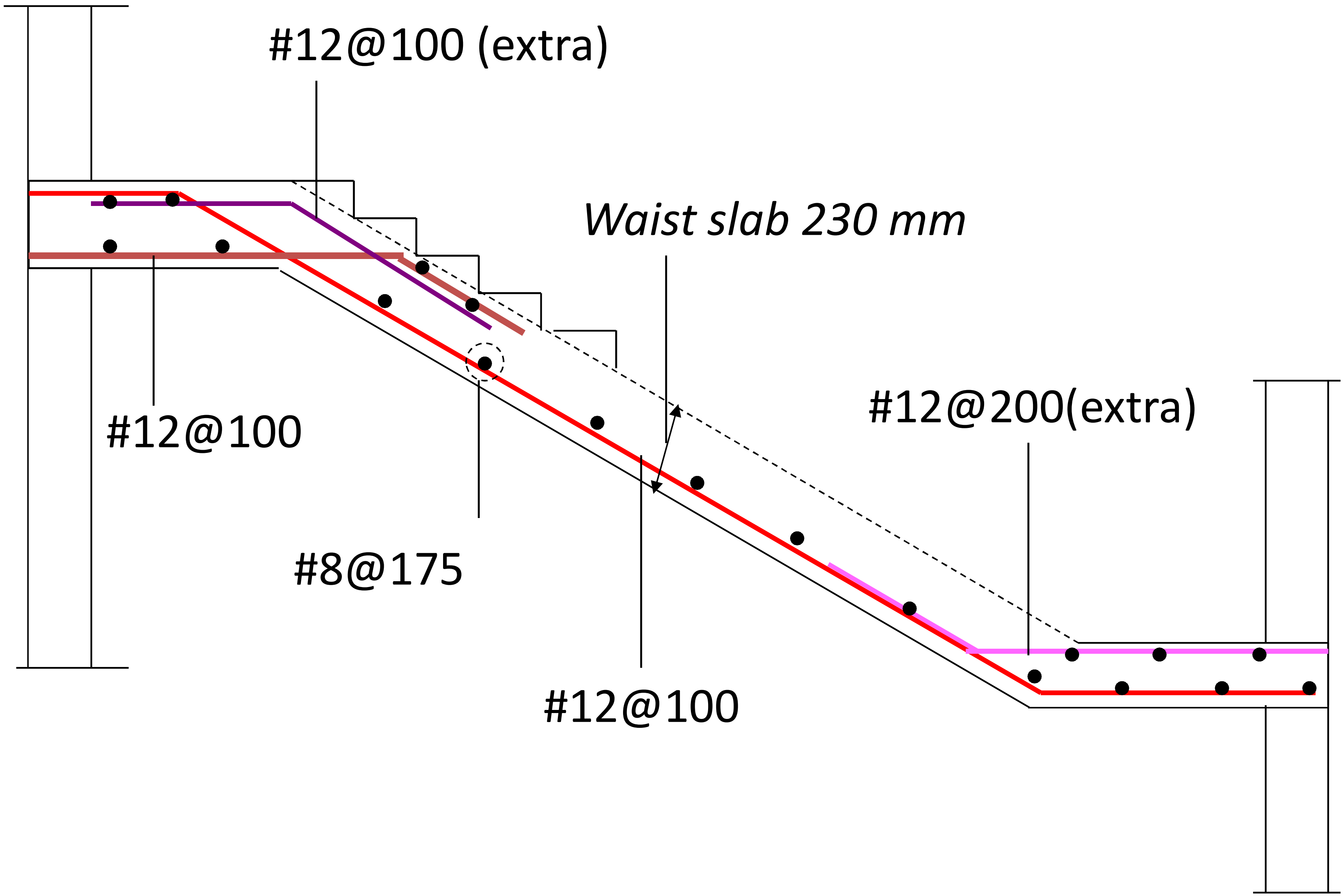
τ_v = 52.49 x1000/(1000x204) = 0.26MPa

p_t = 100x1117/(1000x204) = 0.55%

τ_c = 0.5MPa (Table 19)

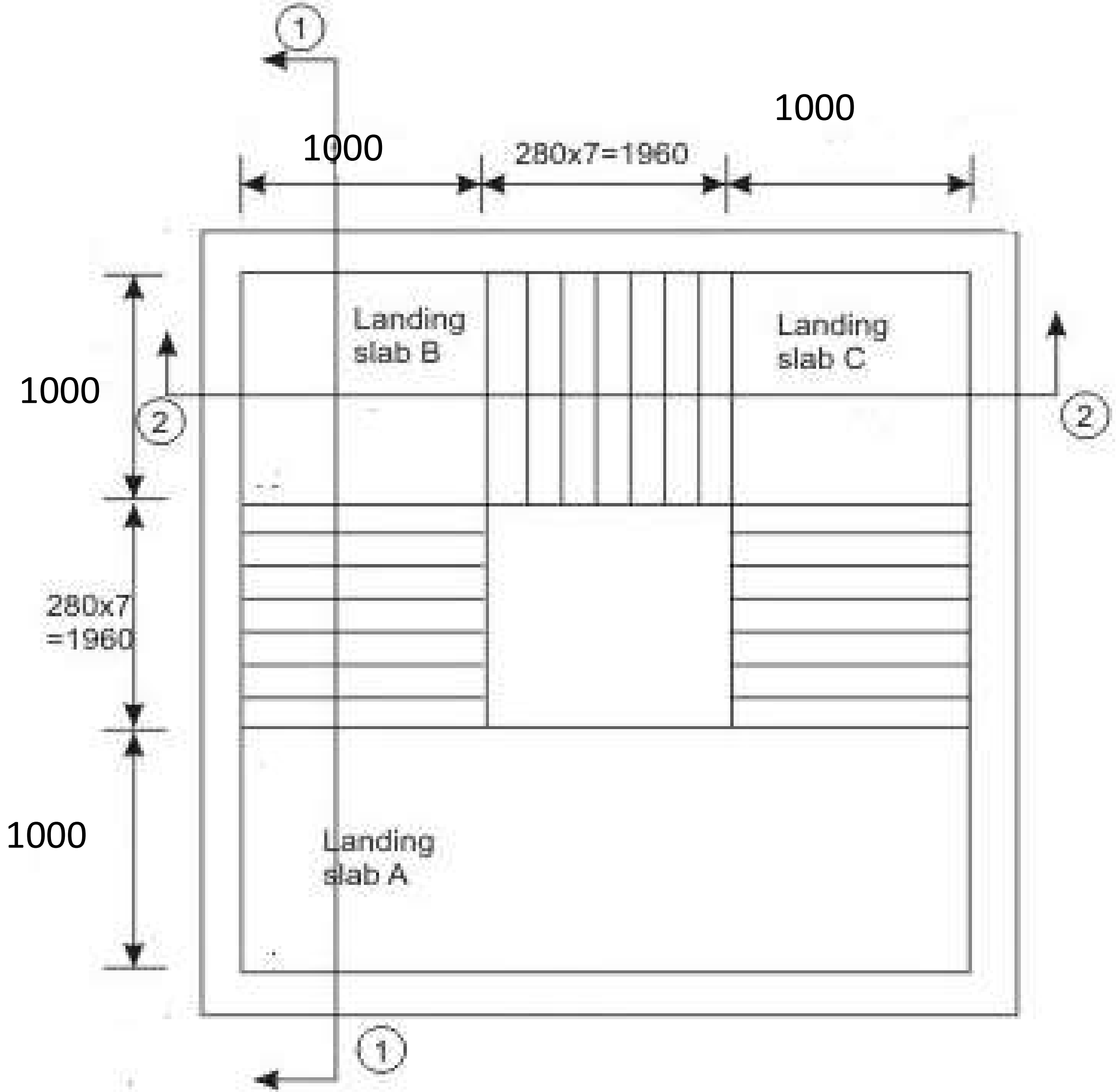
k = 1.1

$\tau_v < k\,\tau_c$ Depth OK


#12@100 (extra)
Waist slab 230 mm
#12@200(extra)
#12@100
#8@175
#12@100

Example 2

Design the open-well staircase supported on brick walls 300 mm thick. Risers =160 mm ,Treads = 280 mm, Finish loads =1 kN/m^2, LL = 5 kN/m^2, Use M 20 Fe 415.



1
1000
280x7=1960
1000
1000
280x7
=1960
1000
Landing
slab B
Landing
slab C
Landing
slab A
2
2
1

Case 1: Design of Flight along 1-1

Step 1: Effective span (Le) CL 33.1 (b)

Le= 300 + 1000 + 1960 +1000 = 4260 mm

Step 2: Trial Depth of Waist Slab

L/d = 25; d = 4260/25 = 170 mm
Clear Cover = 20mm, Dia of bar =12 mm
D = 200 mm; d = 174mm

Step 3: Loads (kN/m^2)

Loads on going

$\text{Cos}(\theta) = 280/(280^2+160^2)^{0.5} = 0.868$

Self weight of waist slab = 25x 0.2/ 0.868 = 5.76

Self weight of steps = 24 x 0.16/2 = 1.92

Finish loads = 1.0

Live loads = 5.0

Total = 13.68 kN/m^2

Factored loads = 1.5(13.68) = 20.5 kN/m^2

Landing slab A

Self weight of slab = 25 x 0.2 = 5.0
Finish loads = 1.00
Live loads = 5.00

Total = 11 kN/m^2

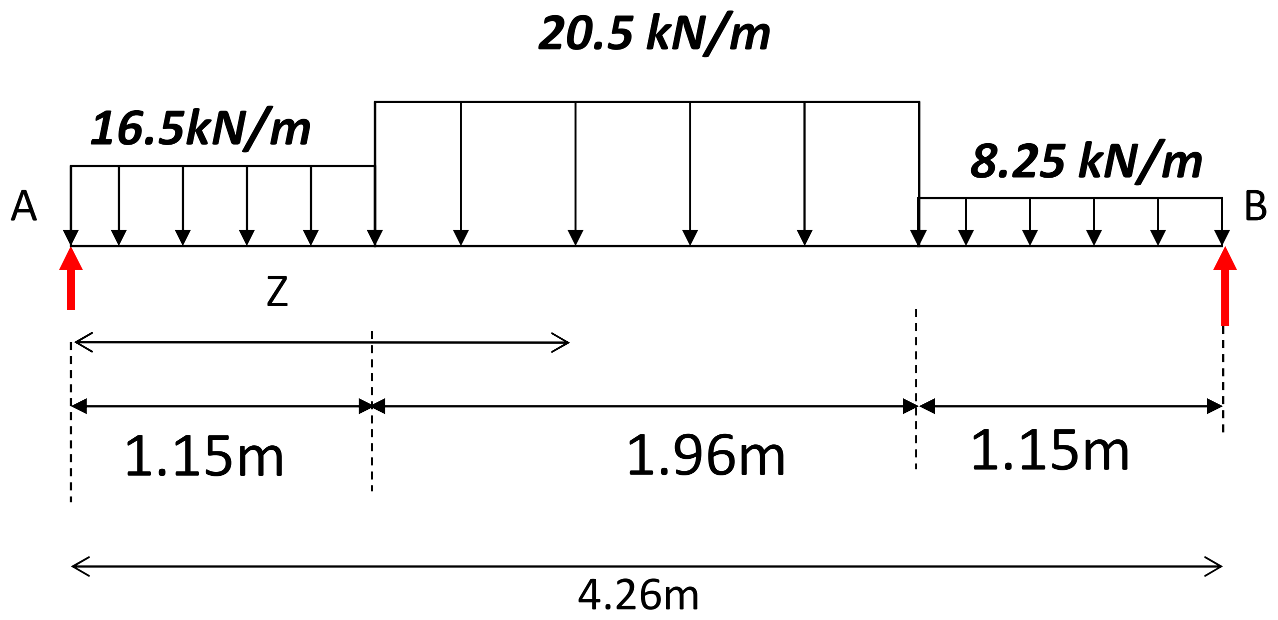
Factored loads = 1.5(11) = 16.5 kN/m^2

Landing slab B (common to both flights) CL 33.2

50 per cent of loads of landing slab A = 8.25 kN/m^2

Step 4: Limit state of Collapse - Flexure

Consider 1m width of flight



i) Reactions : Moments about B

$$Va = [\{16.5 \times 1.15 \times (4.26 - (1.15/2))\} + \{20.5 \times 1.96 \times ((1.96/2) + 1.15)\} + \{8.25 \times 1.15^2/2\}] / 4.26 = 37.78 \text{ kN}$$

Va + Vb = [16.5x1.15] + [20.5x1.96] + [8.25x1.15]

= 68.64 kN

Vb = 30.86 kN

ii) Distance Z from 'A' where SF = 0

37.78 – 16.5 x 1.15 – 20.5 x (Z-1.15) = 0

Z = 2.07 m

iii) Mu at 'Z' is maximum

Mu = [37.78 x 2.07] - [16.5 x1.15 x(2.07 – (1.15/2)]

- [20.5 x(2.07 – 1.15)^2/2]

= 41.16 kNm per m width

iv) $Mu,lim = 0.36x0.48x(1\text{-}0.42x0.48)x1000x20x174^2$

$= 83.54$ kNm > Mu   Depth OK

v) *Compute Ast per m width*

$41.16x10^6 = 0.87x415xAstx174x(1\text{-} 415xAst/(1000x174x20))$

$41.16x10^6 = 62822.7\ Ast – 7.49\ Ast^2$

Ast = 717 mm^2

iv) Ast. Minimum = 0.12 x1000x200/100 = 240 mm^2 < 717mm^2

iv) Rebar Details

Main steel: Assume #12 bars

S = 1000x 113/717= 157 mm c/c < max spacing

Provide #12 @ 150 mm c/c

Distribution Steel: Assume #8 bars

S = 1000x50/240 = 208mm

Provide #8 @ 200 mm c/c

Step 5: Limit state of Collapse - Shear

V_u = 37.78 kN

τ_v = 37.78 x1000/(1000x174) = 0.22MPa

p_t = 100x717/(1000x174) = 0.41%

τ_c = 0.44MPa (Table 19)

k = 1.2

$\tau_v < k\,\tau_c$ Depth OK

Case 2: Design of Flight along 2-2

Le= 300 + 1000 + 1960 +1000 = 4260 mm

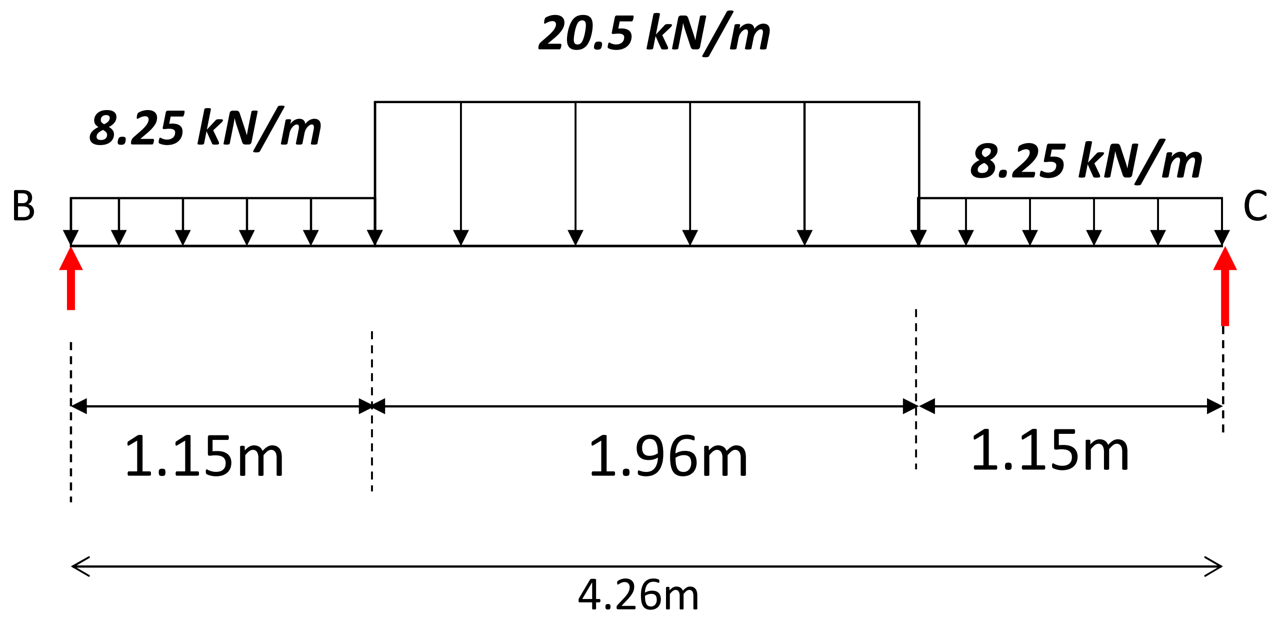
Loads on going : 20.5 kN/m^2

Landing slab B and C (common to both flights

50 per cent of loads of landing slab A = 8.25 kN/m^2

Limit state of Collapse - Flexure

Consider 1m width of flight



i) Reactions :

Vb = Vc = 29.6 kN

Mu at Mid Span is maximum

$Mu = [29.6 \times 2.13] - [\ 8.25 \times 1.15 \times (2.13 - (1.15/2))]$

$- [\ 20.5 \times 0.98^2/2] = 38.45$ kNm < Mu,lim OK

Compute Ast per m width

$38.45 \times 10^6 = 62822.7\ Ast - 7.49\ Ast^2$

Ast = 665 mm^2 > Ast, minimum

iv) Rebar Details

Main steel: Assume #12 bars

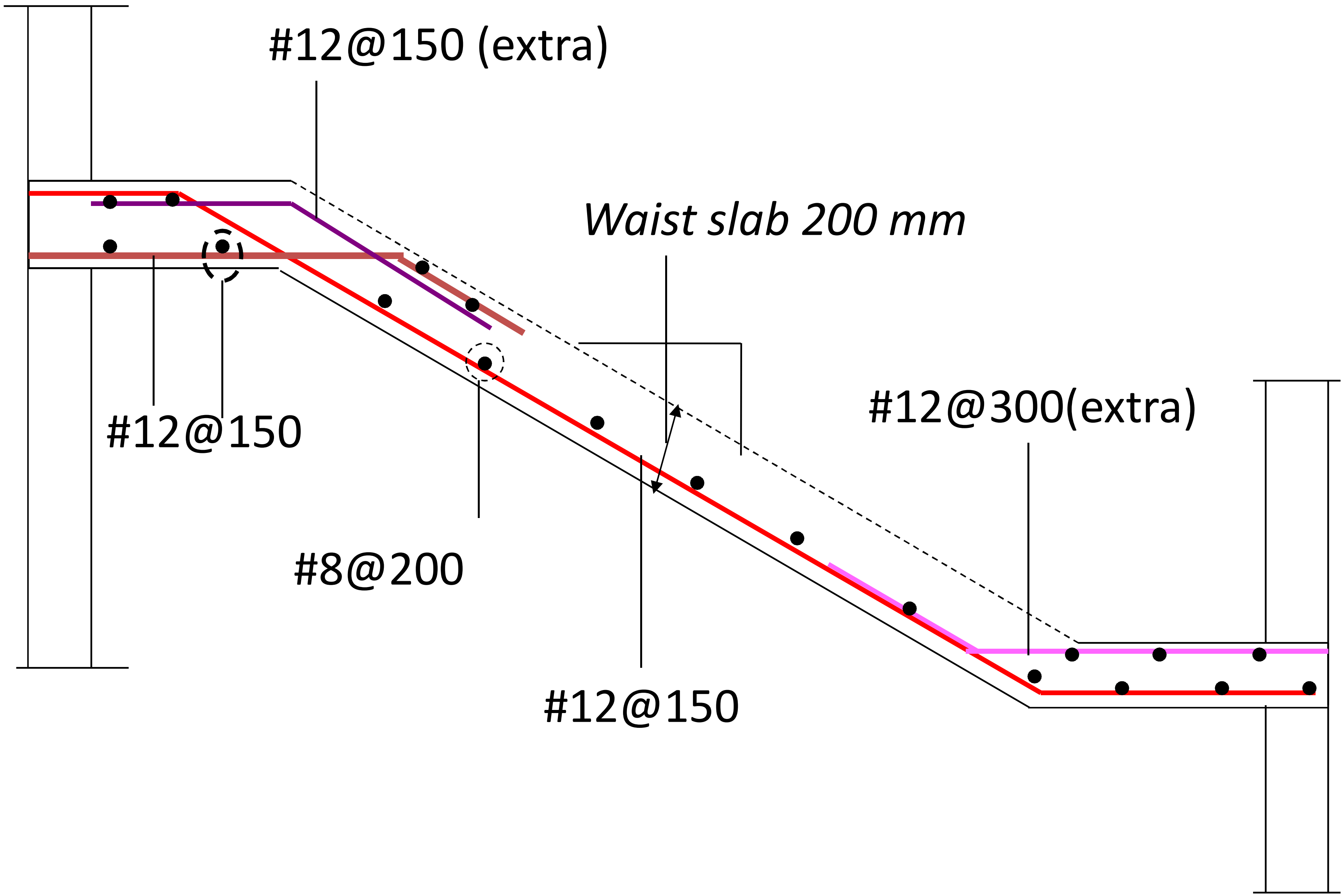
S = 1000x 113/665= 169 mm c/c < max spacing

Provide #12 @ 150 mm c/c

Distribution Steel: Assume #8 bars

S = 1000x50/240 = 208mm

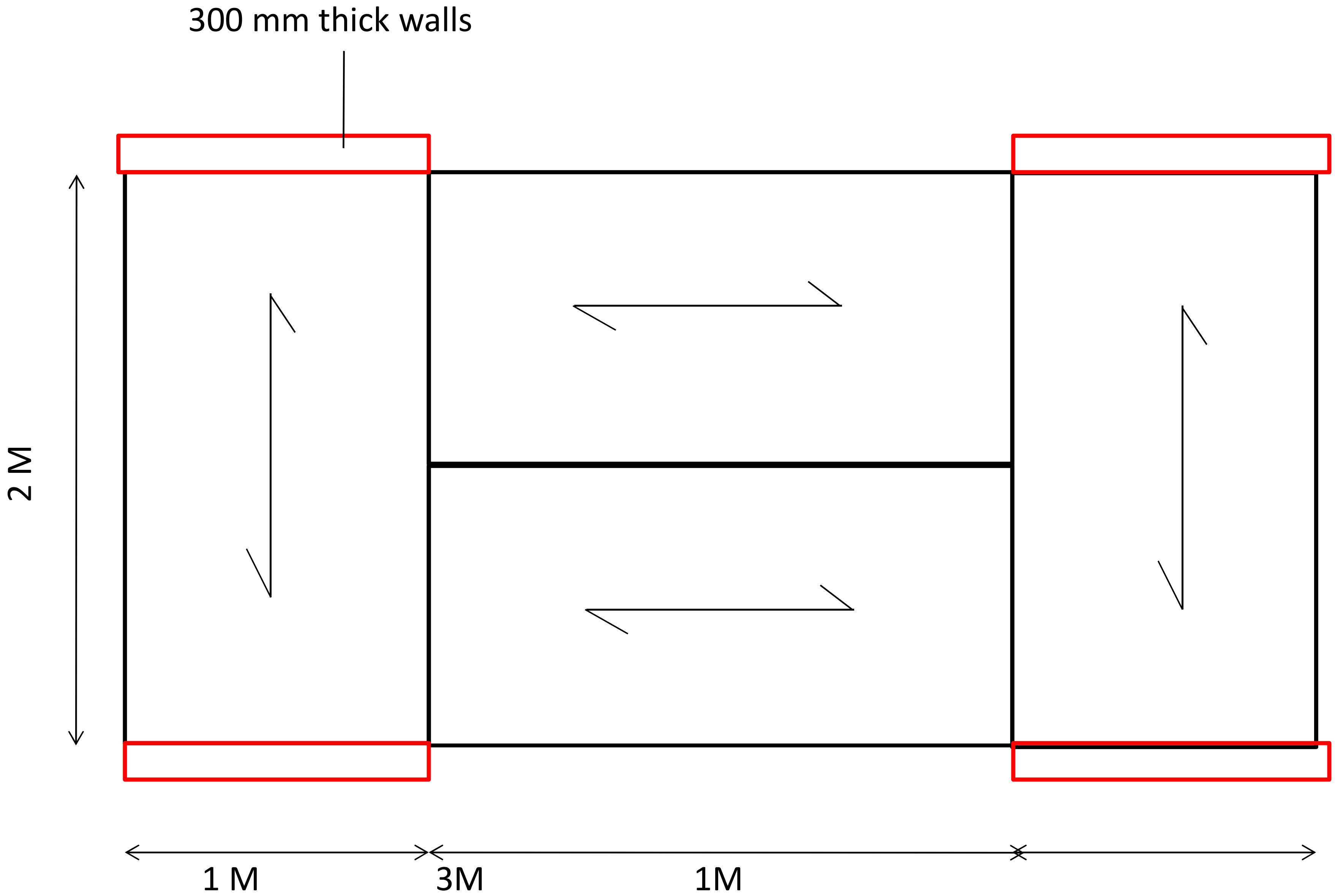
Provide #8 @ 200 mm c/c



Rebar Details in Flights 1-1 and 2-2

Example 3

Design the Dog legged staircase supported on landing slab which is supported on 300 mm thick walls such that landing slab spans transverse to going. Floor finish = 1 kN/m^2, Live load = 5 kN/m^2, riser R = 150 mm, tread T = 300 mm, M 20 and Fe 415.

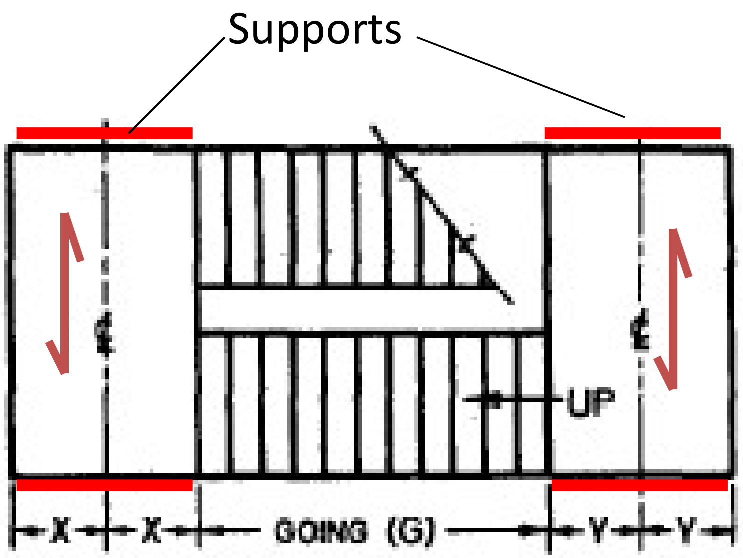


300 mm thick walls
2 M
1 M
3M
1M

ii) Landings Spanning transverse to Going

Going is supported by landings

Effective Span Le Cl 33.1 (b)



X	Y	SPAN IN METRES
<1 m	<1 m	G + X + Y
<1 m	≥ 1 m	G + X + 1
≥ 1 m	<1 m	G + Y + 1
≥ 1 m	≥ 1 m	G + 1 + 1

FIG. 17 EFFECTIVE SPAN FOR STAIRS SUPPORTED AT EACH END BY LANDINGS SPANNING PARALLEL WITH THE RISERS

Step 1: Effective Span (Le) of each flight

Stair case is spanning between Landings

Le = G + X + Y *CL 33.1.(b)*

Le = 3 + 0.5 + 0.5= 4 m

Step 2: Trial Depth of Waist Slab

Le/d = 25 ; d = 4000/25 = 160 mm

Clear cover = 20mm; Dia of bars = 12mm

D = 160 + 20 + 6 = 186 mm

Adopt D = 175 mm, d = 149 mm

Step 3: Design of Going Slab (kN/m^2)

Loads on going (kN/m^2)

$\text{Cos}(\theta) = 300/(300^2+150^2)^{0.5} = 0.894$

Self-weight of waist-slab = 25(0.175) / Cos(θ) = 4.89

Self-weight of steps = 24(0.15/2) = 1.8

Finishes = 1.0

Live loads = 5.0

Total = 12.7

Factored loads = 1.5(12.7) = 21.5 = 19 kN/m^2

Step 4: Limit state of Collapse - Flexure

i) Consider 1m width of flight and assume load to be acting as UDL over 4m Span

$$Mu = 19 \times 4^2/8 = 38.1 \text{ kNm per m width}$$

ii) $Mu,lim = 0.36x0.48x(1\text{-}0.42x0.48)x1000x20x149^2$

$= 61.26$ kNm $> Mu$ Depth OK

iii) *Compute Ast per m width*

$38.1x10^6 = 0.87x415xAstx149x(1- 415xAst/(1000x149x20))$

$38.1x10^6 = 53796.45\ Ast – 7.49\ Ast^2$

Ast = 797 mm^2

iv) Ast. Minimum = 0.12 x1000x175/100 = 210 mm^2 < 797mm^2

iv) Rebar Details

Main steel: Assume #12 bars

S = 1000x 113/797= 140 mm c/c < max spacing

Provide #12 @ 125 mm c/c

Distribution Steel: Assume #8 bars

S = 1000x50/210 = 238mm

Provide #8 @ 230 mm c/c

Step 5 : Design of Landing Slab

Loads on Landing (kN/m^2)

Self-weight of slab = 25(0..175) = 4.4

Finishes = 1.0

Live loads = 5.0

Total = 10.4

Factored loads = 1.5(10.4) = 15.6 kN/m^2

Consider I M width

Load on Landing Slab = 15.6 kN/m

Load from Going = Load on Going/2 = (19x4)/2 = 38kN/m

UDL on Landing Slab = 53.6 kN/m

Le = 2.3 m

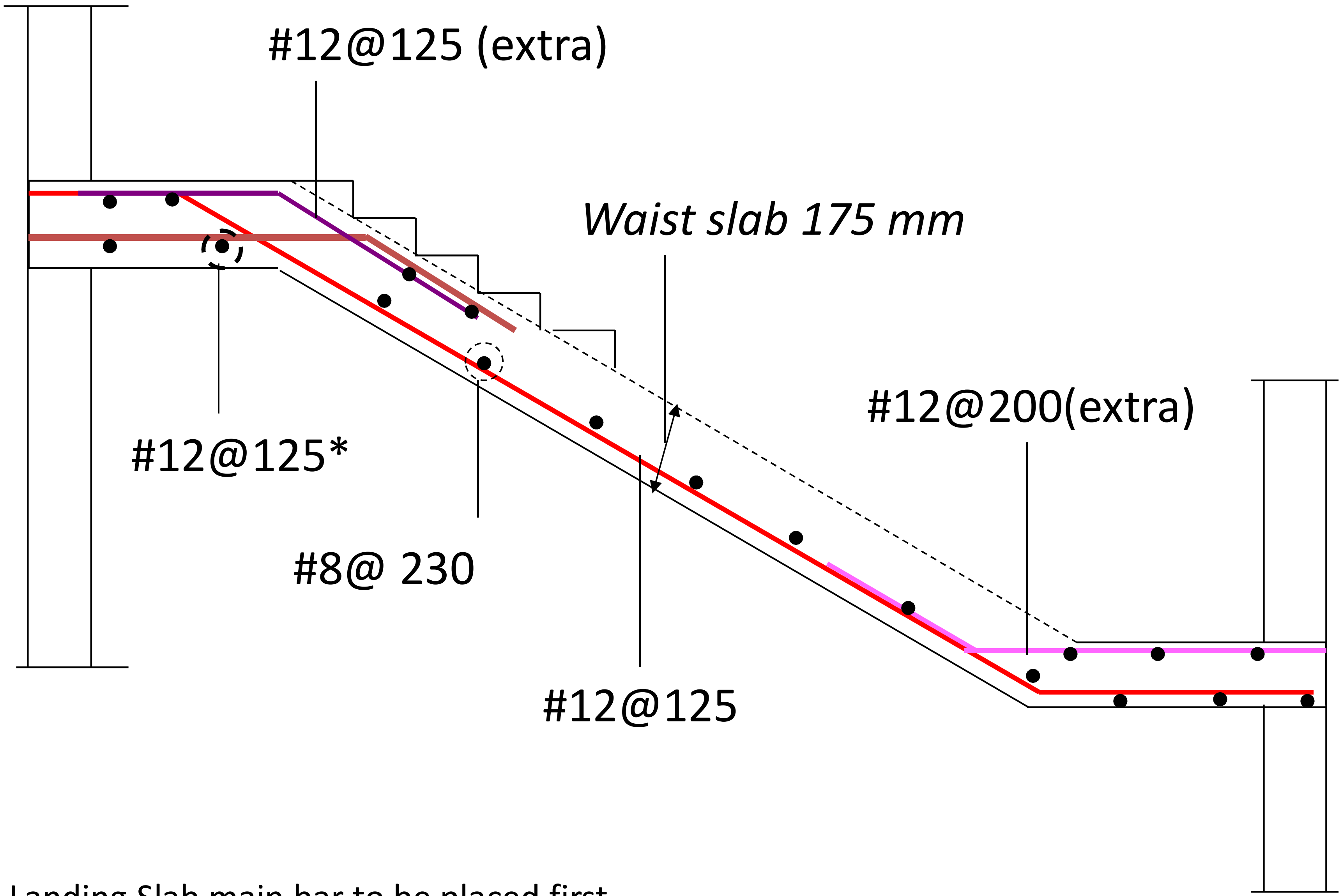
Mu = 53.6 x 2.3 ^{2}/8 = 35.44 kNm per m width < Mu,lim

Depth OK

$35.44 \times 10^6 = 53796.45\ Ast - 7.49\ Ast^2$

Ast = 734 mm^2

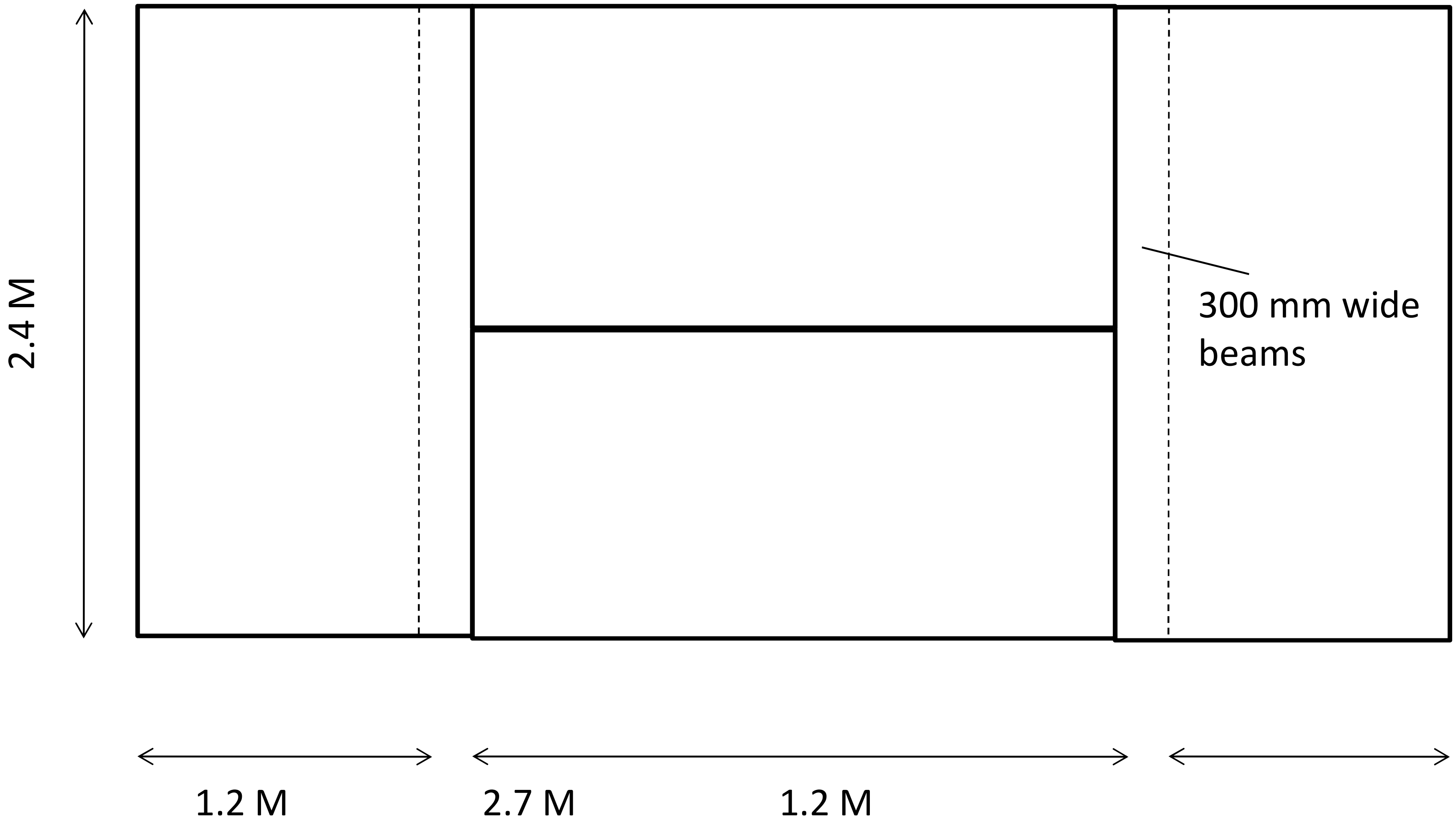
Provide #12 @ 125 mm c/c



* Landing Slab main bar to be placed first

Example 4

Design the Dog legged staircase supported at the junction of landing and going on 300 mm wide beams such that landing slab are cantilevers. Floor finish = 1 kN/m^2, Live load = 5 kN/m^2, riser R = 160 mm, tread T = 270 mm, M 20 and Fe 415.


2.4 M
300 mm wide beams
1.2 M
2.7 M
1.2 M

Step 1: Effective Span (Le) of each flight

Going: Le = 2.7 + 0.3 = 3 m

Landing:Le = 1.2+0.15 = 1.35m

Step 2: Trial Depth of Waist Slab

Le/d = 25 ; d = 3000/25 = 120 mm

Le/d = 8 ; d = 1350/8 = 170 mm

Clear cover = 20mm; Dia of bars = 10mm

D = 160 + 20 + 5 = 185 mm

Adopt D = 175 mm, d = 150 mm

Step 3: Design of Going Slab (kN/m^2)

<u>Loads on going</u> (kN/m^2)

$\text{Cos}(\theta) = 270/(270^2+160^2)^{0.5} = 0.86$

Self-weight of waist-slab = 25(0.175) / Cos(θ) = 5.09
Self-weight of steps = 24(0.16/2) = 1.92
Finishes = 1.0
Live loads = 5.0

Total = 13

Factored loads = 1.5(13) = 19.5 kN/m^2

Loads on Landing *(kN/m²)*

Self-weight of slab = 25(0.175) = 4.4
Finishes = 1.0
Live loads = 5.0

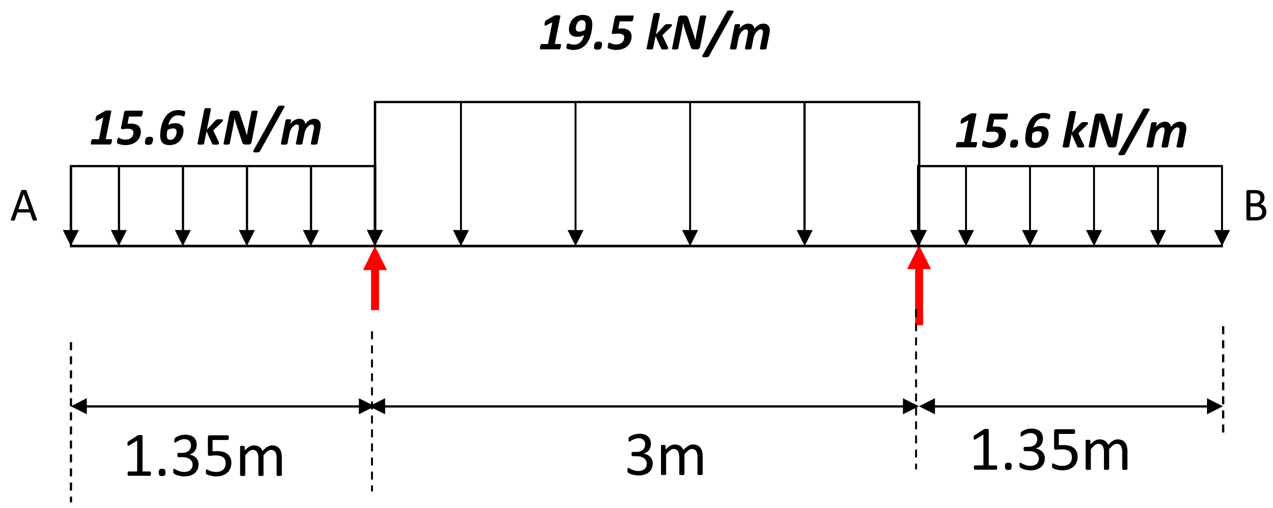
Total = 10.4

Factored loads = 1.5(10.4) = 15.6 kN/m^2

Consider I M width

Step 4: Limit state of Collapse - Flexure

Consider 1m width of flight



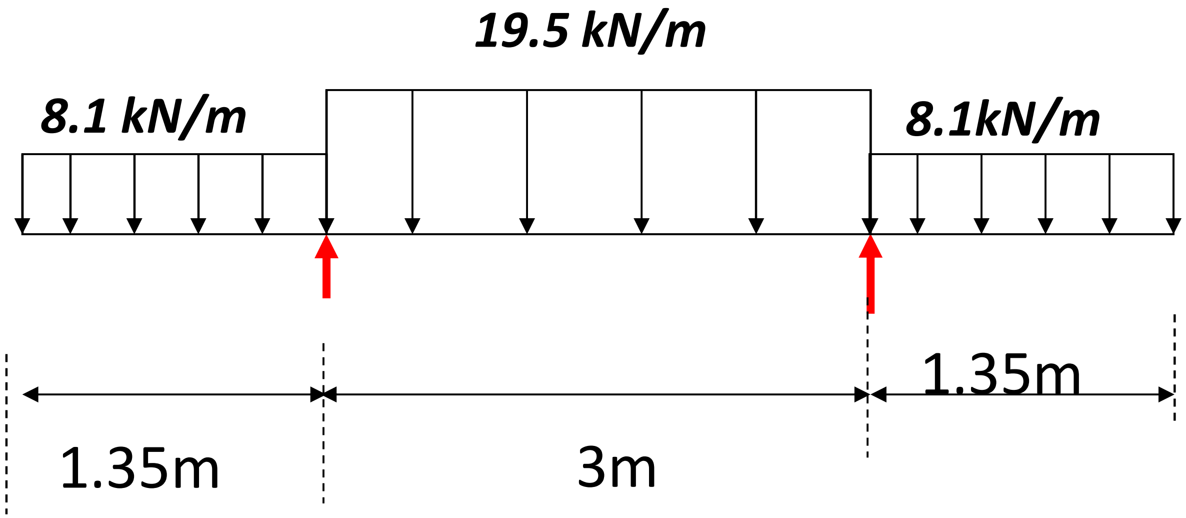
i) <u>Negative Mu(@ supports)</u>

$= 15.6 \times 1.35^2/2 = 14.22$ kNm per m width

ii) Positive Moment at Mid Span

Loading on Going = 19.5 kN/m (DL+LL+Finish)

Loading on Landing = 8.1 kN/m (DL+Finish)



$$= 19.5 \times 3^2/8 - 8.1 \times 1.35^2/2 = 14.56 \text{ kNm per m width}$$

iii) $M_{u,lim} = 0.36 \times 0.48 \times (1-0.42 \times 0.48) \times 1000 \times 20 \times 150^2$

$= 62.1$ kNm > Mu   Depth OK

v) *Compute Ast per m width*

Positive Moment = 14.56 kNm per m width

$14.56 \times 10^6 = 0.87 \times 415 \times Ast \times 150 \times (1- 415 \times Ast/(1000 \times 150 \times 20))$

$14.56 \times 10^6 = 54157.5\ Ast - 7.49\ Ast^2$

Ast = 280 mm^2

Negative Moment = 14.22 kNm per m width

Provide Ast = 280 mm^2

iv) Ast. Minimum = 0.12 x1000x175/100 = 210 $mm^2 < 280\ mm^2$

iv) Rebar Details

Main steel: Assume #10 bars

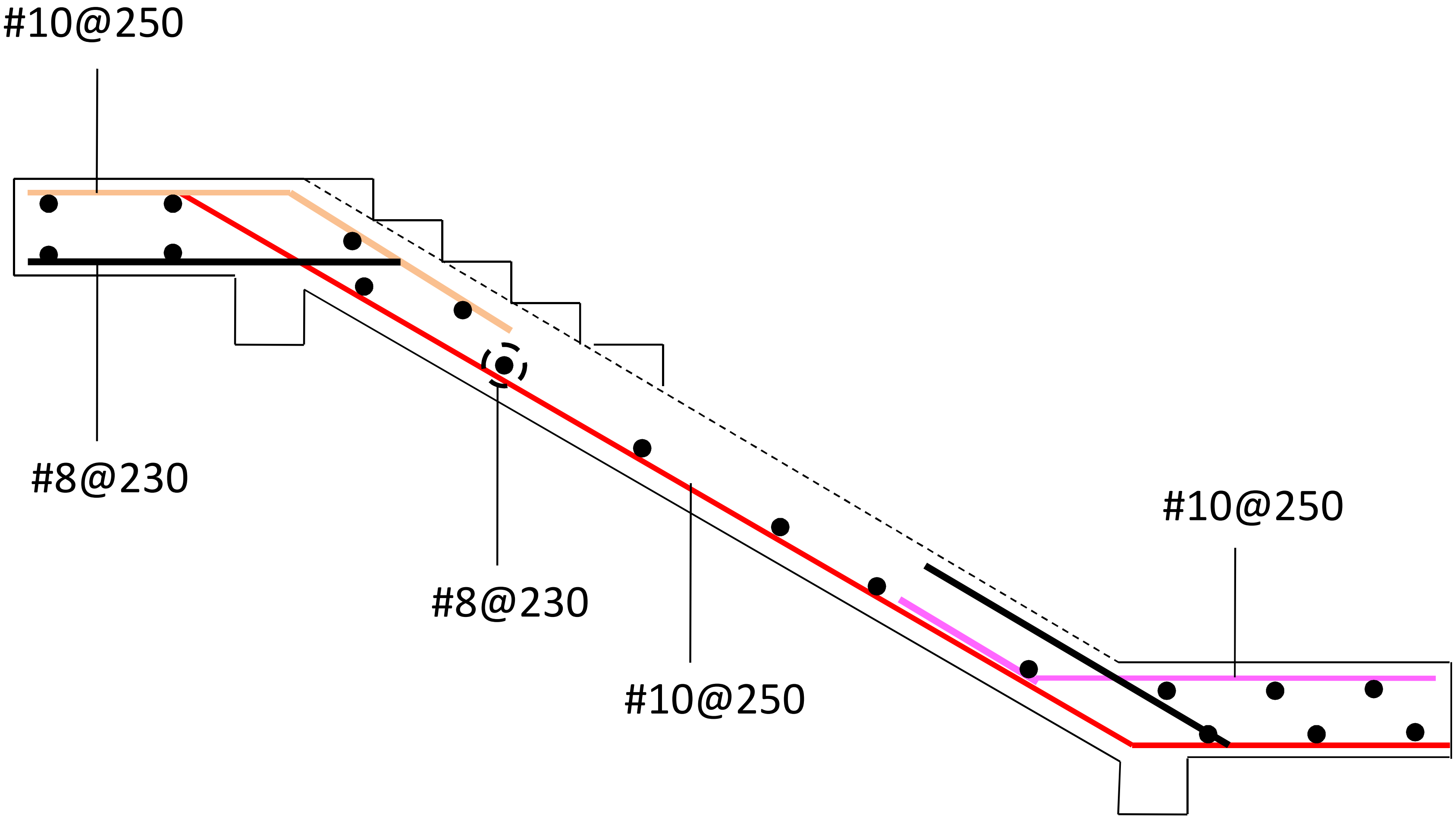
S = 1000x 78.54/280 = 280 mm c/c < max spacing

Provide #10 @ 250 mm c/c both in Going and Landing

Distribution Steel: Assume #8 bars

S = 1000x50/210 = 238mm

Provide #8 @ 230 mm c/c


#10@250
#8@230
#8@230
#10@250
#10@250

Exercise

- A dog legged stair case is to be detailed with the
- following particulars:
- Clear dimension of stair case room=4.48 m x 2.1 m
- The floor to floor height is 3.2 m
- Width of each tread =250 mm
- Width of each rise = 160 mm
- Thickness of waist slab = 150 mm
- Width of flight =1m
- All round wall = 230 mm