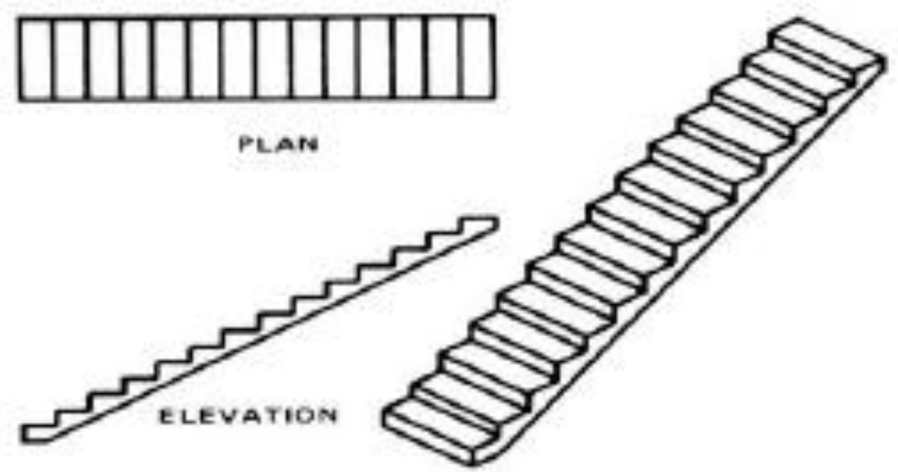
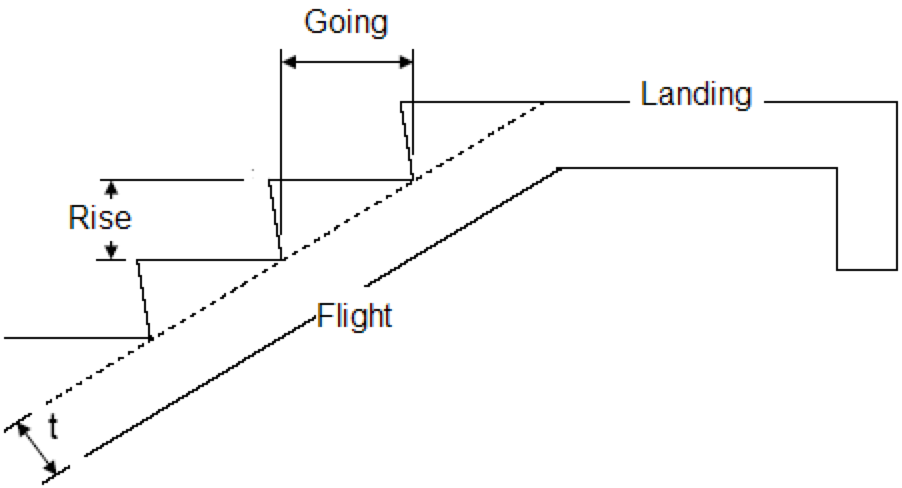
Stair Design

Stair Types

Straight stairs

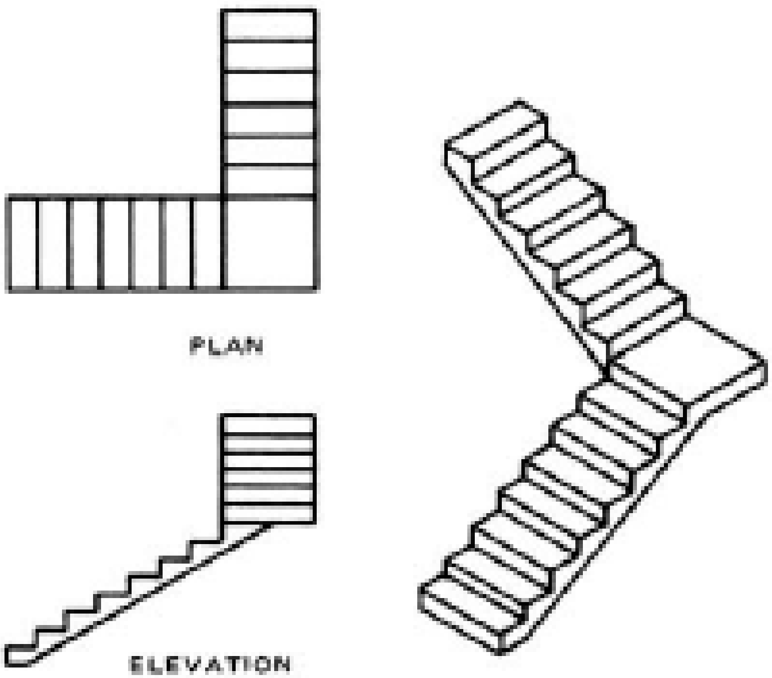




L stairs

a. One landing with a turn

b. Used when little space is available

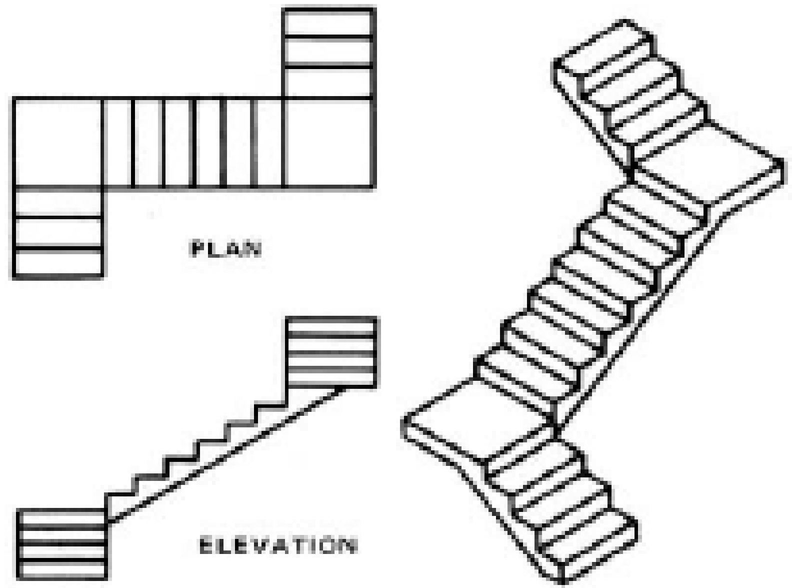


Double-L stairs

a. Two 90 degree turns, and two landings

b. Not U shaped

c. Often used in residential construction



U stairs

a. Two flights of parallel stairs

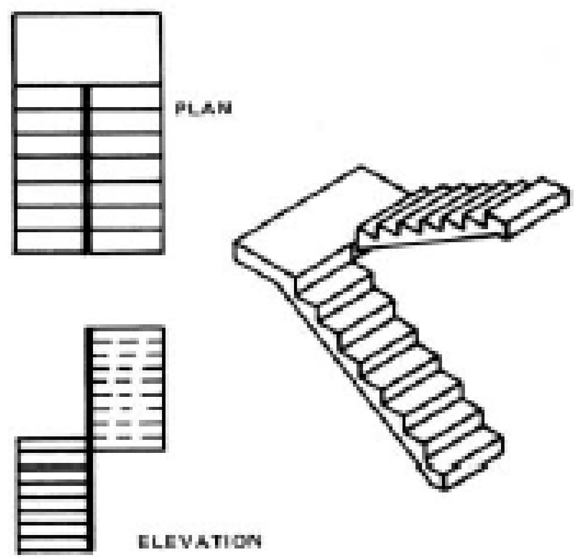
b. Introduces a landing midway the run

c. May be open or closed

d. Types

    1. Narrow U

    2. Wide U



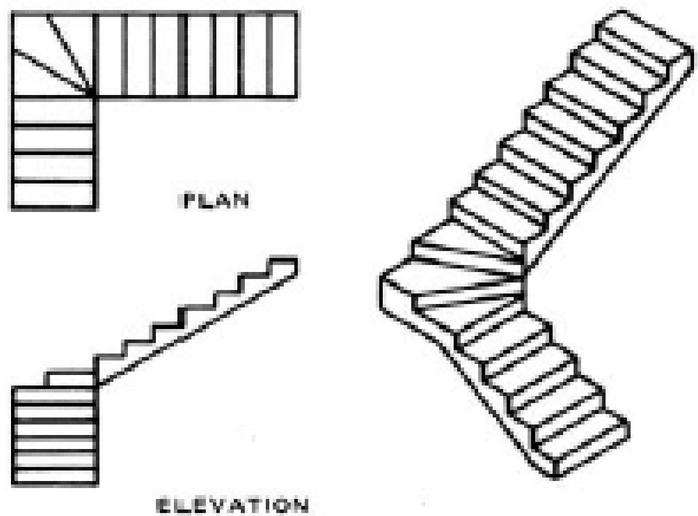
Winder stairs

a. Used in place of a landing

b. Pie-shaped (triangular) steps

c. Mid-point width should be equal to regular tread width.

d. Not very safe

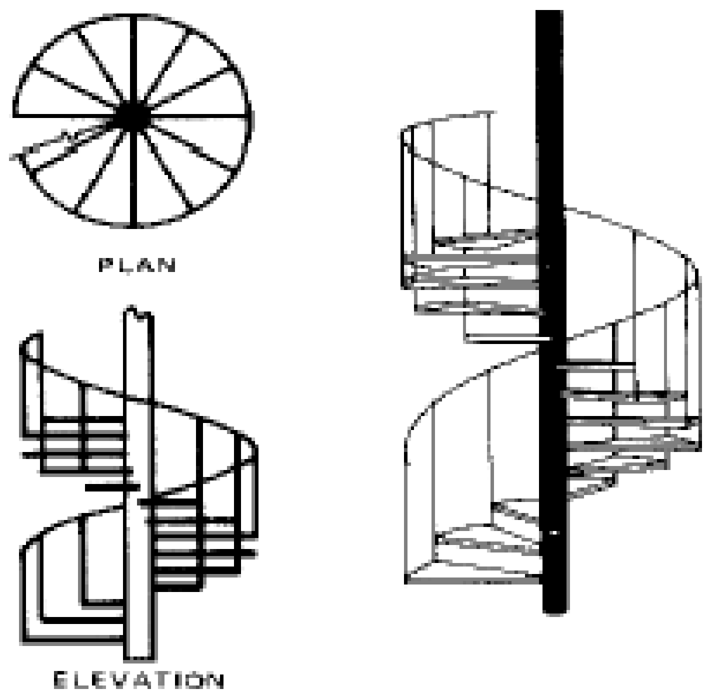


Spiral Stairs

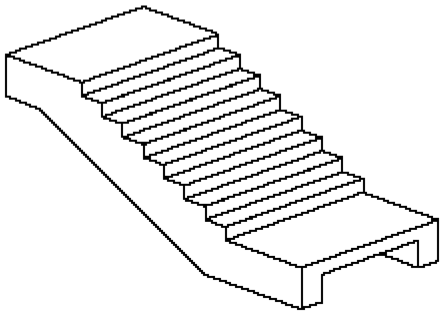
a. Rise in a circle about a point

b. Decorative styles can be used

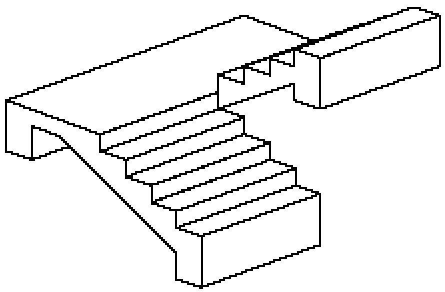
c. Used where little space is available



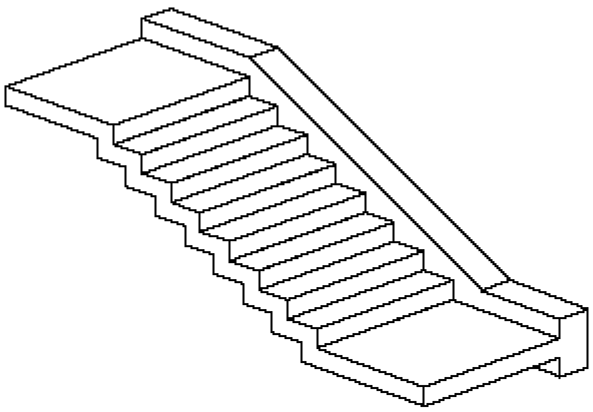
Stair Type based on the structural loading type



Simply supported stair
(transversely supported)



Longitudinally supported stair



Cantilever stair

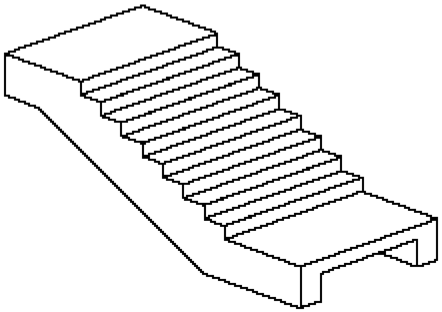
Simply supported stair

Design a straight flight stair in a residential building supported on reinforced concrete wall 1.5 m)(center to center)

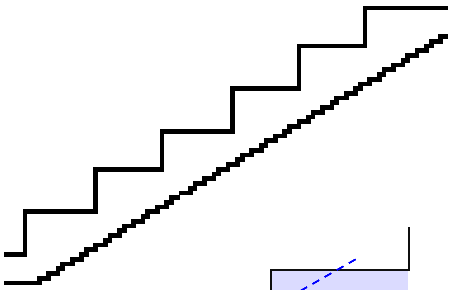
L.L = 3kN/m2

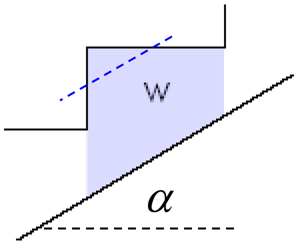
Covering Material = 0.5kN/m

The riser are 16cm and goings are 30 cm



➤Loads and Analysis



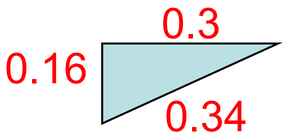


$$h_{\min} = \frac{l}{20} = \frac{150}{20} = 7.5cm$$

$$h_{ave} = 8 + \frac{7.5}{\cos\alpha} = 8 + \frac{7.5}{\frac{16}{\sqrt{30^2+16^2}}} = 16.5cm$$

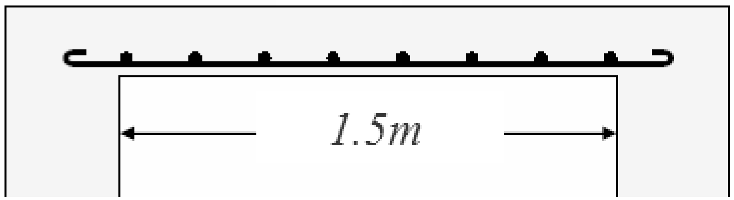
D.L(*O.W*) =0.34*0.075*25 + 0.5*0.16*0.3*25=1.24 kN/m

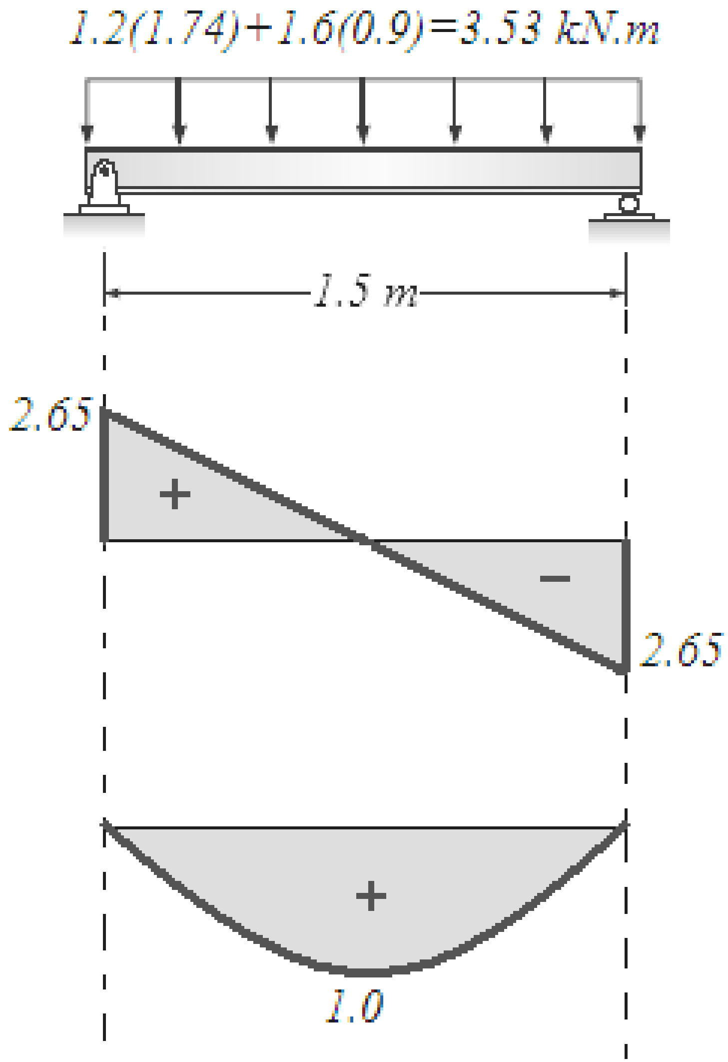
D.L (covering material) = 0.5 kN/m



D.L (total) = 1.74 kN/m

L.L =3*(0.3) =0.9 kN/m




1.2(1.74)+1.6(0.9)=3.53 kN.m
1.5 m
2.65
+
−
2.65
+
1.0

Design for moment

$$M_u = 1kN.m$$

$$d = 16.5 - 2 - 0.6 = 13.9cm = 139mm$$

$$b_w = 30cm = 300mm$$

$$assume \Rightarrow \rho \leq \rho_{\lim} \rightarrow \phi = 0.9$$

$$\rho = \frac{0.85(25)}{420}\left[1 - \sqrt{1 - \left(\frac{2 \times 10^6 \times 1}{0.85(0.9)(25)300 \times 139^2}\right)}\right] = 0.0005 < \rho_{\min}$$

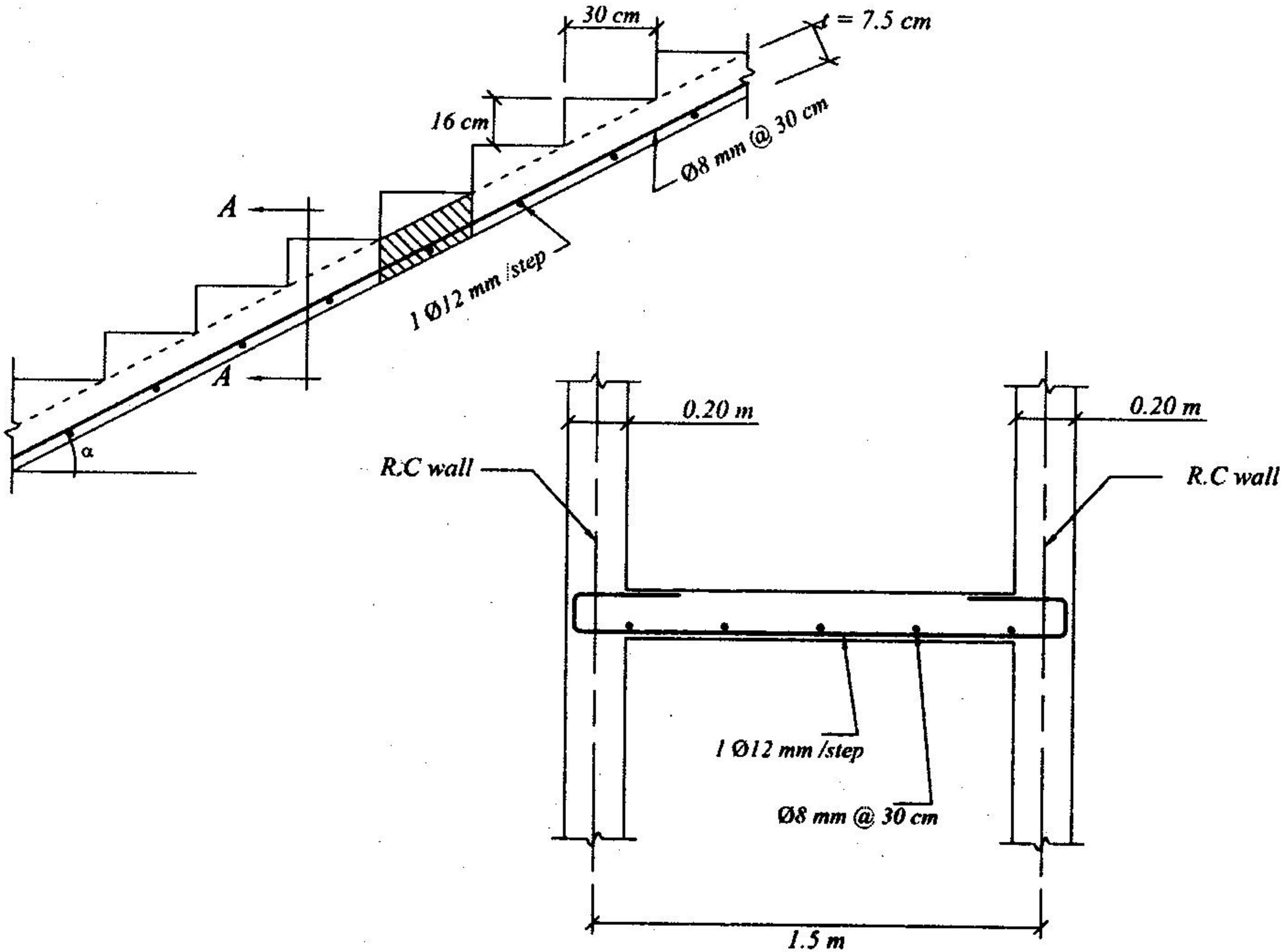
$$As_{\min} = 0.0018 * 300 * 165 = 89.1mm^2 = 0.9cm^2$$

use

$1\phi 12$ for each step

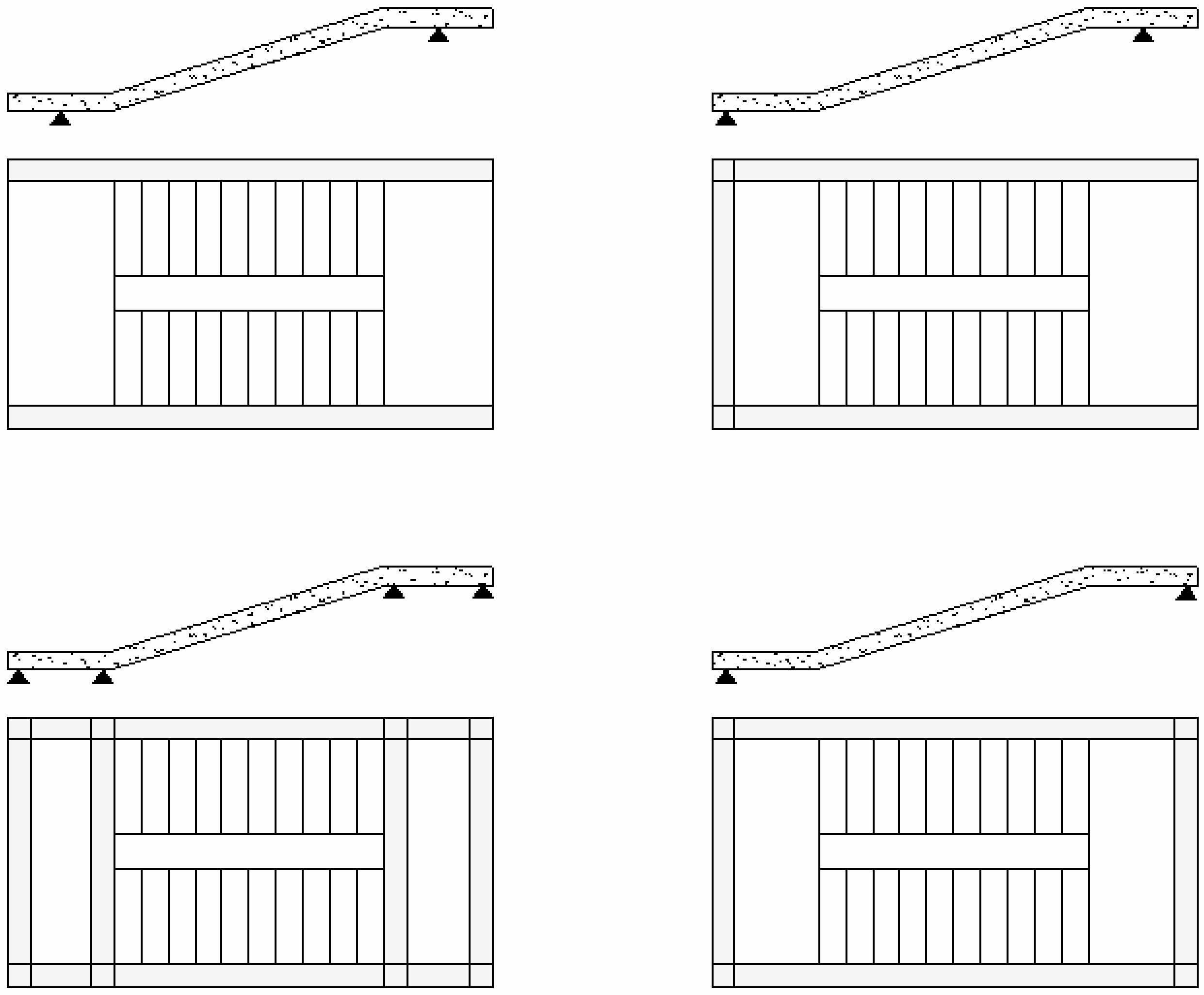
Design for shear

$$\phi V_C = 0.75 \times \frac{\sqrt{25}}{6} \times 139 \times 300 / 1000 = 26kN > V_u$$



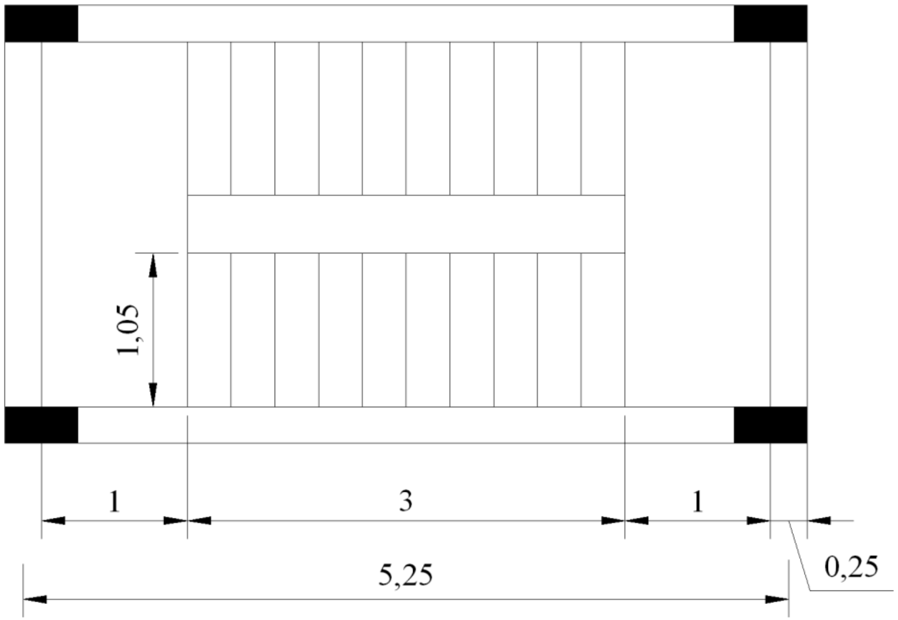
30 cm
t = 7.5 cm
16 cm
Ø8 mm @ 30 cm
A
A
1 Ø12 mm /step
α
0.20 m
0.20 m
R.C wall
R.C wall
1 Ø12 mm /step
Ø8 mm @ 30 cm
1.5 m

Longitudinal – Supported stairs

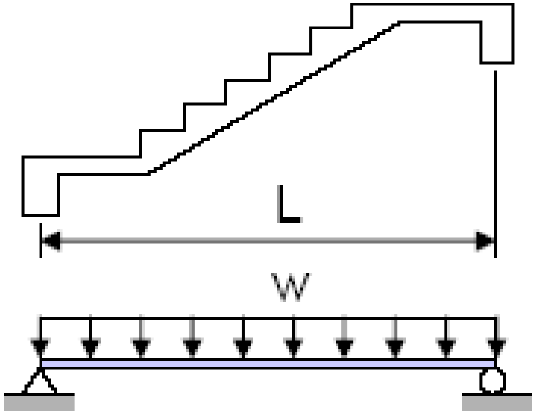


Longitudinal – Supported stairs (Example)

Design a U- stair in a residential building L.L = 3 kN/m2
Covering Material = 2 kN/m²
The riser are 16 cm and goings are 30 cm



➢Loads and Analysis

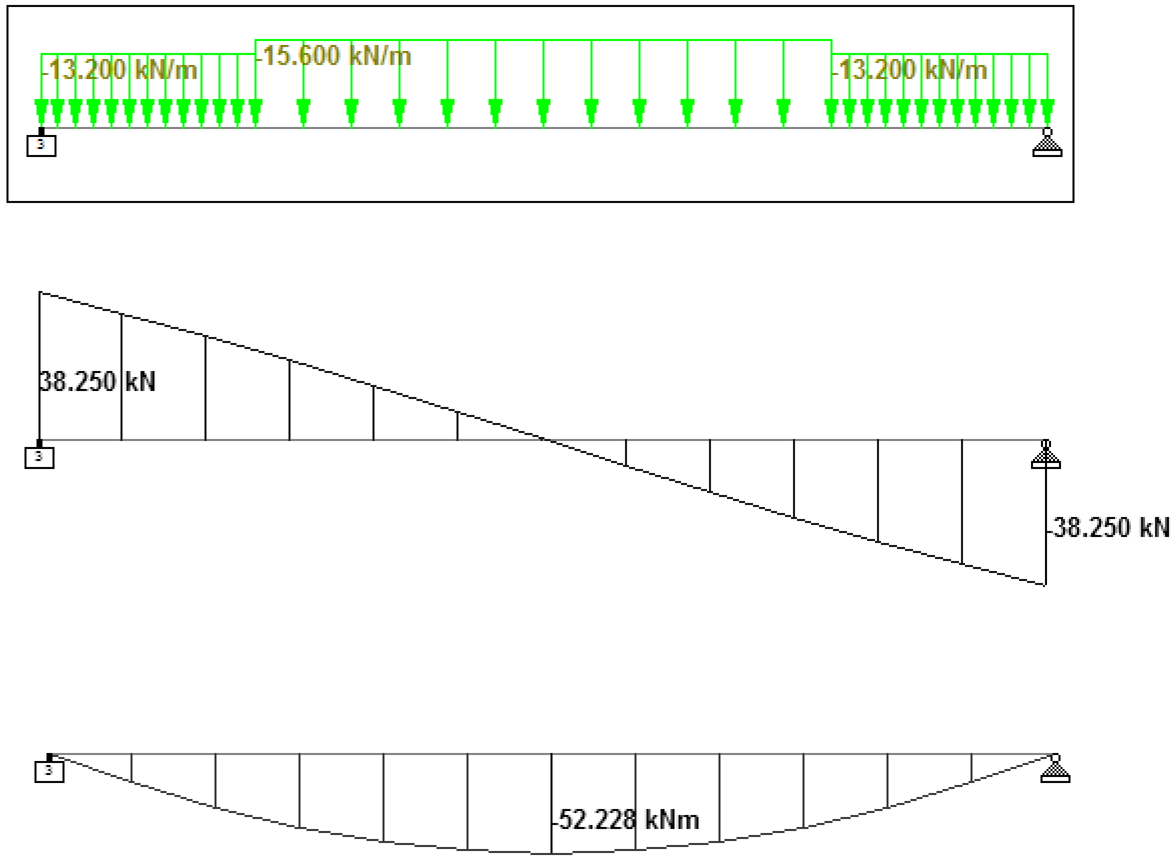


$$h_{\min} = 0.85\frac{l}{20} = \frac{525}{20} \approx 22cm$$

D.L (*slab*) = *0.22*25 =5k*N/*m2*
D.L (*step*) = *0.5*0.16*25=2 k*N/*m2*
D.L (*covering material*) = *2 k*N/*m2*

D.L (flight) = 9 kN/m2
D.L (landing) = 7 kN/m2
L.L =3 kN/m2

W_u (flight) = 1.2(9)+1.6(3)=15.6kN/m
W_u (landing) = 1.2(7)+1.6(3)=13.2kN/m



-13.200 kN/m
-15.600 kN/m
-13.200 kN/m
38.250 kN
-38.250 kN
-52.228 kNm

Design for moment

$$M_u = 52.2kN.m$$

$$d = 22 - 2 - 0.6 = 19.4cm = 194mm$$

$$b_w = 105cm = 1050mm$$

$$assume \Rightarrow \rho \leq \rho_{\lim} \rightarrow \phi = 0.9$$

$$\rho = \frac{0.85(25)}{420}\left[1 - \sqrt{1 - \left(\frac{2 \times 10^6 \times 52.2}{0.85(0.9)(25)1050 \times 194^2}\right)}\right] = 0.0036$$

$$As_{\min} = 0.0036 * 1050 * 194 = 733.32mm^2 = 7.33cm^2$$

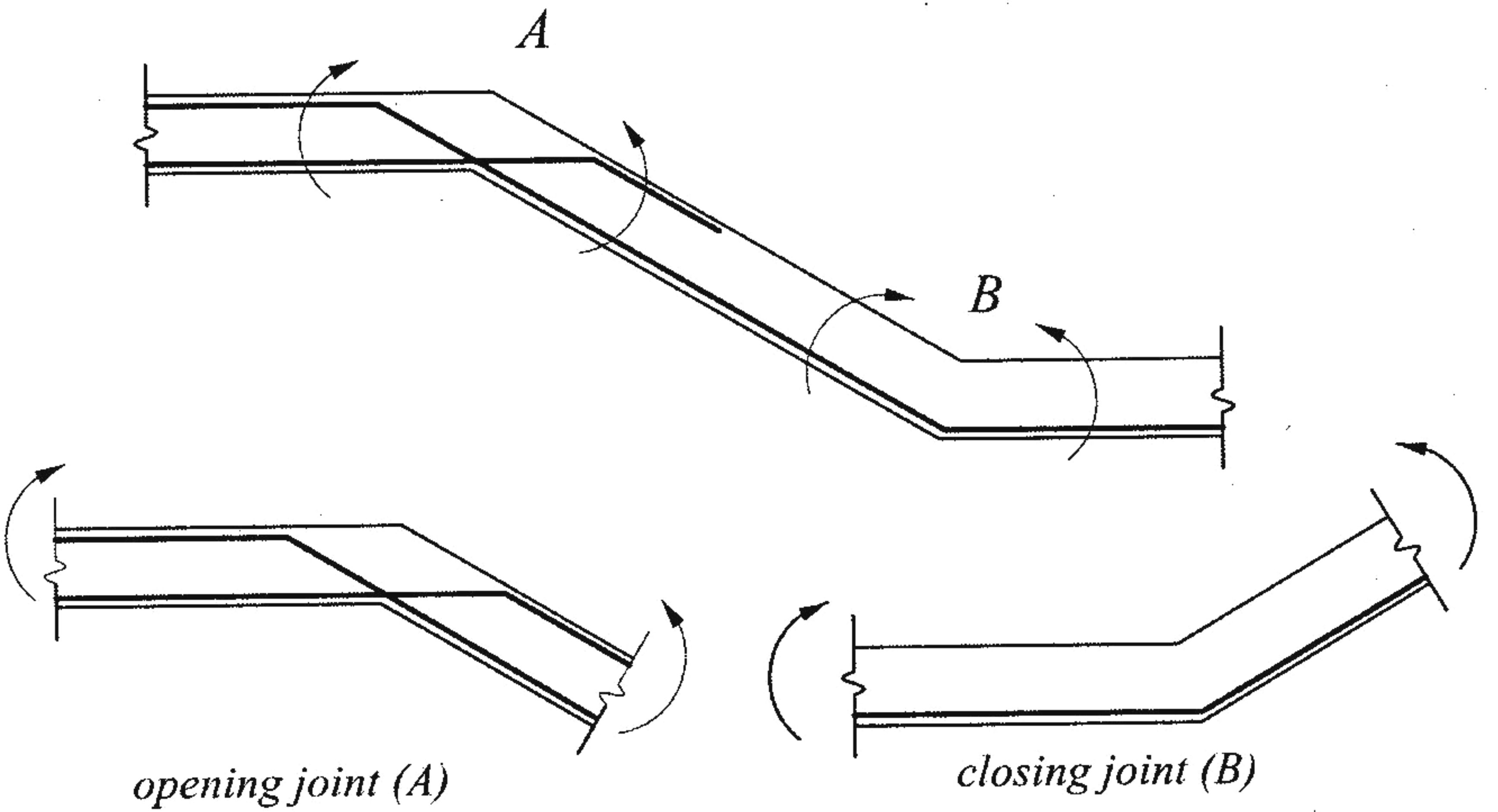
$$use$$

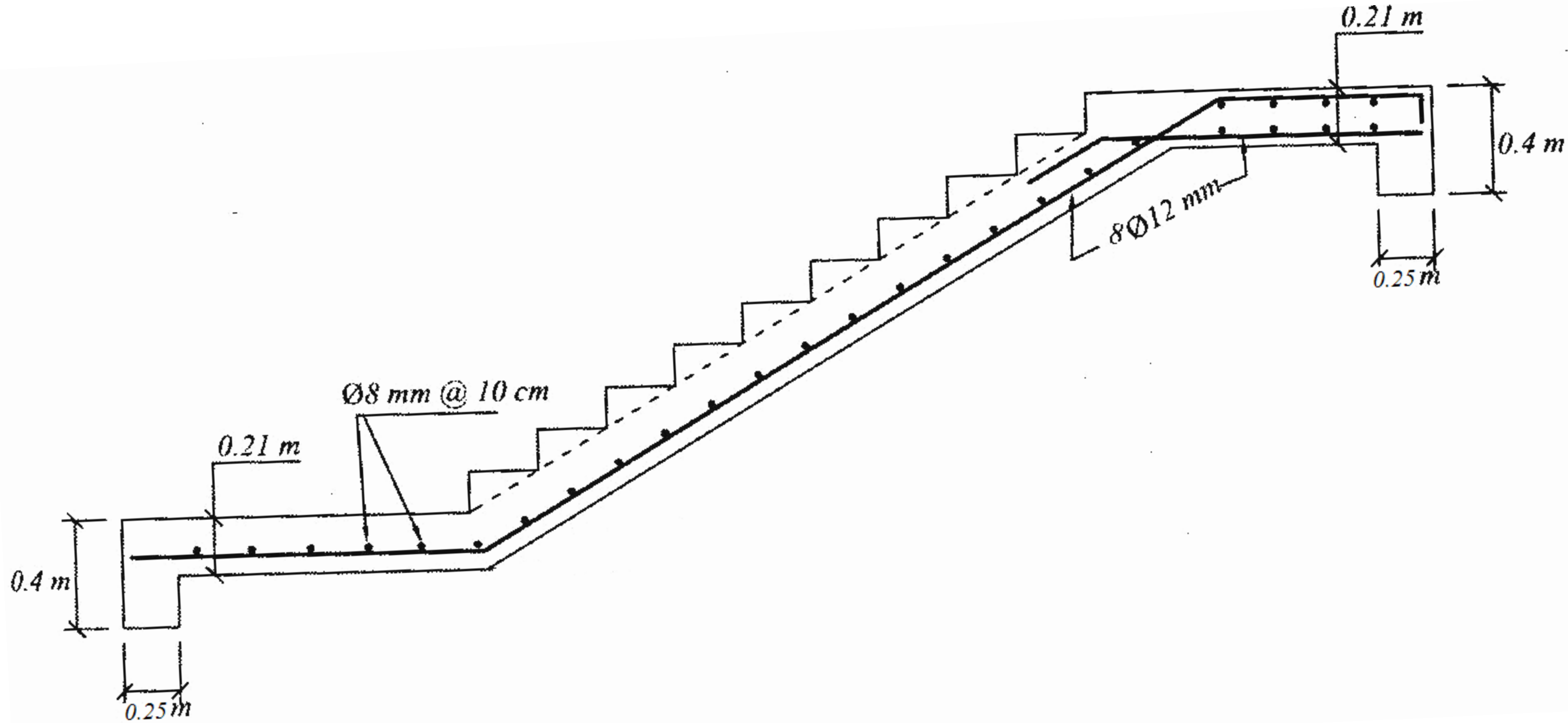
$$8\phi 12$$

Design for shear

$$\phi V_C = 0.75 \times \frac{\sqrt{25}}{6} \times 194 \times 1050 \ / 1000 = 127.3kN > V_u$$

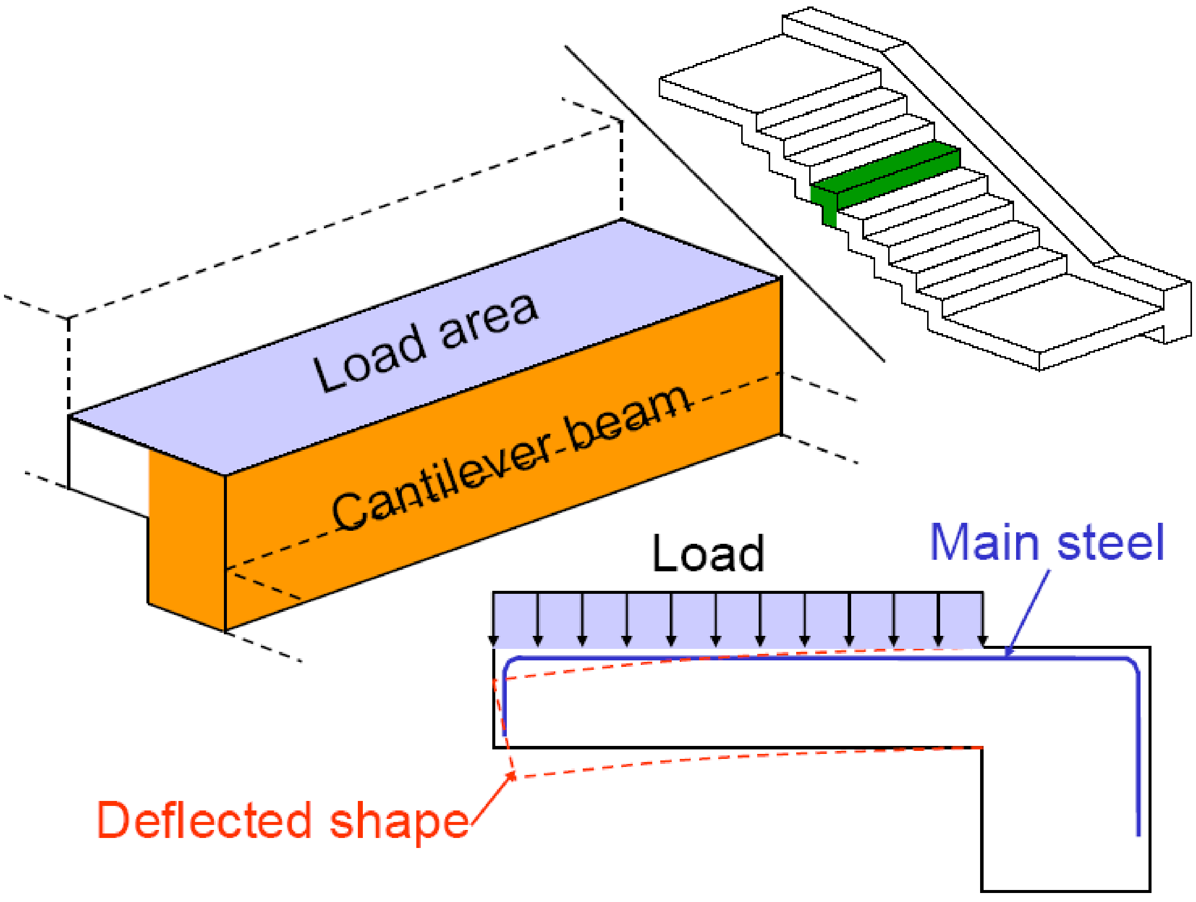
Reinforcement Notes





0.21 m
0.4 m
8Ø12 mm
0.25 m
Ø8 mm @ 10 cm
0.21 m
0.4 m
0.25 m

Cantilever Stair



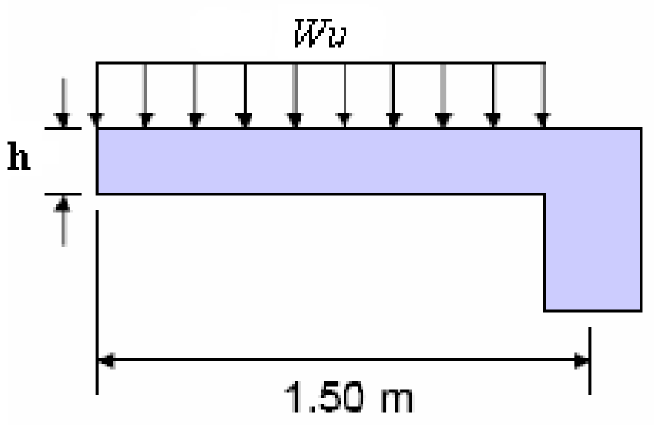
Cantilever stairs (Example)

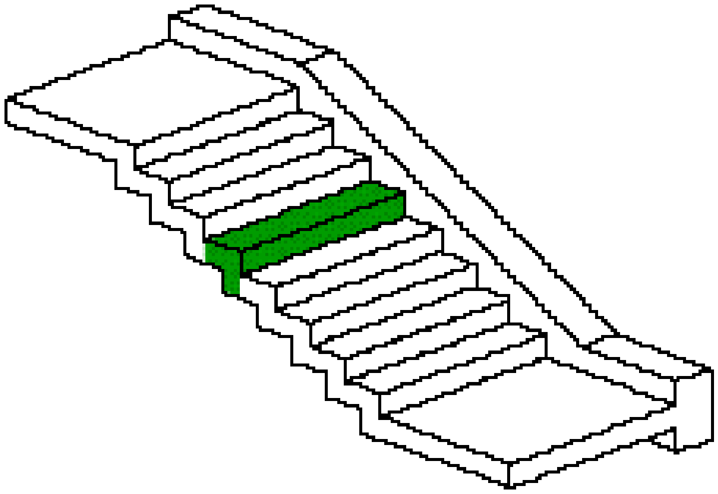
Design a cantilever straight flight stair in a residential building

L.L = 3kN/m2

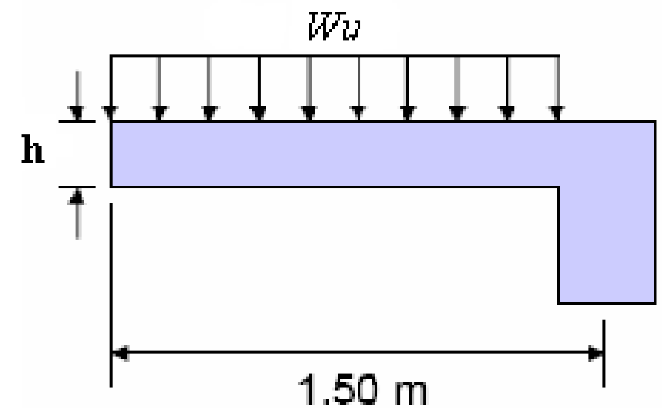
Covering Material = 0.5kN/m

The riser are 16cm and goings are 30 cm





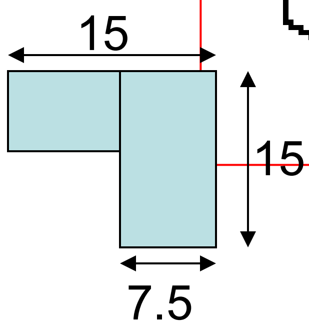
$$h_{\min} = \frac{l}{10} = \frac{150}{10} = 15cm$$

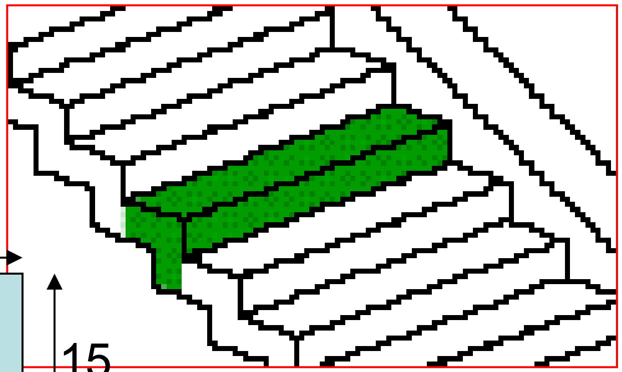


D.L(*O.W*) =0.15*0.075*25 + 0.15*0.075*25=0.6 kN/m
D.L (covering material) = 0.5 kN/m

D.L (total) = 1.1 kN/m
L.L =3*(0.3) =0.9 kN/m

Wu = 1.2(1.1)+1.6(0.9) = 2.76 kN/m
Vu = 2.76(1.5) = 4.14 kN
Mu = $W_u L^2/2$ = 3.1 kN.m





Design for moment

$$M_u = 3.1kN.m$$

$$d = 15 - 2 - 0.6 = 12.4cm = 194mm$$

$$b_w = 7.5cm = 75mm$$

$$assume \Rightarrow \rho \le \rho_{\lim} \rightarrow \phi = 0.9$$

$$\rho = \frac{0.85(25)}{420}\left[1 - \sqrt{1 - \left(\frac{2\times 10^6 \times 3.1}{0.85(0.9)(25)75\times 124^2}\right)}\right] = 0.0077$$

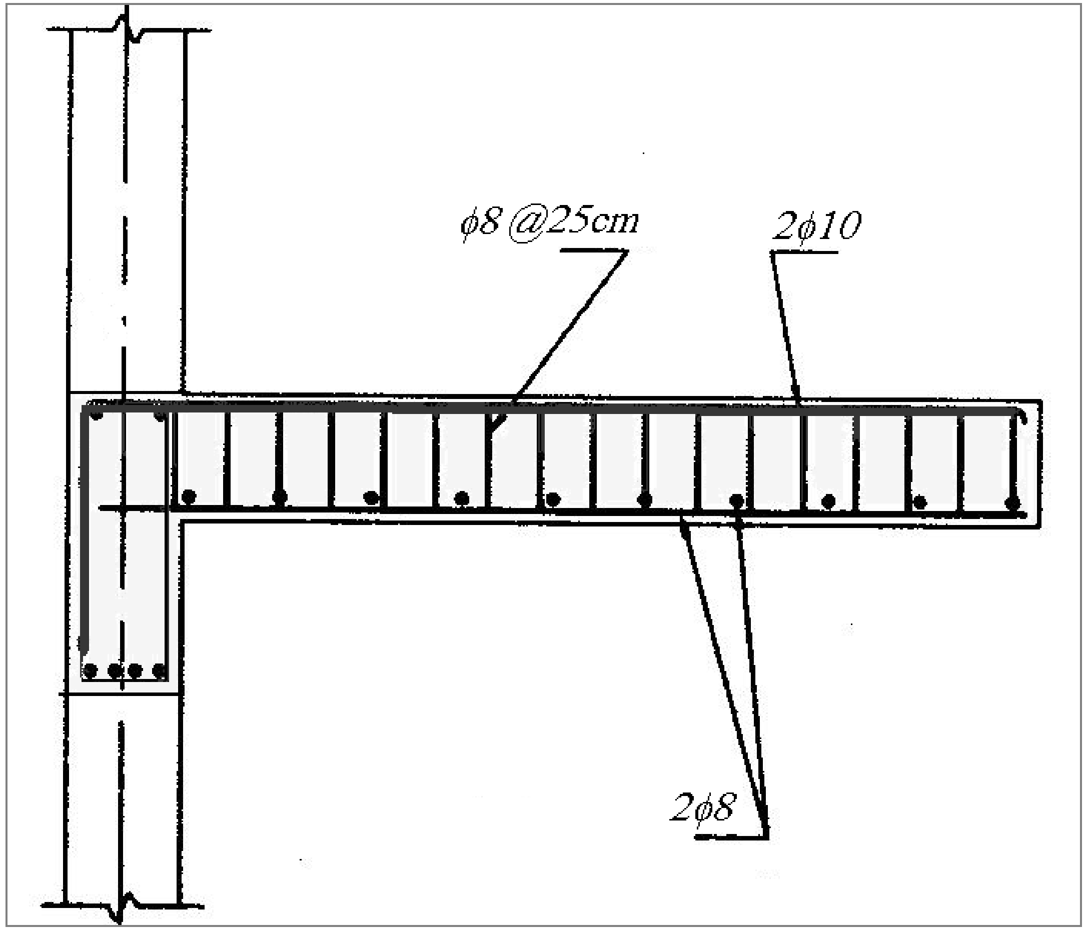
$$As_{\min} = 0.0077 * 75 * 124 = 71.61mm^2 = 0.72cm^2$$

$$use$$

$$2\phi 10$$

Design for shear

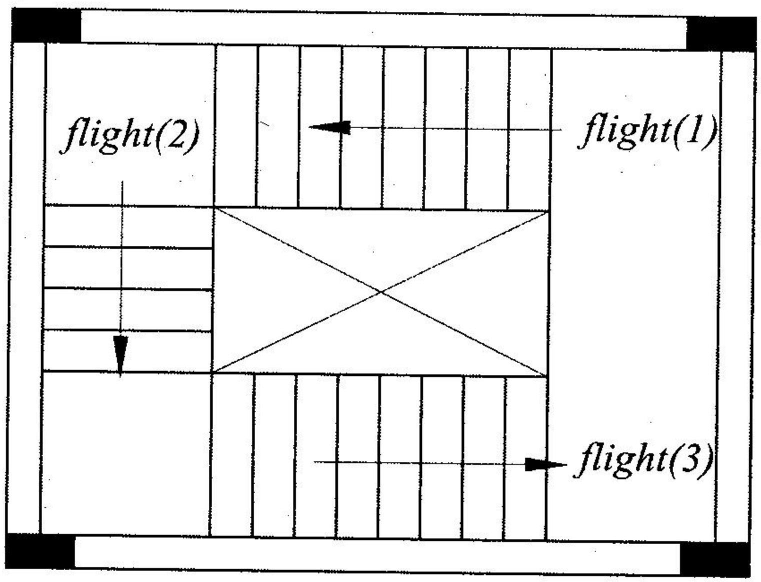
$$\phi V_C = 0.75 \times \frac{\sqrt{25}}{6} \times 124 \times 75 / 1000 = 5.8kN > V_u$$

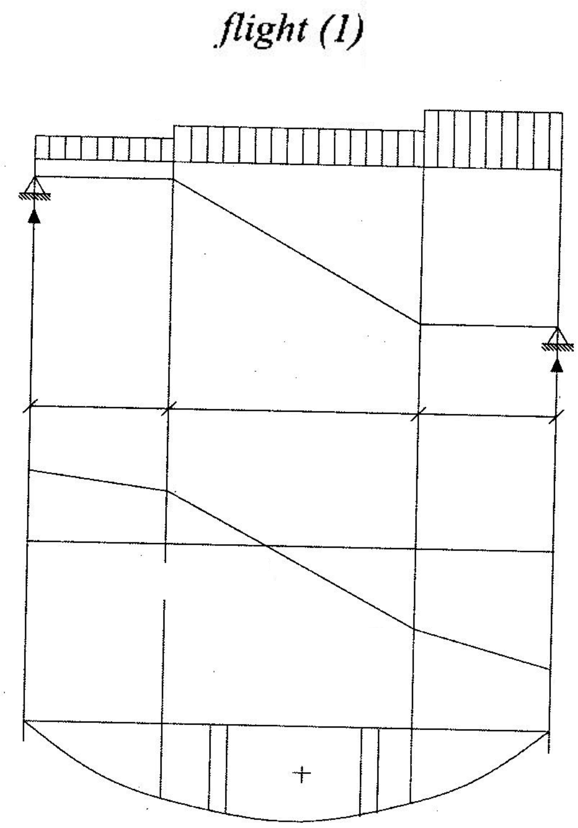


ϕ8 @25cm
2ϕ10
2ϕ8

Longitudinal – Supported stairs

Open-well stairs





General Example