STRUCTURAL DESIGN - I

Design of Staircase

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_ STAIRCASES_

A staircase is an important component of a building providing access *between the various levels or floors in a building. (Vertical Transportation)*

Technical Terms

The definitions of some technical terms, that are used in connection with the design of stairs, are given.

a) Tread or Going: horizontal upper portion of a step.

b) Riser: vertical portion of a step.

c) Rise: vertical distance between two consecutive treads.

d) Flight: a series of steps provided between two landings.

e) Landing: a horizontal slab provided between two flights.

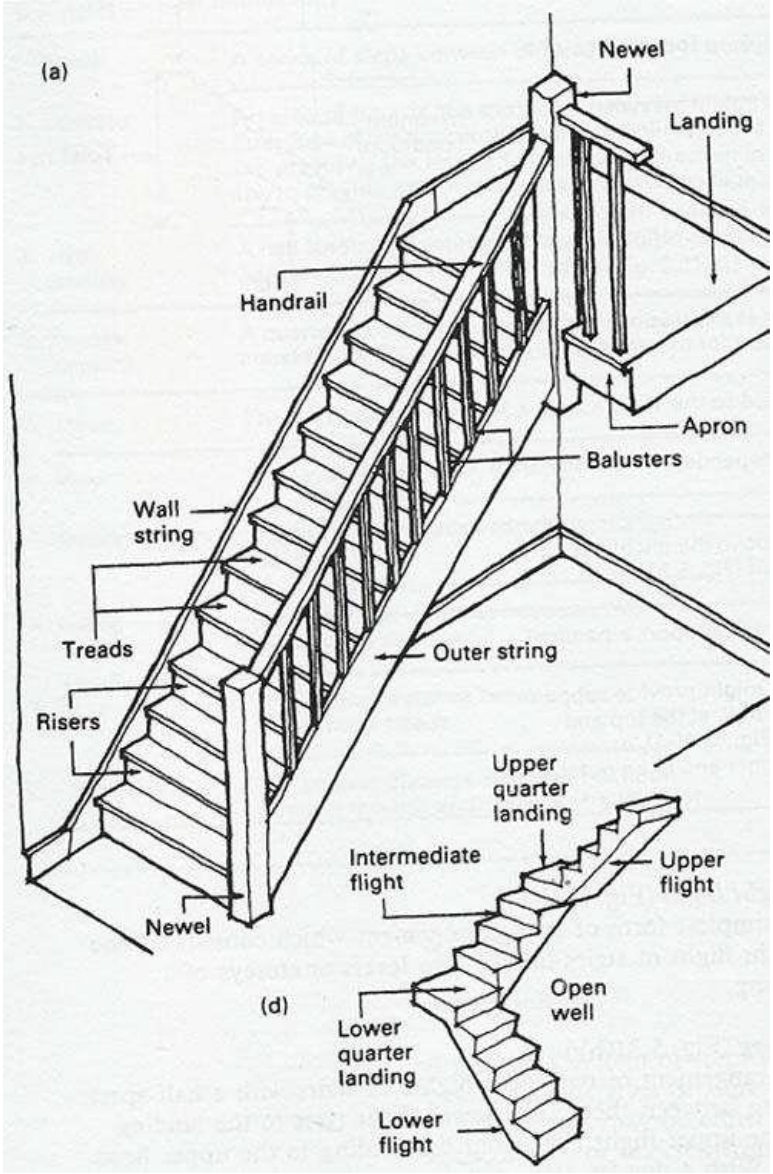
f) Waist: the least thickness of a stair slab.

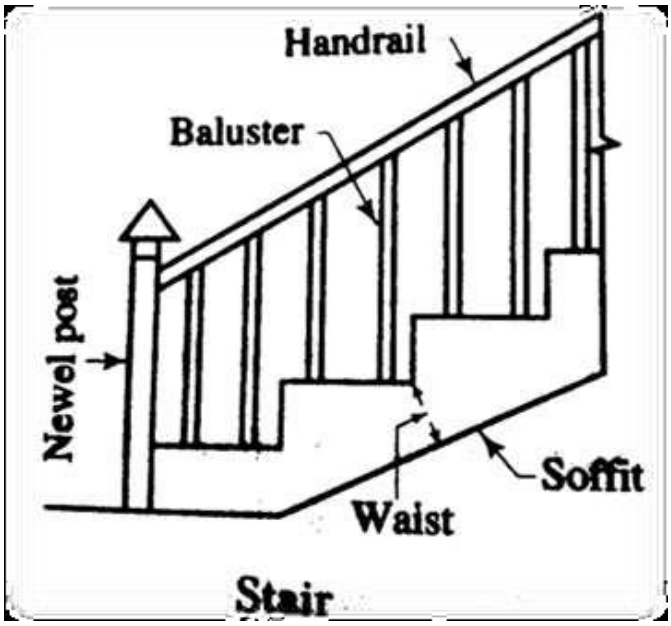
g) Winder: radiating or angular tapering steps.

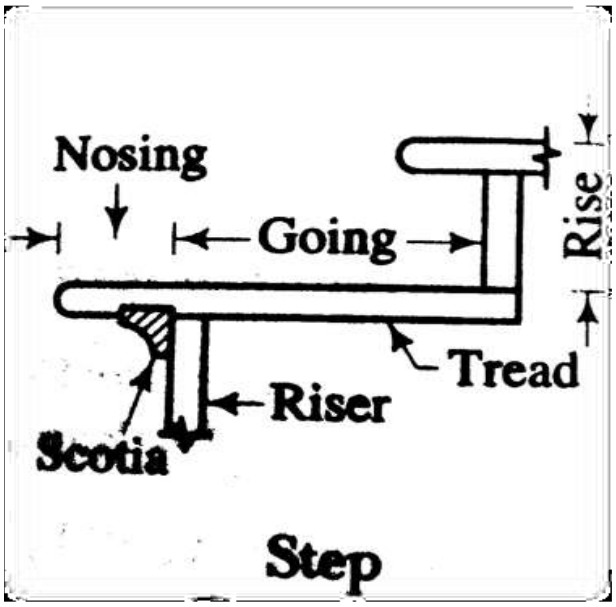
h) Soffit: the bottom surface of a stair slab.

i) Nosing: the intersection of the tread and the riser.

j) Headroom: the vertical distance from a line connecting the nosing of all treads and the soffit above.







Types of Staircase

The various types of staircases adopted in different types of buildings can be grouped under geometrical and structural classifications depending upon their shape and plan pattern and their structural behavior under loads.

Geometrical Classification

a) Straight stairs

- All steps lead in one direction.
- This may be continuous with two flights with an intermediate landing Adopted when staircase is narrow.

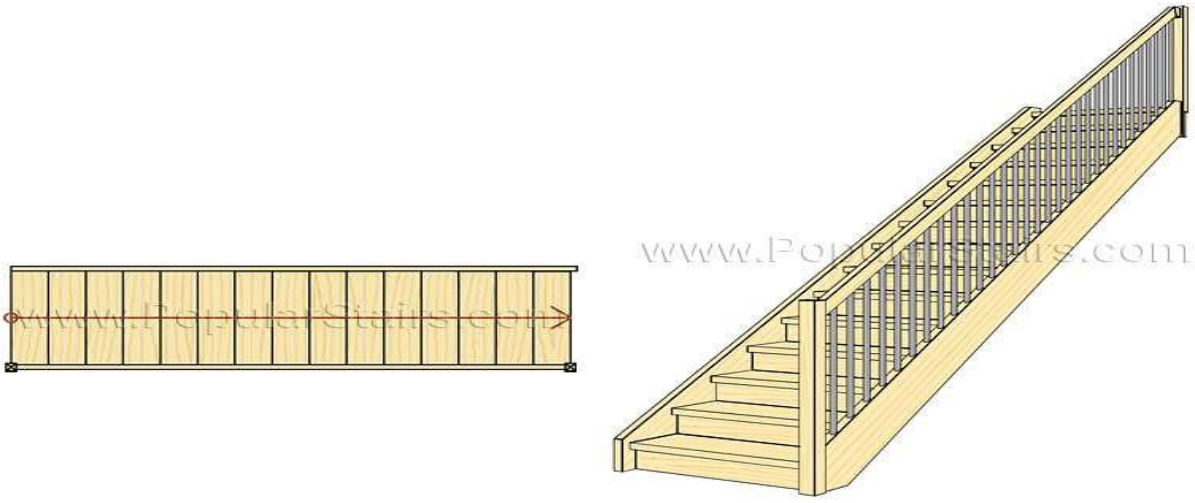


Fig.:1 Straight staircase

b) Dog-legged staircase

- Consist of two straight flights running in opposite direction
- There is no space between flights in plan
- Landing is provided at level which direction of flight changes.

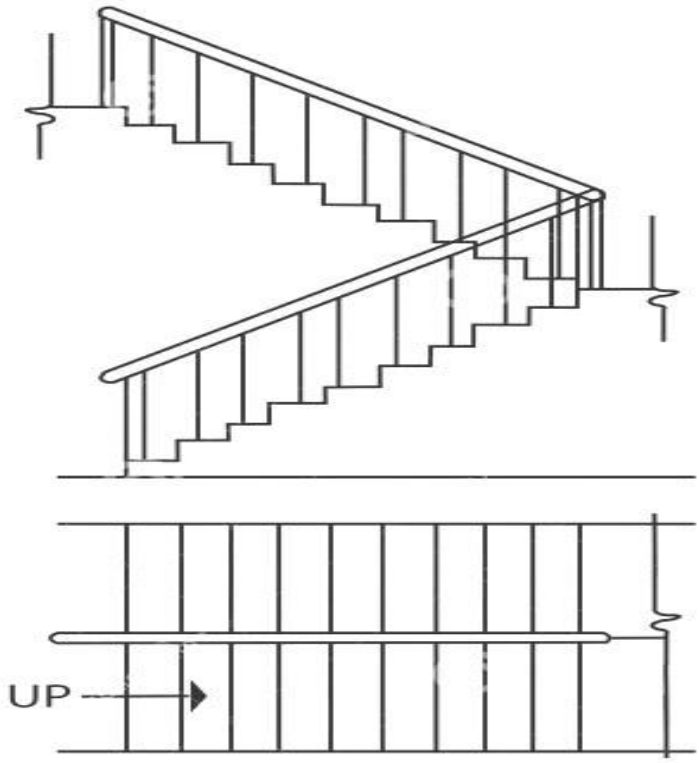


Fig.:2 Dog Legged staircase

c) Quarter turn Newel:

- A stair turning through 90˚ with the help of level landing
- Used in shops and public buildings

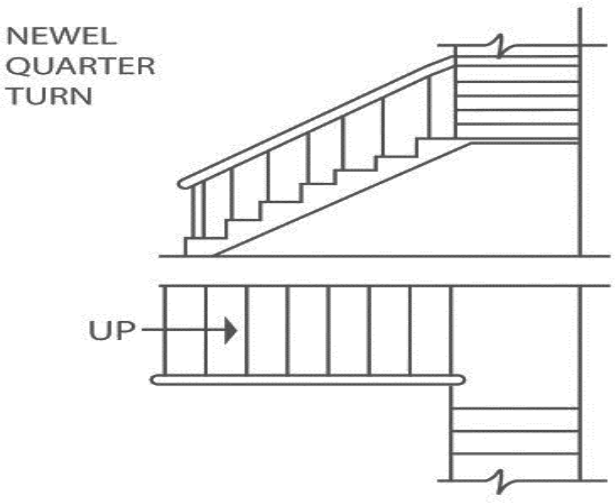


Fig.:3 Quarter turn Newel

d) Open Newel Stairs:

- Popularly known as open well stairs
- A well or opening is left between forward and backward flight

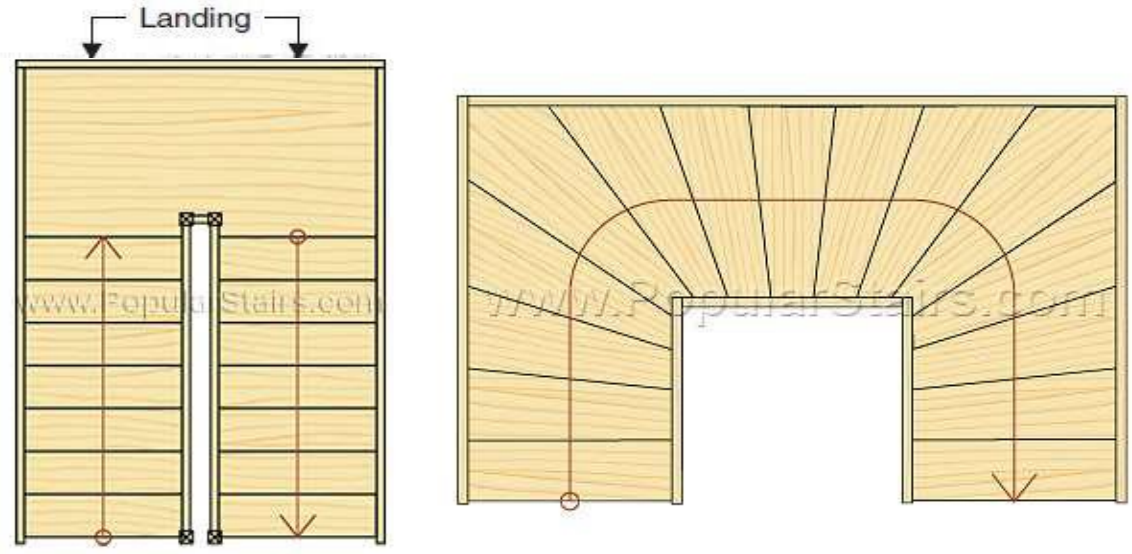


Fig.:4 Open Well or Newel

e) Circular stairs:

- All the steps radiate from a new post or well-hole
- Mostly located at the rear of the building

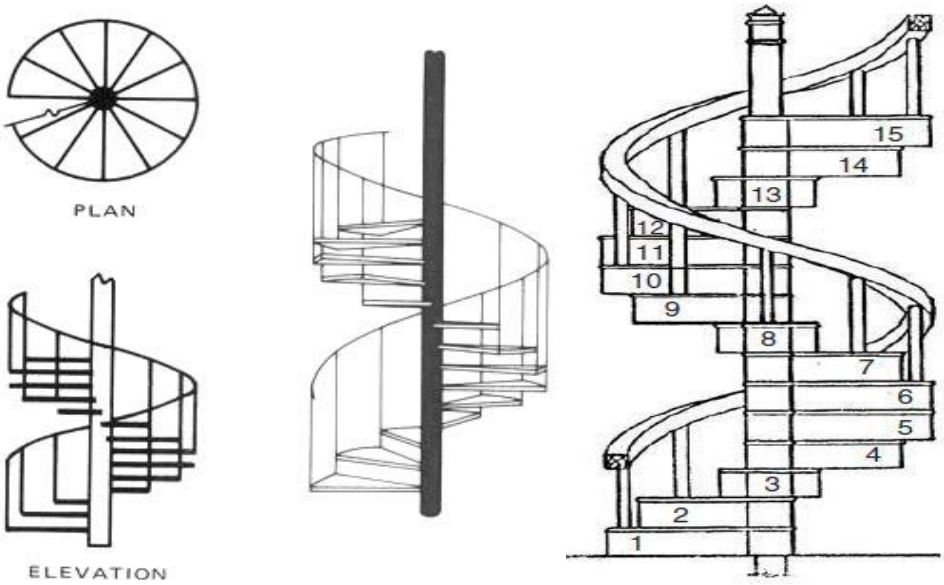
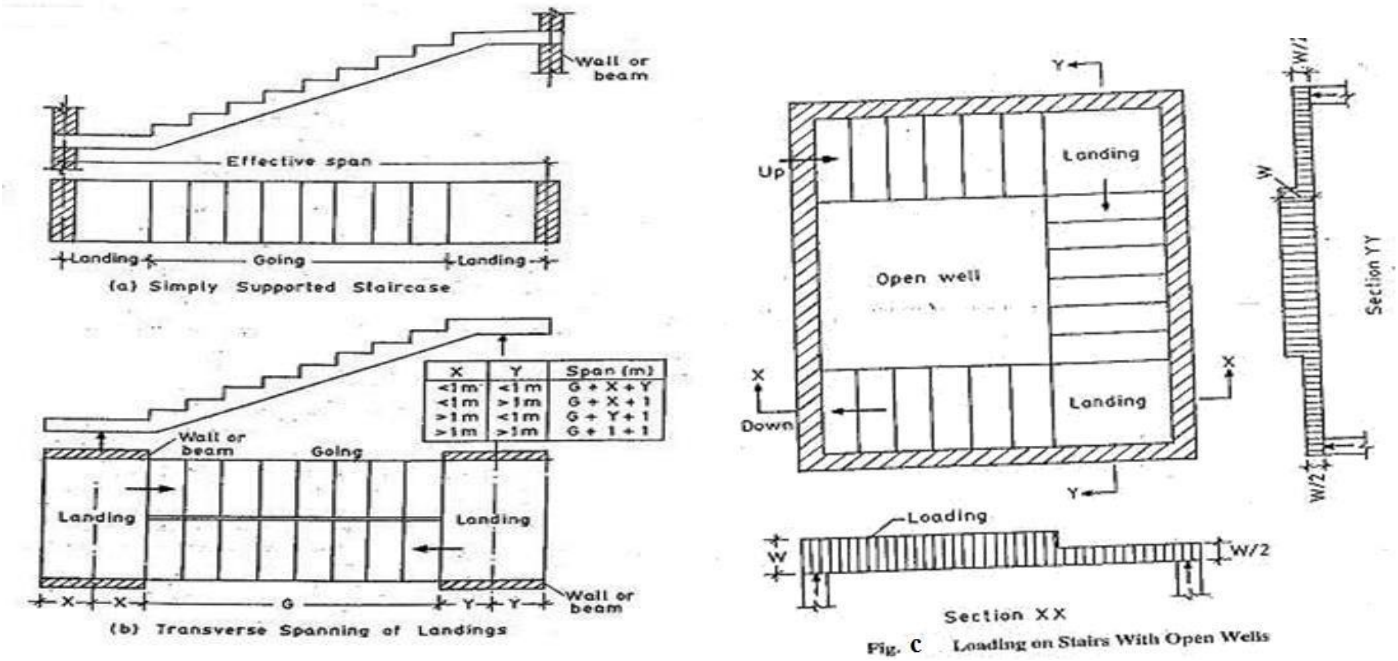


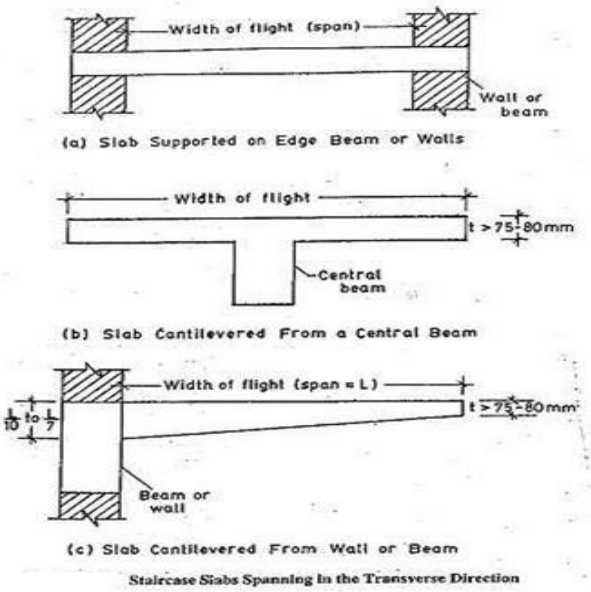
Fig.:5 Circular stairs

Structural behavior of staircases

a) Stairs Spanning in a Longitudinal direction:

- Inclined stair flight together with landing are supported on wall and beams
- The effective span is considered between the center to center of supports as in Figure a
- As in Figure b, the transverse spanning of landings span is taken
- In case of open well stairs where span partly cross at right angles the load on common area may distributed as one half in each direction in figure c.





Staircase Slabs Spanning in the Transverse Direction

b) Stair slab spanning in the transverse direction:

- Following are the examples of slabs spanning in the transverse direction
- In these slabs width of a flight being small (1-1.5m)
- A minimum thickness of 75 to 80mm should be provided.
- Minimum percentage reinforcement to resist maximum bending moment should be provided.

General Guidelines

The following are some of the general guidelines to be considered while planning a staircase:

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.

DESIGN GUIDELINES

a. Geometrical Design

- ✓ Assume Suitable Tread and Riser
- ✓ No. of Riser = (F/F Height)/Rise
- ✓ No. of Risers in One Flight =0.5*(No. Of Risers)
- ✓ No. of Tread = (No. of Risers —1)
- ✓ Going distance = (No. of tread) × (tread width)
- ✓ Width of landing ≥ width of stair

b. Structural Design

Effective span calculation

Effective span calculation = c/c distance between supports

If not given width of support can be taken in between 200 to 300 mm

- **Load Calculation**

Calculations should be made by considering the width of the slab equal to 1 meter

Self-weight of slab = 25 × D × √ $(R^2+T^2)/T$ (KN.m)

Wt of steps = 25 × 0.5 × R (KN.m)

Wt of floor finish = 1 × 1 (KN.m) (ASSUME)

Live load = 3 KN/m² (RESIDENTIAL BUILDING)

Live load = 4-5 KN/m² (PUBLIC BUILDING)

Netload (W) =W1 +W2 +W3+W4

Factored load = Wu=1.2Wd + 1.6 Wl

✓ **Calculation of design moments**

Find max bending

Notes:-

1. The dead loads especially the selfweight should be calculated for the whole inclined staircase. This self-weight includes the waist and the steps (for the horizontal span only).

2. The surfacing loads are usually horizontal (on treads of steps).

3. The live load is usually high (above $5 KN/m^2$) and acts vertically (on horizontal span).

دائماً الحمل الحي عالي جداً، لتلافي الفشل عند الازدحام في المدارس والسينما مثلاً؟ يصمم لمقدار كبير ؟؟

4. If W_u is the total ultimate load, the maximum positive bending moment is

$$M^+ = \frac{w_u \cdot l}{8}$$

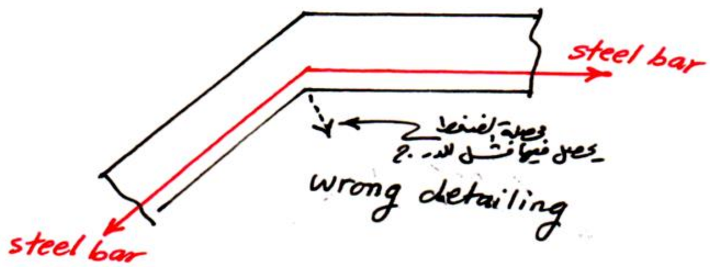
هذا العزم يؤثر في المركز (لكل الفضاء)؟ لم يؤخذ $\frac{w_u \cdot l^2}{8}$ ؟

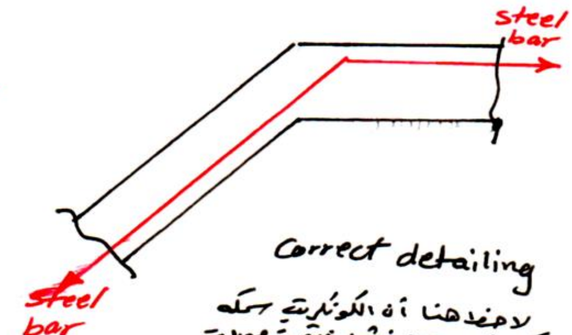
لماذا؟ لأنه هنا أي هذا المقدار (per unit length) ؟

Important note on reinforcement detailing:- ملاحظة مهمة لتفصيل الحديد

The staircase usually has bends (كسرات). The reinforcement at the bends must not follow the bend otherwise the small concrete cover at the bend will spall off (تتفتت أو يتقشر).

التسليح لا يتبع الكسرات لأنه يتقشر ؟



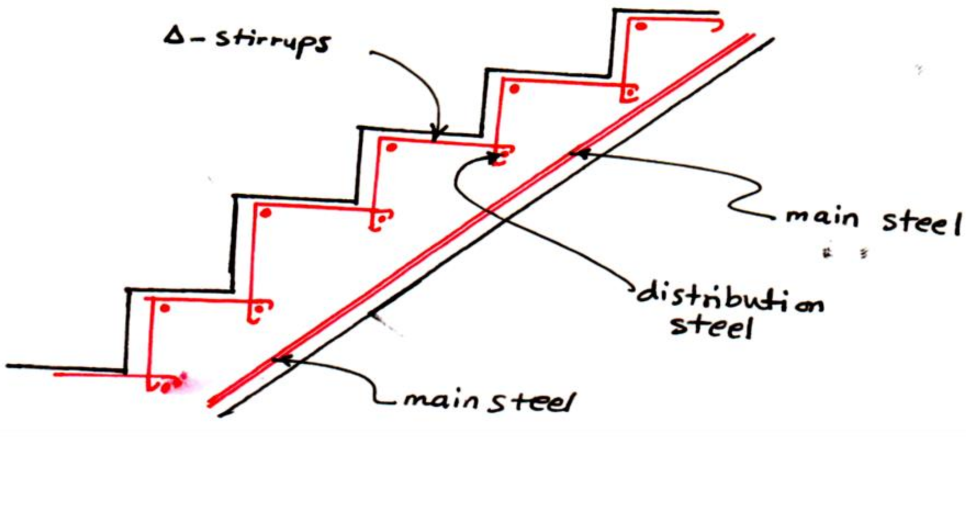


لاحظ هنا أن الكونكريت سمكه كبير فلا يحصل فشل نتيجة محصلة الشد بالاتجاهين (من حديد التسليح) ؟

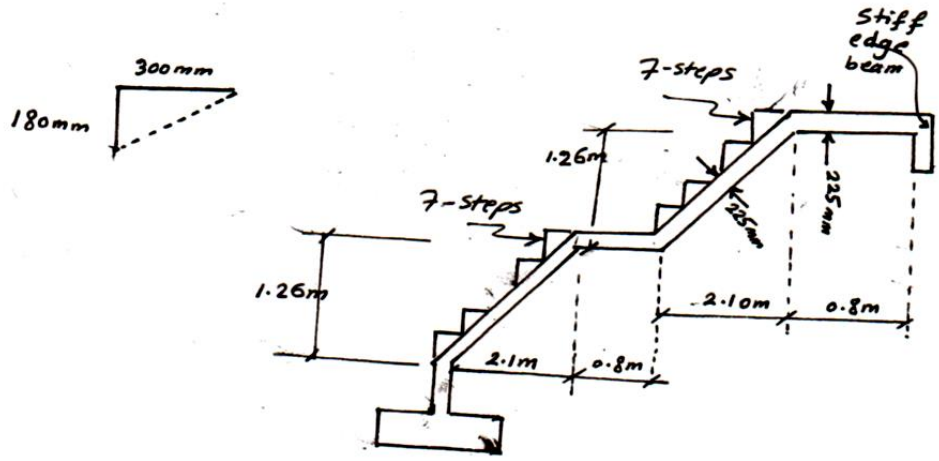
ملاحظة :- في حالة الاضطرار بأن الحديد يتبع الكسرة الـ (bend) يربط هذا الحديد بأتاري (Stirrups) أو بحديد عرضي ويلحم الـ (welding) اللحام ، كل ذلك من أجل عدم الضغط على الكونكريت الذي تحت حديد التسليح (مقدار سمكه قليل ؟؟) ، حيث يرفع الحديد السفلي للأعلى بواسطة الحديد العرضي ؟؟

The steps theoretically need no reinforcement. They are dead loads. In Iraq, nominal steel is used.

* لا تسلح لأنها حمل ميت وغالباً ما تسلح أحياناً (حديد رمزي) بسيط ؟



Example:- (design of staircase)



width of staircase $b = 1.10\ m$, concrete strength $f'_c = 25\ MPa$, concrete weight, $\gamma_c = 24.5\ KN/m^3$, steel yield $f_y = 345\ MPa$. Tiling load $0.98\ KN/m^2$ (horizontally), live load $5.0\ KN/m^2$ (horizontally), use or take waist thickness $225\ mm$. Use clear cover $20\ mm$. use $\phi 16mm$ for main steel & $\phi 10mm$ for others.

Solution:-

First the total selfweight must be calculated.

length of each going is

$$\sqrt{1.26^2 + 2.10^2} = 2.449\ m$$

Total selfweight of waist (only):

$$W_g = 0.225 * 1.10 * \left(2.449 + 0.8 + 2.449 + \frac{0.8}{2}\right) * 24.5$$

$$= 36.977\ KN$$

Total load of steps :

$$W_s = \left(\frac{1}{2} * 0.180 * 0.300 * 1.1\right) * 24.5 * 14 \leftarrow \text{steps no.}$$

$$= 10.187 \text{ kN}$$

Tiling load

$$W_t = 1.1 * \left(2.1 + 0.8 + 2.1 + \frac{0.8}{2}\right) * 0.98 \text{ (tiling load kN/m}^2\text{)}$$

$$= 5.821 \text{ kN}$$

Total dead loads

$$W_d = W_g + W_s + W_t$$

$$= 52.985 \text{ kN}$$

Total live load $W_l = 1.1 * \left(2.1 + 0.8 + 2.1 + \frac{0.8}{2}\right) * 5.0$

$$= 29.7 \text{ kN}$$

Total ultimate load $W_u = 1.4 W_d + 1.7 W_l$

$$= 1.4\,(52.985) + 1.7\,(29.7)$$

$$= 124.669 \text{ kN}$$

The effective span is $l = 2.1 + 0.8 + 2.1 + \frac{0.8}{2}$

$$= 5.4 \text{ m}$$

Thus the max. positive B.M. (at center) is:-

$$M^+ = \frac{W_u \cdot l}{8} = \frac{(124.669) * (5.4)}{8}$$

$$= 84.152 \text{ kN.m}$$

The effective depth is

$$d = 225 - 20 - \frac{16}{2}$$

$$= 197 \text{ mm}$$

Find ρ (by any method):

$$\rho = 0.006716$$

check this with $\rho_{min} = \frac{1.4}{f_y} = \frac{1.4}{345} = 0.004058$

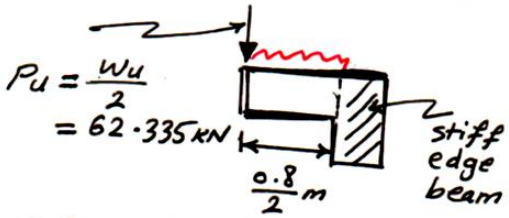
use $\rho = 0.006716$

Then

$$A_s = 0.006716 * 1100 * 197$$
$$= 1455.4\ mm^2$$

use $8\phi\ 16 \rightarrow A_s = 1609\ mm^2$ (O.K.)

Next consider the cantilever part of the landing slab :



The concentrated load (at free edge of slab) is :

$$P_u = \frac{w_u}{2} = \frac{124.669}{2} = 62.335\ kN$$

self weight $w_g = 0.225 * 1.10 * \frac{0.8}{2} * 24.5$

$= 2.426\ kN$

weight of tiling $w_t = 1.10 * \frac{0.8}{2} * 0.98$

$= 0.431\ kN$

Total distributed dead load $w_d = w_g + w_f$

$= 2.857\ kN$

Total distributed live load

$w_l = 1.10 * 0.4 * 5.0$

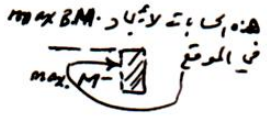
$= 2.2\ kN$

Total ultimate load distributed :

$w_u = 1.4 w_d + 1.7 w_l$

$= 7.740\ kN$

Max. negitive B.M. (at the fixed end) is:



$$M^- = P_u \cdot \ell + \frac{W_u \cdot \ell}{2}$$

$$= 62.335 * 0.4 + \frac{7.740 * 0.4}{2}$$

$$= 26.482 \text{ KN.m}$$

As befor $d = 197 mm$

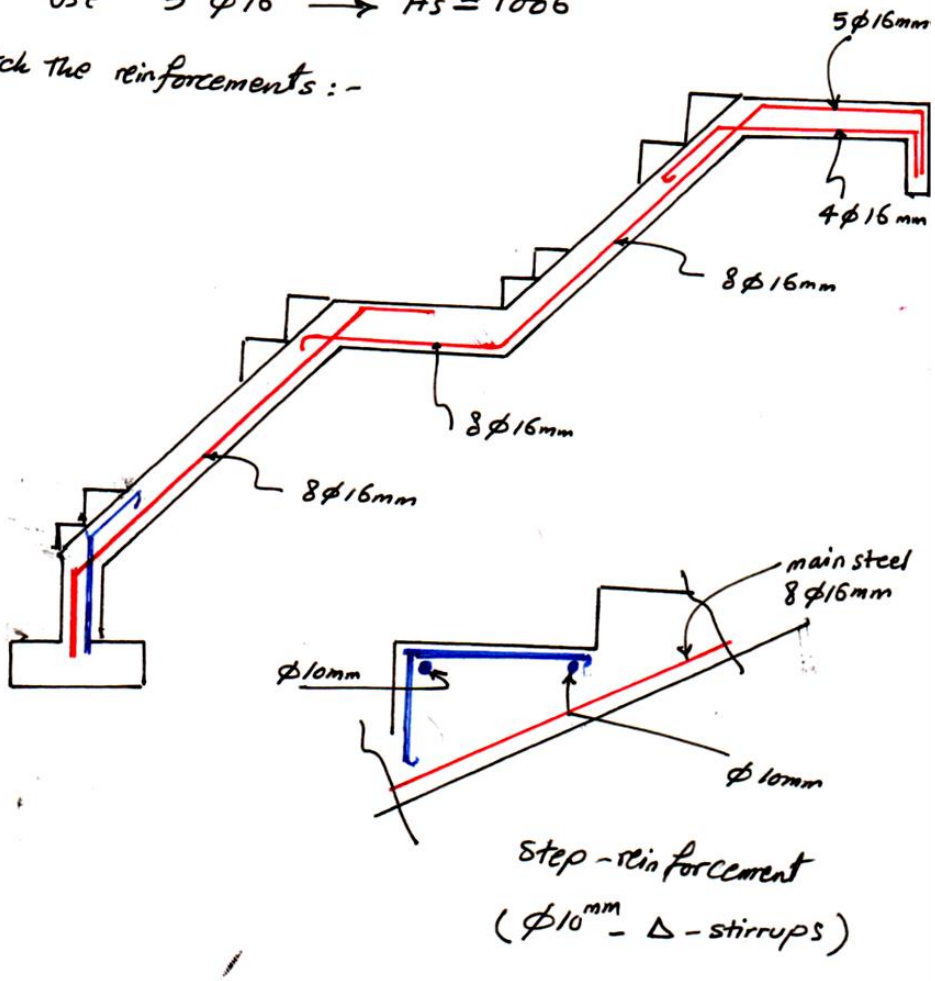
find $\rho = 0.002032$

This $\rho < \rho_{min}$, so use $\rho = \rho_{min} = 0.004058$

$$A_s = 0.004 * 1100 * 197 = 866.8 mm^2$$

use $5 \phi 16 \longrightarrow A_s = 1006$

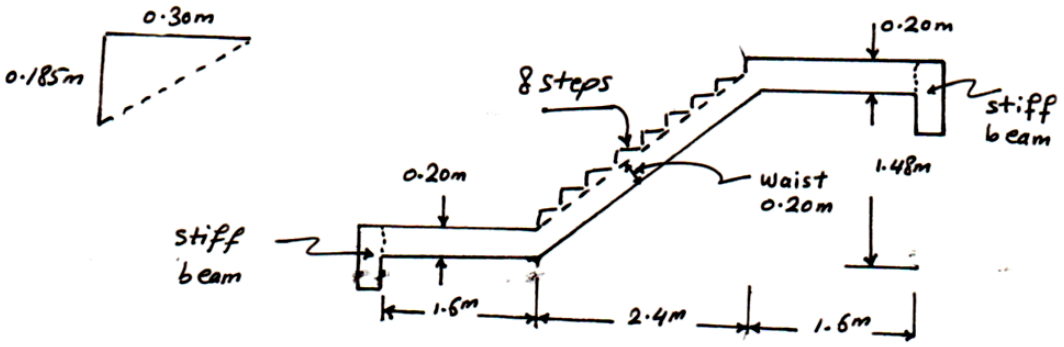
Sketch the reinforcements :-



Step - reinforcement

($\phi 10^{mm}$ - Δ - stirrups)

Design of R.C. staircase



Design and sketch accurately the steel reinforcement for the staircase shown in the figure above.

For concrete $f'_c = 27.5$ MPa $\quad \gamma_c = 24.5\ KN/m^3$

For steel $f_y = 345$ MPa $\quad \phi 12$ mm bars

Surfacing load $0.92\ KN/m^2$ (horizontally).

Live load $5.80\ KN/m^2$ (horizontally).

Stair width $b = 1.20$m. clear cover 20 mm.

Hint: weight of waist 25.990 KN. weight of steps 6.527KN. surfacing load 4.416 KN.

$W_d = 36.933\ KN$, $W_l = 27.84\ KN$, $W_u = 99.034\ KN$

span $l = 4.0$m, $M_u = \frac{W_u \cdot l}{8} = 49.517\ KN.m$,

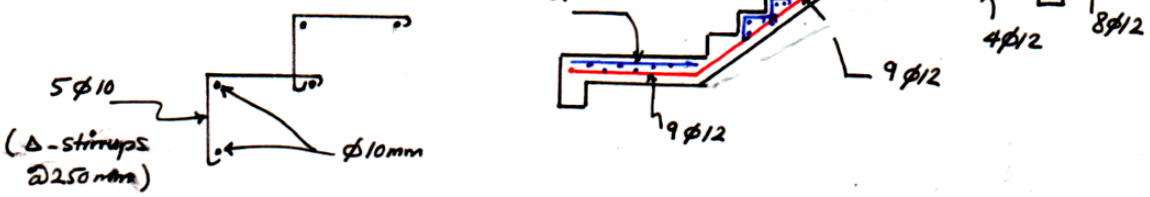
$d = 174$mm, $\rho = 0.004544$, $A_s = 939.6\ mm^2$,

use $9\phi 12$mm $\rightarrow A_s = 1018 mm^2$. For landing slabs

$M_u = 49.517 * 0.8 + \frac{1}{2} * 21.710 * 0.8^2$

$= 46.561\ KN.m$ $\rho = 0.004255$, $A_s = 887.4\ mm^2$

use $8\phi 12$.



STRUCTURAL DESIGN - II

Design of Circular Slabs
Opening in Slabs
Transfer of Loads in Building Frames
Prestressed Concrete
Reinforced concrete Tanks
Torsion

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