STRUCTURAL DESIGN, DETAILING AND CONSTRUCTION OF REINFORCED CONCRETE STAIRCASES

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ABSTRACT

This technical material provides recommendations in the sizing of stair element, such as the rise, tread, maximum number of steps, minimum headroom and clearance, and the height of handrail from the pitch line of the stair.

It also gives illustration examples of the structural design of straight flight by transverse and longitudinal design.

The technical material uses BS 5395-1-200 (stairs, ladder, and walkway) and BS 8110 as a normative reference.

The technical information also provided recommended reinforcement layout for straight stairs supported longitudinally.

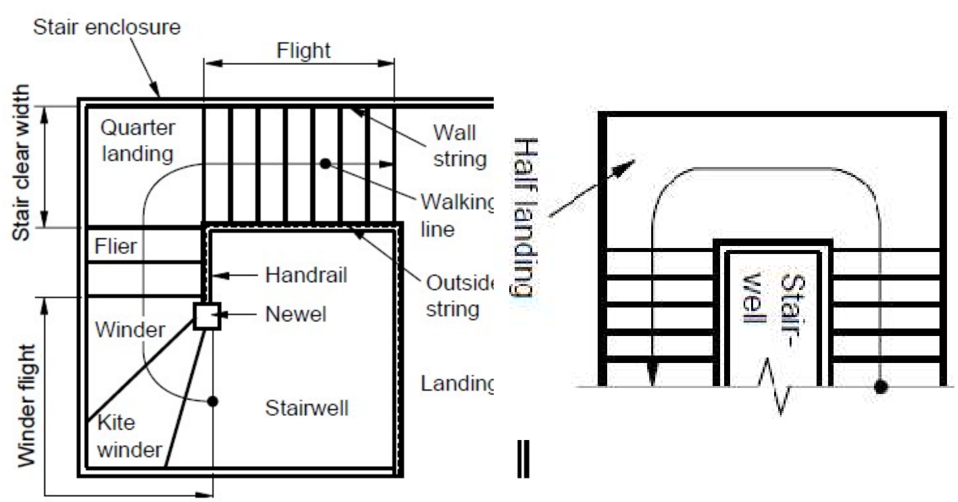
CHAPTER ONE
INTRODUCTION

1.1. BACKGROUND OF THE STUDY

Stairs are used to create a pedestrian route between different vertical levels by dividing the height between the levels into manageable steps. For example, stairs connect a ground floor level of a building to the floor above it (first floor) by dividing the height between the levels into manageable steps. Very generally, the word 'stairs' refers to a staircase, whereas the word 'step' refers to the individual steps that make up the staircase.

Staircases are generally classified as straight stairs and curved stairs. The straight staircase includes various configurations such as a single flight stairs, half turn stairs, single quarter turn stairs, and three quarter turn stairs. The various straight staircase configurations will include elements like flights, landing slabs (half landing, quarter landing or full landing) and sometimes winders.

Winders are steps that are narrower on one side than the other. They are used to change the direction of the stairs without landings. The half landing is found in half turn staircase, the quarter landing is found in found in a single or three turn staircase.

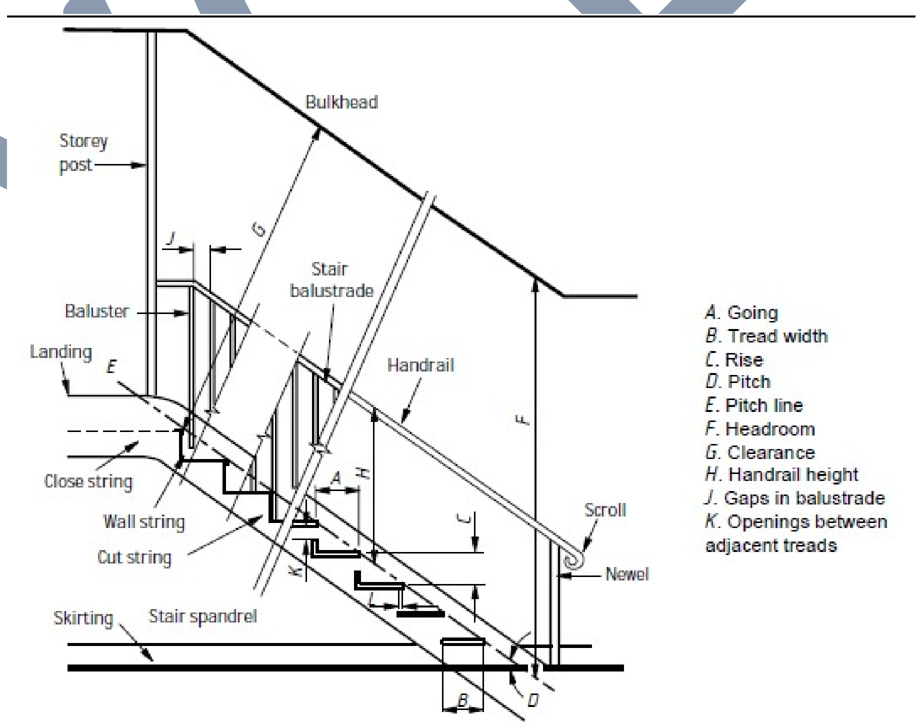


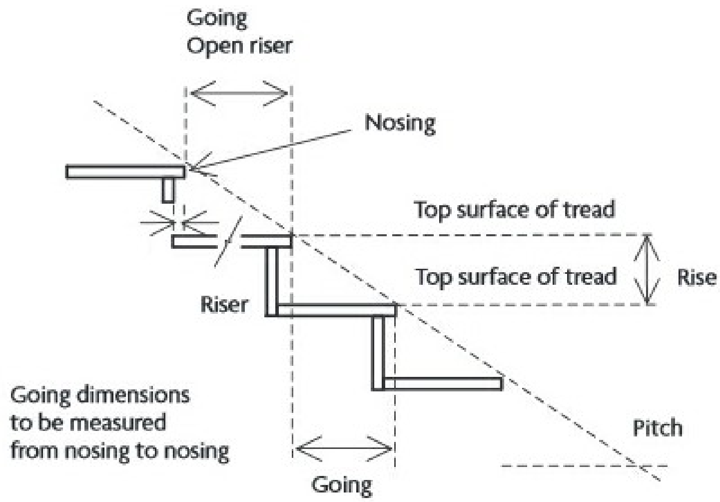
The curve staircases are classified into two categories. It includes the Helical and Spiral staircase. The Helical stair has a void in the middle while the spiral staircase has a column in the middle. Both stairs are curved in shape.

Any of these staircases may have a railing system which prevents people from falling over the edge.

BS 5395 Clause 3.1 classifies stairs into three categories. They include public stairs, private stairs and assembly stairs. The private stairs provide access for private dwellings and it is used by a small number of people that are familiar with it. The public stairs is used by large number of people who may not be familiar with it and this stairs are located in commercial buildings, offices or public building such as library. While the Assembly stairs stair used simultaneously by a large number of people, many of whom are not familiar with the stair, and which is located in an assembly building such as a theatre, concert hall, educational establishment or stadium

1.2. TERMINOLOGY INSTAIRCASE INCLUDES





Tread is the part of the stairway that is stepped on.**Riser** is the vertical portion between each tread on the stair. The tread width (**going**) is the horizontal distance between two consecutive risers. The riser is the vertical distance between the top surfaces of two consecutive treads.

Winders are steps that are narrower on one side than the other. They are used to change the direction of the stairs without landings. A series of winders form a circular or spiral stairway. When three steps are used to turn a 90° corner, the middle step is called a kite winder as a kite-shaped quadrilateral.

The **slope** or **pitch** of the stairs is the ratio between the rise and the going. It is sometimes called the **rake** of the stairs. The **pitch line** is the imaginary line along the tip of the nosing of the treads. In the UK, **stair pitch** is the angle the pitch line makes with the horizontal, measured in degrees.

Bulkhead is the soffit of a ceiling above a stair and usually constructed parallel to its pitch line.

Headroom is the height above the nosing of a tread to the ceiling above it.

A flight is an uninterrupted series of steps.

1.3. GENERAL GUIDELINE IN THE DESIGN OF STAIRCASE

WIDTH OF STAIRS

The width of stairs for public and assembly stairs should be a minimum of 1.2m, while for private stairs the width of stairs should be a minimum of 1m.

LENGTH OF FLIGHT

The maximum number of risers in a flight should be restricted to 12.

HEADROOM: The minimum **Headroom** should be 2m, While clearance should be aminimum of 1.8m.

CLEARANCE: This is the perpendicular distance from the pitch line to the soffit of the waist slab above it or bulkhead (roof level). The minimum clearance should be restricted to 1.8m

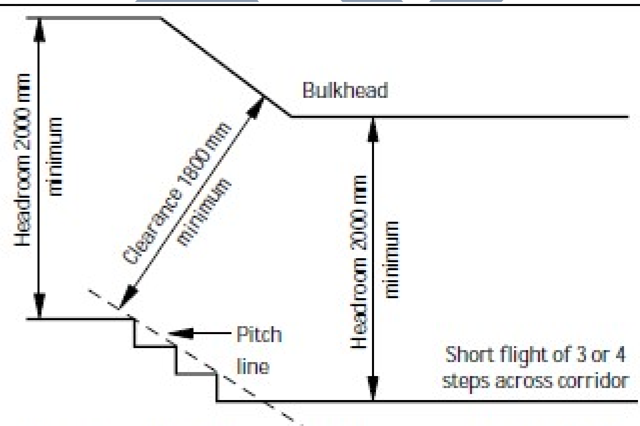


Figure 5 — Headroom and clearance on short flights

HANDRAILS: The height of handrail should be 900 mm to 1000 mm from the pitch line or the floor. If the stair is 1000 mm wide or more, handrail should be provided at both sides.

RECOMMENDED SIZES OF STRAIGHT STAIRS BASED ON BS 5395

Table 1 — Recommended sizes for straight stairs and winders

1 Stair category	2 Rise, *r*		3 Going, *g*		4 Sum of $g + 2r$ [a]		5 Pitch	6 Stair clear width (see note 2)		7 Handrail height	
	Min. mm	Max. mm	Min. mm	Max. mm	Min. mm	Max. mm	Max. degrees	Min. mm	Reduced min. where limited use[c] mm	Min. mm	Max. mm
A ***Private stair***	100	220	225	350	550	700	41.5	800	600	900	900
B ***Public stair***	100	190	250	350	550	700	38	1 000	800	900	1 000
C ***Assembly stair***	100	180	280	350	550	700	33	1 000[b]	—	900	1 000

NOTE 1 Special circumstances may demand easier limiting sizes than some of those given in this table.

NOTE 2 Requirements for means of escape in case of fire can necessitate an increase on the minimum values given here for stair clear width. Where means of escape is a factor, the relevant mandatory regulations apply. See **4.2**.

NOTE 3 The limiting sizes in each column apply to the stair as a whole. The most onerous requirement should be met in each case.

[a] See **7.5**

[b] For hospitals, the minimum stair clear width is 1 200 mm.

[c] For example, access to a loft space.

1.4. LOADING IN STAIRCASE

Dead loads should be calculated in accordancewith BS 6399-1 from the unit masses given in BS 648or from the actual known mass of the material used, while **Imposed loads** should be calculated in accordance with BS 6399-1 and BS 6399-3. (See also BS 648). Care is necessary in selecting the imposed loading appropriate to any particular area of circulation space in a building to ensure that adequate allowance is made for the effects of temporary loads arising from the initial installation or replacement of machinery, equipment or furniture.

1.5. FORMS OF REINFORCED CONCRETE STAIRCASE CONSTRUCTION BASED ON BS 5395

CRANKED SLAB STAIRS

There are no trimmers and the landings and flight are designed as a single structural slab spanning the stair enclosure or frame. If there are supports at the ends of landings, so that the landings can span at right angles to the direction of the flight, the landing slab becomes a beam supporting the flights. The effective span should be calculated in accordance with BS 8110-1.

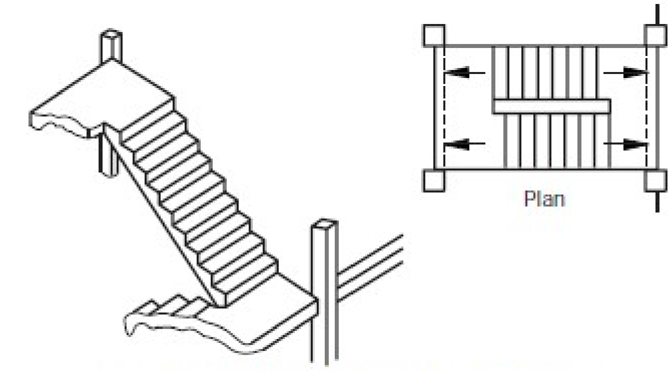


Figure 10 — Cranked concrete slab stair

INCLINED SLAB STAIR

This form of stair is designed with a trimmer beam at the junction of the flight and landing. It can beused for architectural effect where the span and corresponding thickness of waist is otherwise undesirable or where constraints are placed on support positions. The landing may cantilever from the trimmer beam where there is no provision for support at the outer end. Conventionally, the trimmer beam should be expressed in the stair soffit.

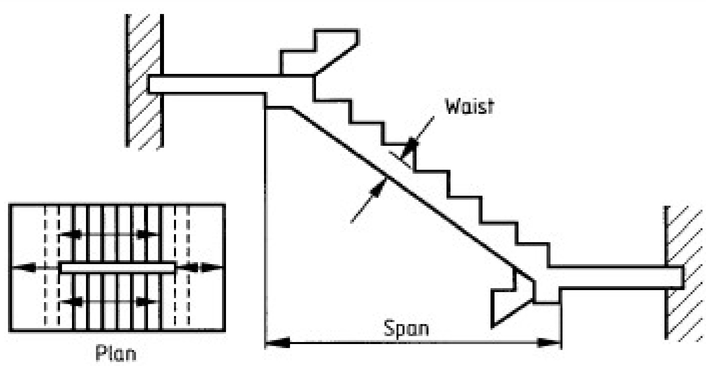


Figure 11 — Concrete inclined slab stair

CANTILEVERED SPINE WALL STAIR

The flights and landings can be cast in-situ and cantilevered from a wall that is either the stair enclosure or a central spine wall. Alternatively, the spine can be shuttered about precast treads and landings, forming a monolithic structure.

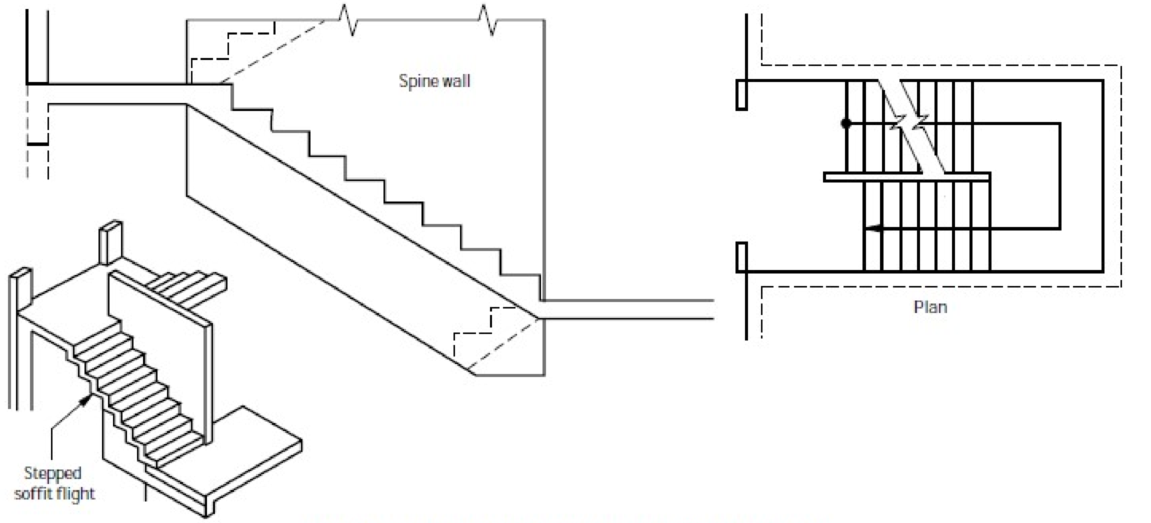


Figure 13 — Cantilevered concrete stair with spine wall

CONTINUOUS SLAB (SCISSOR) STAIR

This is a double-flight stair with a half-landing and is supported only at floor levels. It comprises a continuous slab, monolithic with the floors, running from one floor to the landing, turning, and continuing without support to the next floor. In addition to the normal stresses of bending and shear, it is necessary to resist torsional stresses, and therefore thicknesses should be greater than in cranked slab stairs.

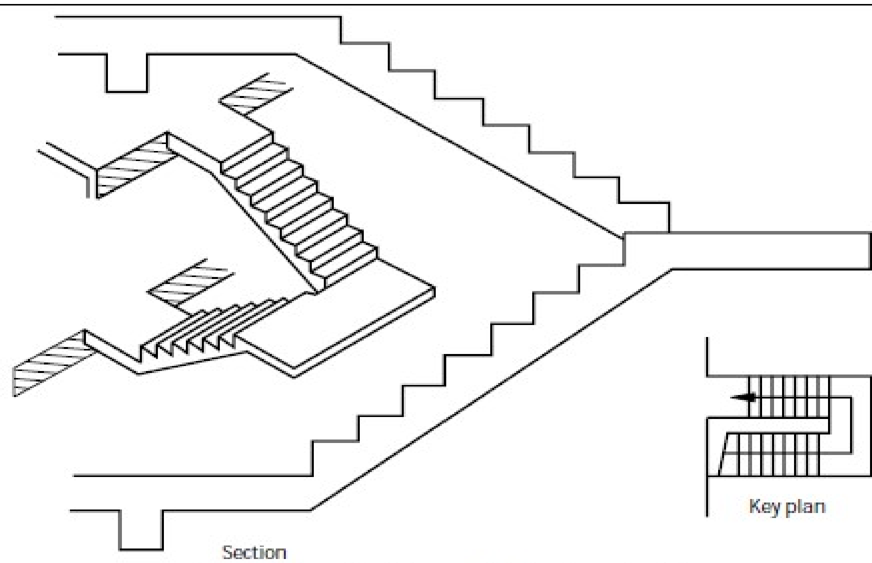


Figure 14 — Continuous slab (scissor) stair

1.6. STRUCTURAL DESIGN OF RC STAIRCASE

This structural design of staircase follows BS 8110. It follows the limit state design philosophy. Like the beam and slab elements, the staircase is design to check the ultimate limit and the serviceability limit states. The Ultimate limit state include Strength limit state (bending moment and shear force), while the serviceability limit state of deflection and crack width is checked for satisfactory performance

TRANSVERSE SPANNING STAIR SLABS

Transverse spanning stair slabs (flight) span between walls, a wall and stringer (an edge beam), or between two stringers. The stair slab may also cantilever from a wall. A stair slab may also be cantilevered from a wall. A stair slab spanning between a wall and a stringer is shown in the image below.

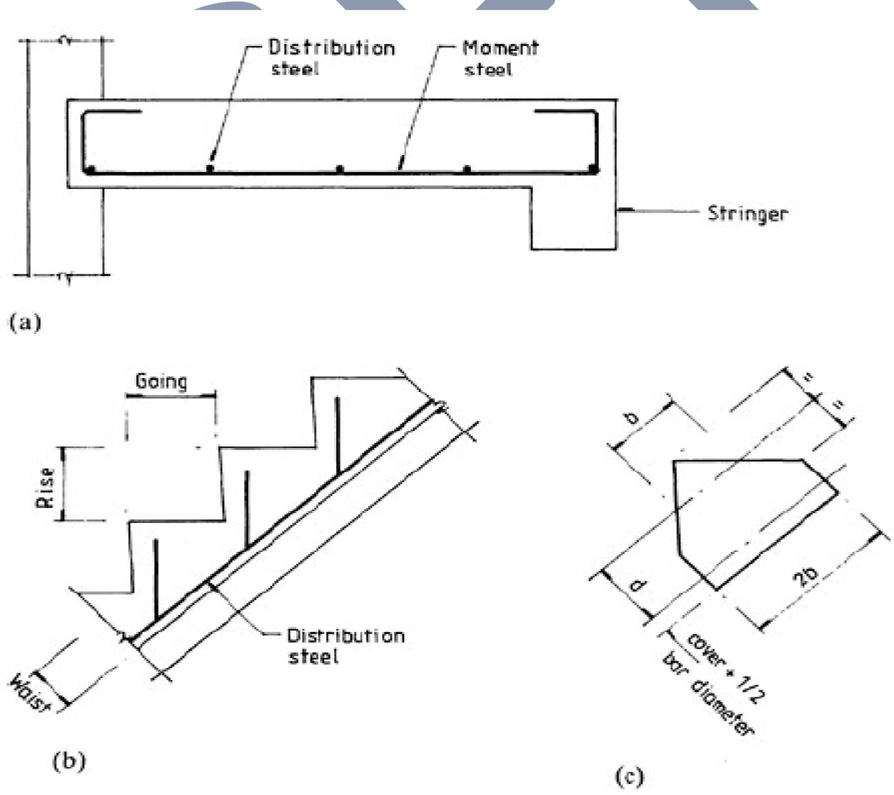
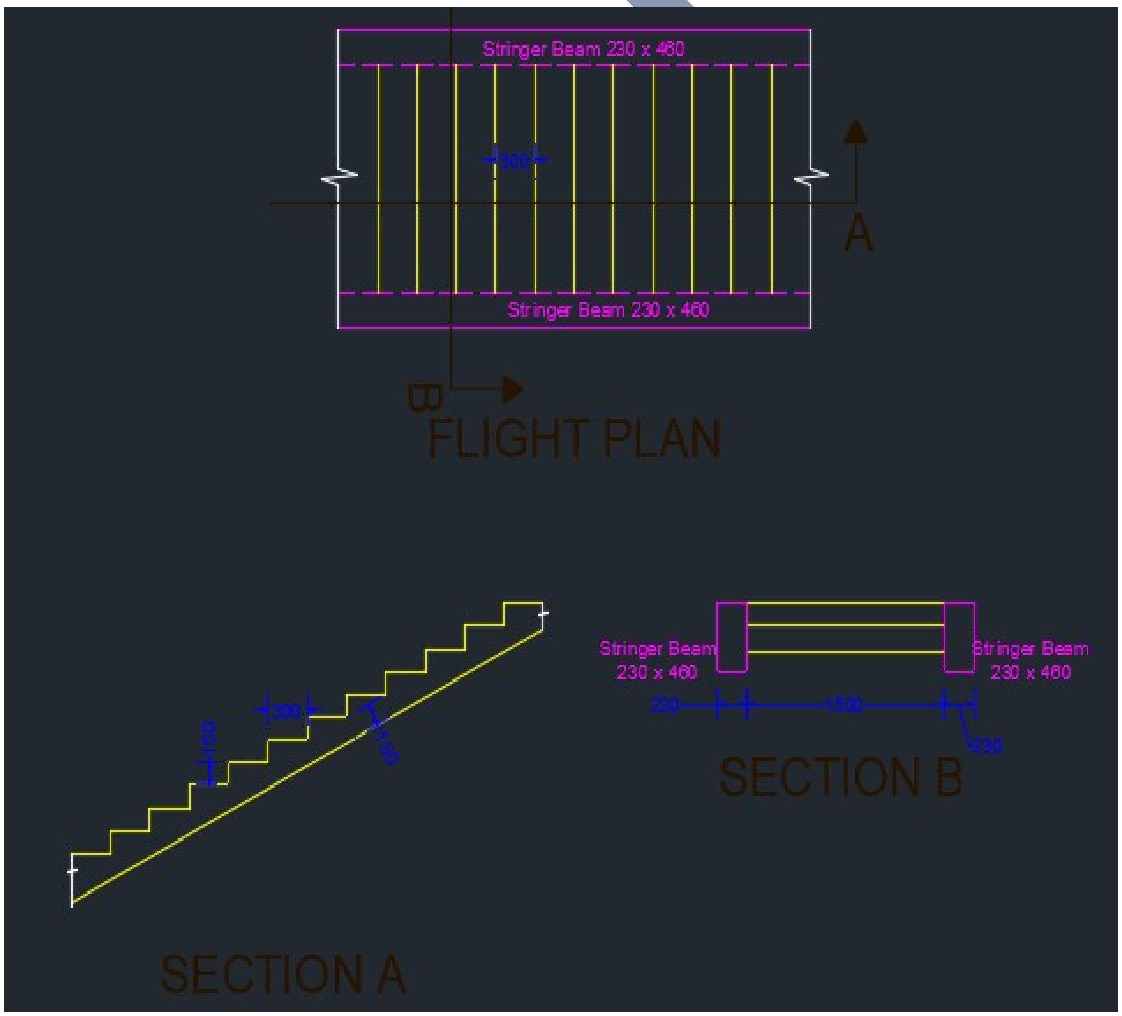


Fig. 8.41 (a) Transverse section; (b) longitudinal section; (c) assumptions for design.

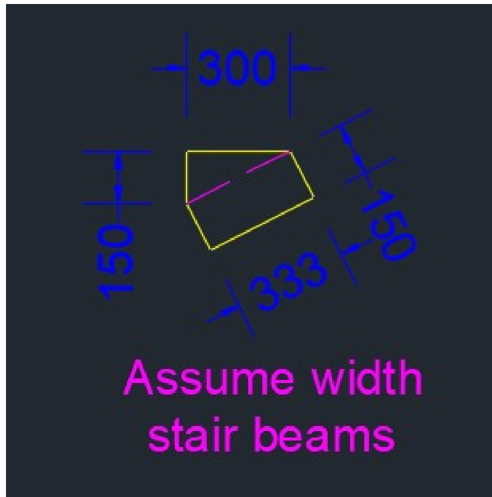
The stair slab is designed as a series of beams consisting of one step with assumedbreadth and effective depth shown in the image above. The one step is modeled as a simply supported beam carrying uniform distributed load. The moment reinforcement isgenerally one bar per step. Secondary reinforcement is placed longitudinally along theflight.

Example 1 on Transverse design

Design a stair flight supported by two stringer beams at his ends. Tread width (going) = 300, Rise = 150, waist slab = 150, Stringer beams = 230 x 460, Flight clear width from stringer beams = 1500. The material strength used fy = 410N/mm2, fcu = 30N/mm2



FLIGHT LOADING ON STAIRCASE:



Waist slab load = 24 x 0.15 x 0.333 = 1.2kN/m

Steps= 24 x 0.5 x 0.15 x 0.3 = 0.54kN/m

Terrazzo Finishes + screed say =1kN/m

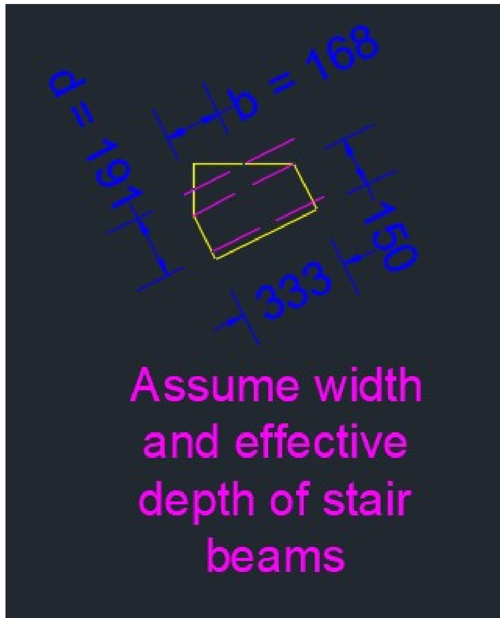
Live load, qk = 3.5kN/m

F=1.4gk+1.6qk= 1.4(1.2 + 0.54 + 1) + 1.6(3) = 8.64kN/m

Effective span,l

BS 8110 Clause 3.4.1.2

The effective span of a simply-supported beam may be taken as the smaller of the distance between thecentres of bearings, or the clear distance between supports plus the effective depth.

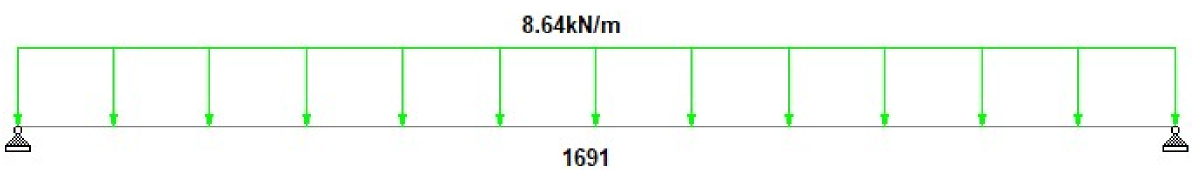


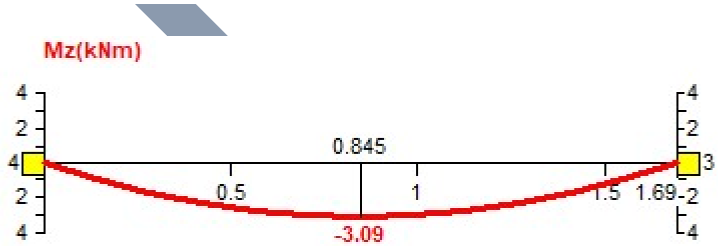
l = 1500 +115 +115 = 1730

Or

l =1500 + 191 = 1691

Therefore effective span, l =1691





Design Bending moment = $\frac{w \times l^2}{8} = \frac{8.64 \times 1.691^2}{8}$ = 3.1kNm per step

Design Shear force = $\frac{w \times l}{2} = \frac{8.64 \times 1.691}{2} = 7.31kN$

b=168mm, Cover = 20mm, $\emptyset = 12$mm

d = 191mm

K=M/(bd^{2}fcu)= (3.1x10^6) / (168 x 191^{2}x 30) = 0.017< 0.156

Compression reinforcement isn't required.

Z = d {0.5 + √[0.25-(0.017/0.9)]} = 0.96d < 0.95d

As = M / (0.95fyZ) = 1.85 x10^6/ (0.95 x 410 x 0.95 x 191) = 26.2mm^2

Provide 1Y12 bars (113mm^2)per step of stairs

MINIMUM REINFORCEMENT

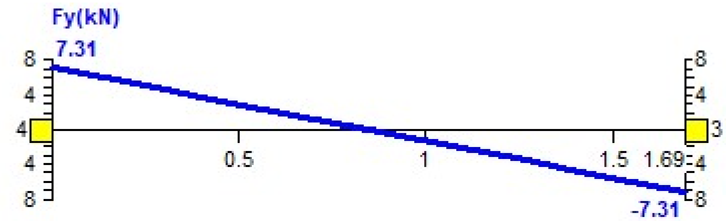
$$\frac{100 \ \times A_s}{A_c} = 0.13$$

Ac = (150 x 333) + (0.5 x 150 x 300) = 72450mm2

As =0.13 x 72450/100 = 94.2mm2

Provide Y12@300 c/c as distribution reinforcement

SHEAR STRESS CHECK



Vmax = 5.64kN

$$v = \frac{Vmax}{b \times d} = \frac{7.31 \times 10^3}{168 \times 191} = 0.228N/mm2$$

$$v_c = 0.79 \times \left\{\frac{100As}{bv \times d}\right\}^{\frac{1}{3}} \times \left(\frac{400}{d}\right)^{\frac{1}{4}} \times \left\{\frac{f_{cu}}{25}\right\}^{1/3} \div \gamma m$$

$$v_c = 0.79 \times \left\{\frac{100 \times 113}{168 \times 191}\right\}^{\frac{1}{3}} \times \left(\frac{400}{191}\right)^{\frac{1}{4}} \times \left\{\frac{30}{25}\right\}^{1/3} \div 1.25$$

$$\boldsymbol{v_c} = 0.57N/mm2$$

$$0.5v_c = 0.5 \times 0.57 = 0.285$$

$$v < 0.5v_c$$

Ok

DEFLECTION

$$\frac{\text{Span}}{\text{d}} = \frac{1309}{191} = 6.85$$

$$\text{f}_s = \frac{2 \times 410 \times 26.2}{3 \times 113} = 63.4\text{N/mm}^2$$

$$\frac{\text{M}}{\text{bd}^2} = \frac{1.85 \times 10^6}{168 \times 191^2} = 0.3$$

$$\mathrm{MF} = 0.55 + \frac{477 - 63.4}{120(0.9 + 0.3)} = 3.42 > 2$$

$$\frac{\text{Modified Span}}{d} = 2 \times 20 = 40$$

6.85 < 40

Deflection is Ok.

CRACK CONTROL

3.12.11.2.4

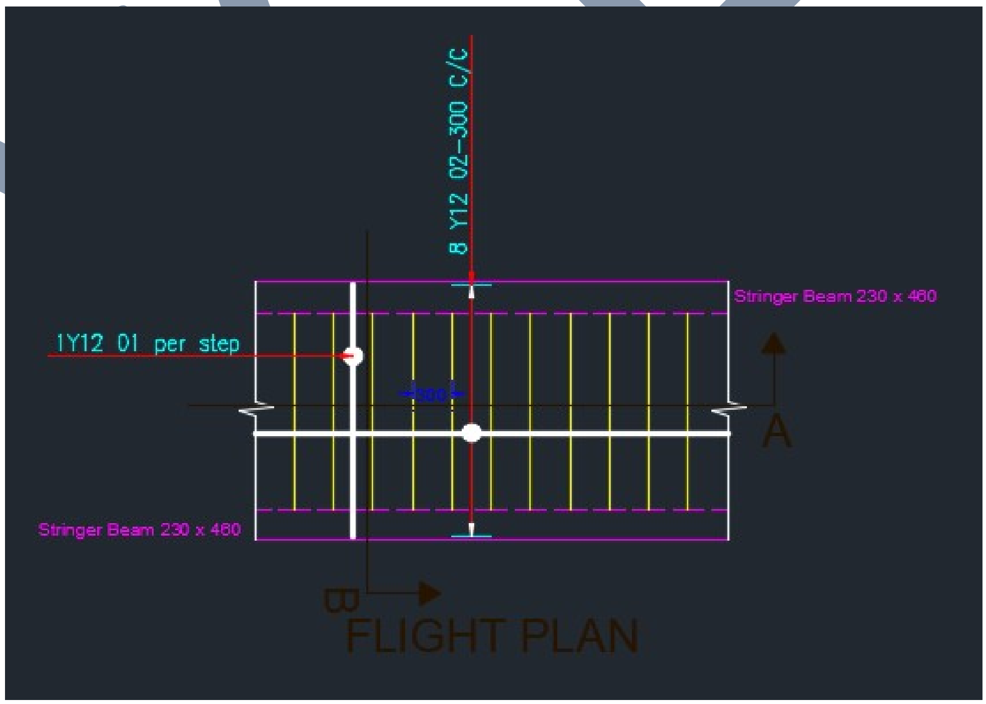
$$\text{Clear spacing} = \frac{47{,}000}{F_s} = \mathbf{300}$$

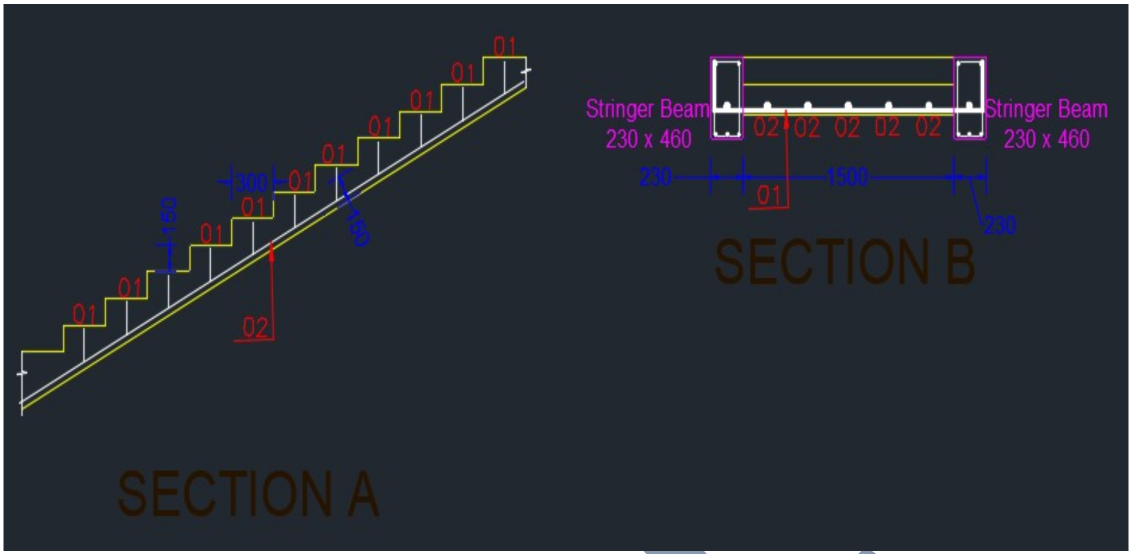
$$F_s = 63.4$$

Clear spacing = 47,000/63.4 = 741.3 > 288

Crack control is Ok .

STAIR DETAILS





Longitudinal spanning stair slab

The stair slab spans between supports at the top and bottom of the flight. The supports may be beams, walls or landing slabs. The waist slab is the main structural part in the flight. The steps on the flight are only considered as dead loads on the stairs, they don't contribute to the strength of the stairs, unlike in transverse spanning stairs where the waist slab and steps act as the structural part of the flight.

There are different structural systems for longitudinal spanning stairs based on the position of the supporting beams. The image below shows these structural systems.

Structural Systems

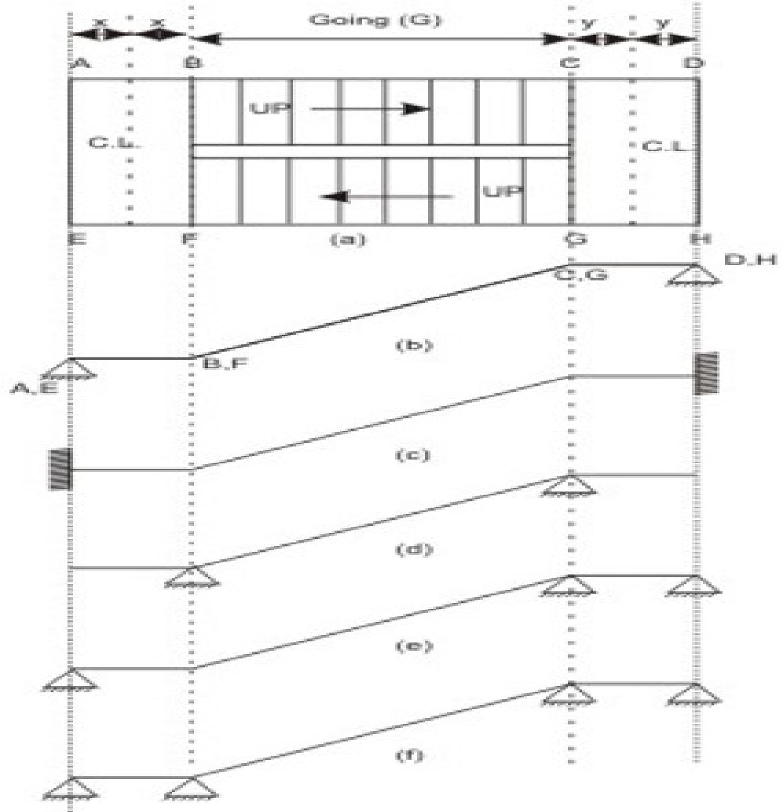


Fig. 9.20.3: Longitudinally spanning staircases

(i) Supported on edges AE and DH

(ii) Clamped along edges AE and DH

(iii) Supported on edges BF and CG

(iv) Supported on edges AE, CG (or BF) and DH

(v) Supported on edges AE, BF, CG and DH

Cantilevered landing and intermediate supports (in the image d, e and f) are helpful to induce negative moments near the supports which reduce the positive moment and thereby the depth of slab becomes economic.

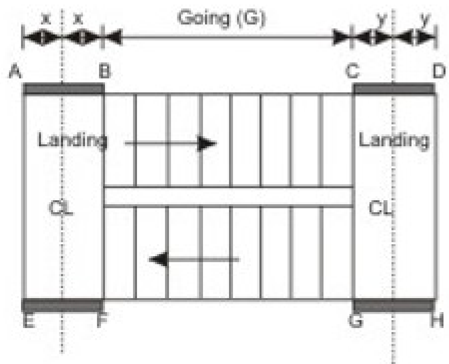


Fig. 9.20.4(a): Beams at two ends of landings

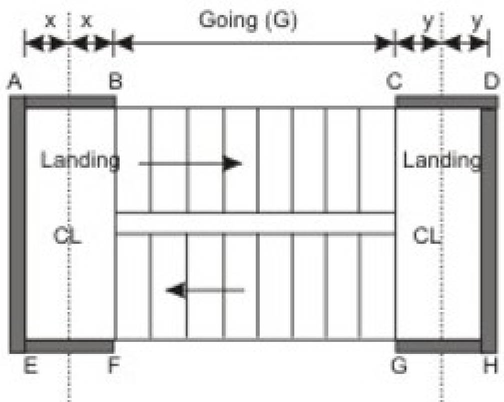


Fig. 9.20.4(b): Beams at three ends of landings

Fig. 9.20.4: Staircases (spanning longitudinally) and landings (spanning transversely)

In the case of half turn stair, sometimes the flight is supported between the landings which span transversely in the image above. It is worth mentioning that some of the above mentioned structural systems are statically determinate while others are statically indeterminate where deformation conditions have to taken into account for the analysis.

EFFECTIVE SPAN OF LONGITUDINAL SPANNING STAIRS

In half turn stairs, when the staircase (flight) is built monolithically at its ends into structural members (half landings) spanning at right angles to its span, the effective span of the monolithic stairs (flight) without stringer beam should be as given in equation the equation below:

$$effective\ span = l_a + 0.5(l_{b,1} + l_{b,2})$$

Where,

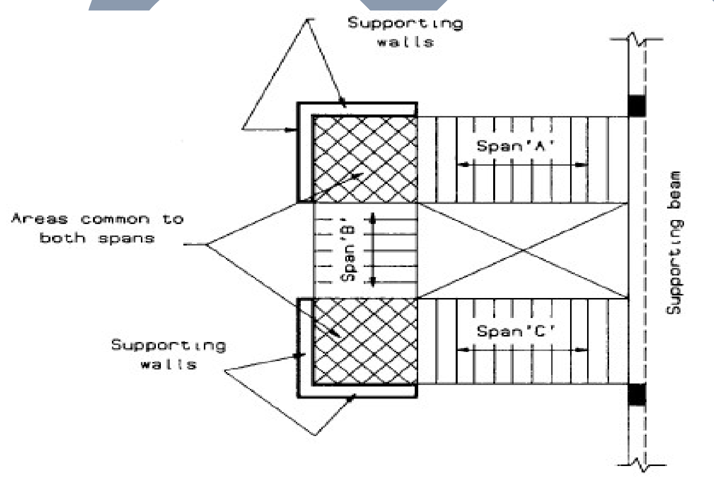
l_a is the clear horizontal distance between the supporting members;

$l_{b,1}$ is the breadth of the supporting member at one end or 1.8m, whichever is the lesser

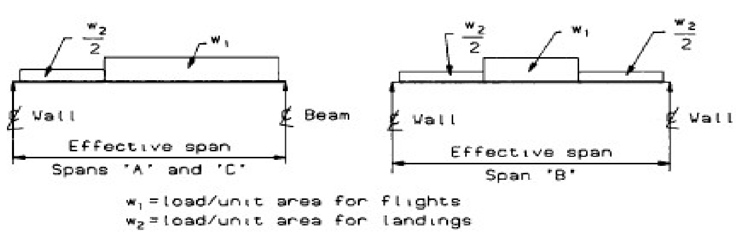
$l_{b,2}$ is the breadth of the supporting member at the other end or 1.8m, whichever is the lesser.

Also, in half turn stairs where the flight is built monolithically at its ends into structural members (beams), the effective span should be taken as the horizontal distance between the centre-lines of the supports or the clear distance between the faces of supports plus the effective depth, whichever is the lesser.

Lastly, in single or three quarter turn stairs the effective span of the flight is depicted in the image below.



16 Stairs with open wells



17 Loading diagram

DISTRIBUTION OF LOADING IN QUARTER TURN STAIRS

In general, the design ultimate load on flight should be assumed to be uniformly distributed over the plan area of a staircase. When, however, in quarter turn staircases surrounding open wells include two flights that intersect at right angles, the load on the areas (quarter landing loads) common to both flights may be assumed to be divided equally between the two flights as shown in the image above.

SLOPE FACTOR IN LOADING

$\frac{\sqrt{R^2+T^2}}{T}$ **,** The slope factor is multiplied with the dead load on flight to convert dead this load of the inclined elements in the flight to an equivalent horizontal load on plan. Note that the slope factor is only apply to the steps and finishes, however it is not applied to the waist slab dead load.

THE ALTERNATIVE DESIGN MOMENT IN THE FLIGHT OF LONGITUDINAL SPANNING SLAB SUPPORTED BY LANDING SLABS OR BEAMS AT ITS ENDS.

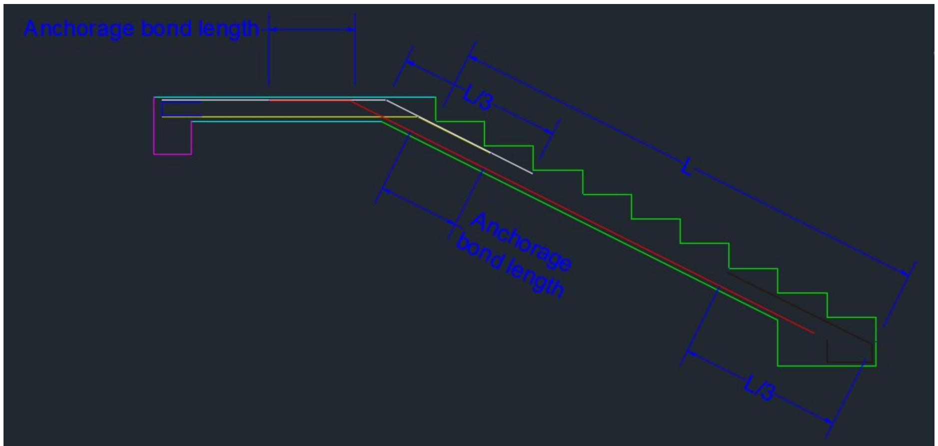
When the flight is supported by landing slabs at its ends, the mid span design moment can be deduced as;

$$\frac{w \times l^2}{10}$$

When the flight is supported by Beams at its ends, the mid span design moment can be deduced as;

$$\frac{w \times l^2}{8}$$

DETAILING



The reinforcement arrangement in stair flights follows a standard pattern as shown above. Deviation from the above image is not recommended unless a specific need arises. Longitudinal steel is the main reinforcement and in the transverse direction the minimum percentage of steel is provided as distribution steel to help prevent cracking.

The main reinforcement (Red line) in the flight is placed near bottom of waist slab and it extends into the landing slab a length equal to the anchorage bond length.

The main reinforcement (Yellow line) in the flight is placed near bottom of the landing slab and it extend into the waist slab a length equal to the anchorage bond length.

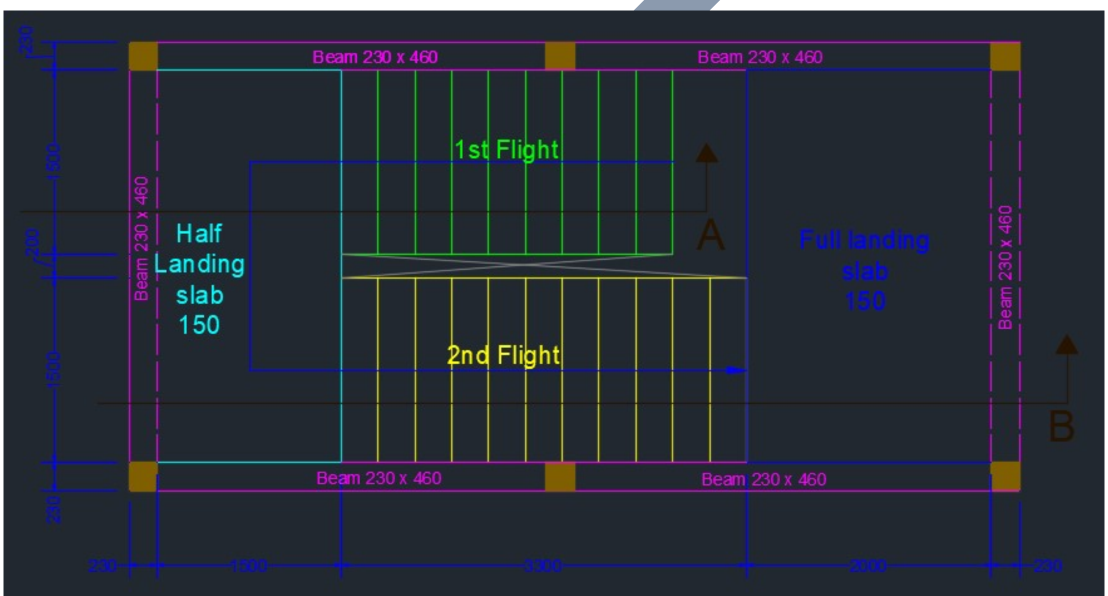
I normally take the anchorage bond length = 500

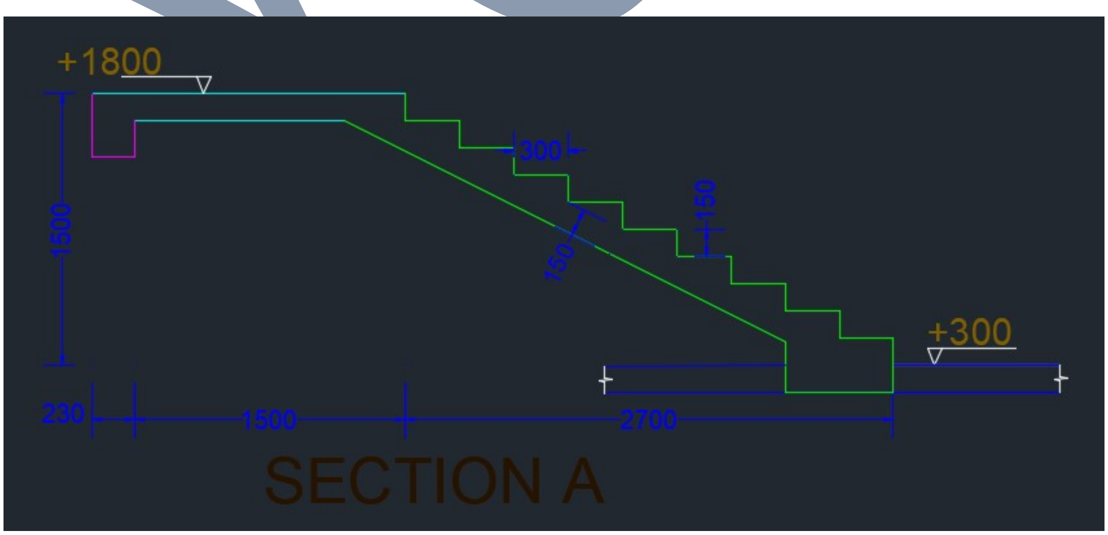
Extra Reinforcement(White line) is also provided at the junction between the flight and the landing at the top due to hogging moment that may be induce to control cracking at that point. The amount of reinforcement may be taking as equal the distribution reinforcement. Also the reinforcement should extend at least L/3, Where L is shown in the image above.

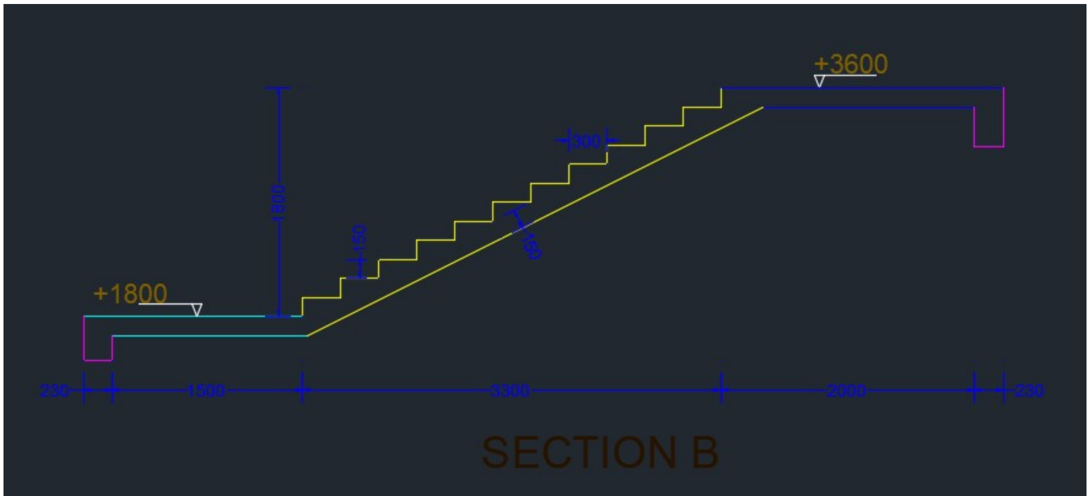
Landing U bar (blue line) may be provided at the end of the landing to connect the top and bottom reinforcement in the landing slab.

EXAMPLE 2:

Design the half turn stairs with flights spanning longitudinal between landings in the image above, the half landing and full landing are both supported by beams at only one end. The beams parallel to the flight does not support the stairs, they only carry the stair wall (block wall) surrounding the stairs.   The stairs connect the ground floor to the first floor in residential buildings. The proposed size parameter of this stair include: Rise = 150, Going = 300, waist slab = 180. The material strength parameter include fcu = 25N/mm2, fy = 410N/mm2.







Floor to floor height =3300mm

Height of rise = (floor to floor height / number of Risers) =3300/22 =150mm

Length of going= 300mm

Assuming 150mm waist,

LOADING ON STAIRCASE:

Flight loading

Concrete own weight (+20mm plaster below waist slab) = 24 x (0.15+0.02) = 4.08kN/m^2

Steps=0.5 x 0.15 x 24 = 1.8kN/m^2

Terrazzo Finishes + screed say = 0.5kN/m^2

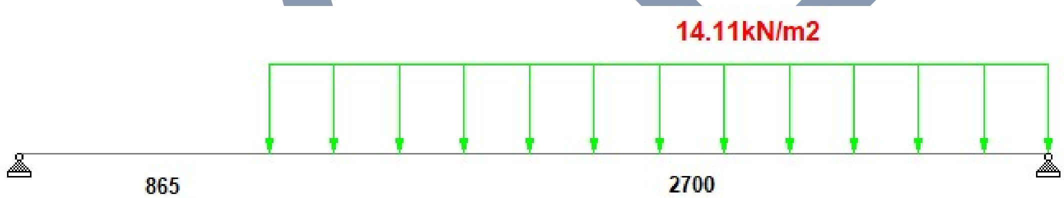
Live load, qk = 3kN/m^2

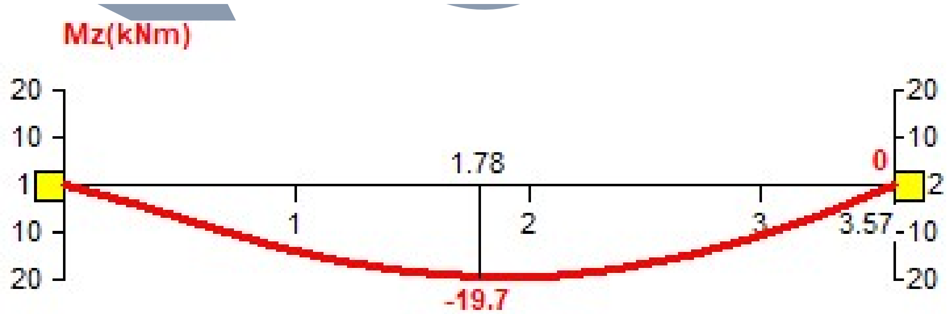
Slope factor = $\frac{\sqrt{\mathbf{R}^2 + \mathbf{T}^2}}{\mathbf{T}} = \frac{\sqrt{\mathbf{150}^2 + \mathbf{300}^2}}{\mathbf{300}}$ = 1.118

F = 1.4gk+1.6qk = 1.4(2.3 x 1.118) +1.4(4.08) + 1.6(3) = 14.11kN/m^2

For first flight

Effective Span = (2700) + 0.5(1730) = 3565mm





M_{max} = 19.7kNm

b=1000mm, Cover = 20mm, $\emptyset = 12\text{mm}$

d = 150 -20 – (12/2) =124mm

K = M / (bd^2fcu) = ($19.7x10^6$) / (1000 x 124^2 x 25) = 0.05 < 0.156

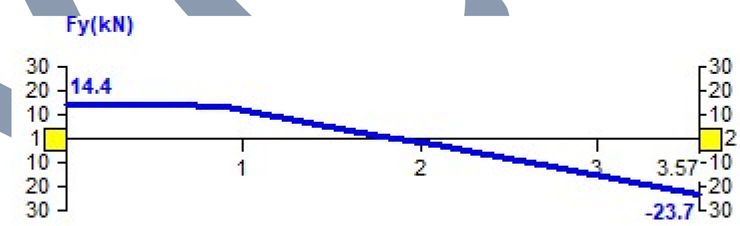
Compression reinforcement isn't required.

Z = d {0.5 + √[0.25-(0.05/0.9)]} = 0.94d < 0.95d

As = M / (0.95fyZ) = 19.7 x 10^6/ (0.95 x 410 x 0.94 x 124) = 434.2mm^2

Provide Y12 bars at 200c/c (566mm^2) at bottom of waist slab

SHEAR STRESS CHECK



Vmax = 23.7kN

$$v = \frac{Vmax}{b \times d} = \frac{23.7 \times 10^3}{1000 \times 124} = 0.19N/mm2$$

$$v_c = 0.79 \times \left\{\frac{100As}{bv \times d}\right\}^{\frac{1}{3}} \times \left(\frac{400}{d}\right)^{\frac{1}{4}} \div ym$$

$$v_c = 0.79 \times \left\{\frac{100 \times 566}{1000 \times 124}\right\}^{\frac{1}{3}} \times \left(\frac{400}{124}\right)^{\frac{1}{4}} \div 1.25$$

$$\boldsymbol{v_c} = 0.65N/mm2$$

$$0.5v_c = 0.5 \times 0.65 = 0.325$$

$$v < 0.5v_c$$

Ok

DEFLECTION

$$\frac{\mathrm{Span}}{\mathrm{d}} = \frac{3565}{124} = 28.75$$

$$\mathrm{f}_s = \frac{2 \times 410 \times 434.2}{3 \times 566} = 209.68\mathrm{N/mm^2}$$

$$\frac{\mathrm{M}}{\mathrm{bd^2}} = \frac{19.7 \times 10^6}{1000 \times 124^2} = 1.28$$

$$\mathrm{MF} = 0.55 + \frac{477 - 209.68}{120(0.9 + 1.28)} = 1.57$$

$$\frac{\text{Modified Span}}{d} = 1.57 \times 20 = 31.44$$

25.34 < 31.44

Deflection is Ok.

CRACK CONTROL

3.12.11.2.4

Clear spacing = $\frac{47,000}{F_s} \leq \mathbf{300}$

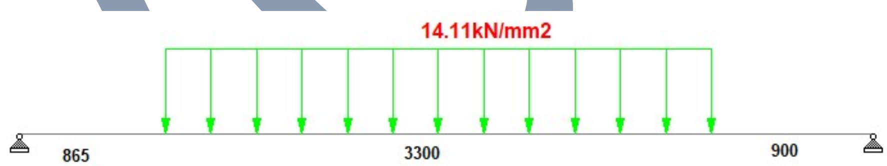
$$F_s = 209.68$$

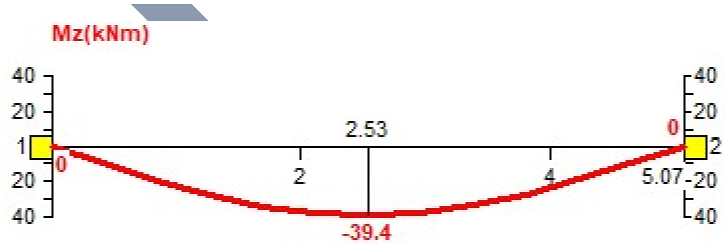
Clear spacing = 47,000/209.68 = 224.15 > 188

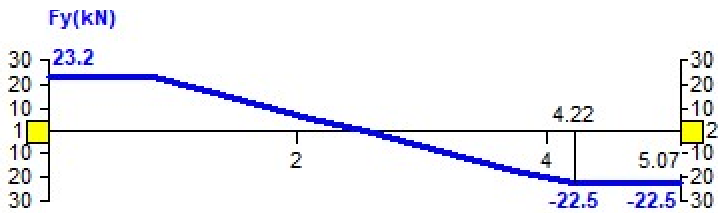
Crack control is Ok.

For second flight

Effective Span = (3300) + 0.5(1730 +1800) = 5065mm







M_{max} = 39.4kNm/m

b=1000mm, Cover = 20mm, $\emptyset = 16\text{mm}$

d = 150 -20 – (16/2) =122mm

K = M / (bd^2f_{cu}) = (39.4×10^6) / ($1000 \times 122^2 \times 25$) = 0.11 < 0.156

Compression reinforcement isn't required.

Z = d {0.5 + √[0.25-(0.11/0.9)]} = 0.864d < 0.95d

As = M / (0.95fyZ) = 39.4×10^6/ (0.95 x 410 x 0.864 x 122) = 959.9mm^2

Provide Y16 bars at 175c/c (1150mm^2) at bottom of waist slab

DEFLECTION

$$\frac{\text{Span}}{\text{d}} = \frac{3300 + 865 + 900}{122} = 41.52$$

$$MF \ \leq 2$$

$$\frac{\text{Modified Span}}{d} = 2 \ \times 20 = 40$$

41.52 > 40

Deflection is not Ok.

Increase depth of waist slab to **190**

Flight loading

Concrete own weight (+20mm plaster below waist slab) = 24 x (0.19+0.02) = 5.04kN/m^2

Steps=0.5 x 0.15 x 24 = 1.8kN/m^2

Terrazzo Finishes + screed say = 0.5kN/m^2

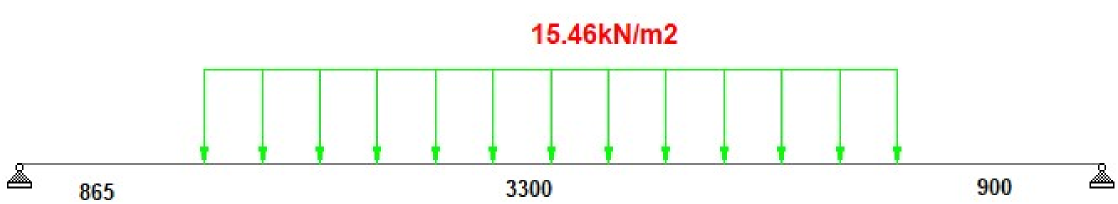
Live load, qk = 3kN/m^2

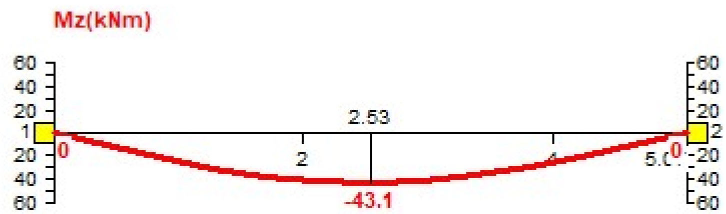
Slope factor = $\frac{\sqrt{R^2+T^2}}{T} = \frac{\sqrt{150^2+300^2}}{300}$ = 1.118

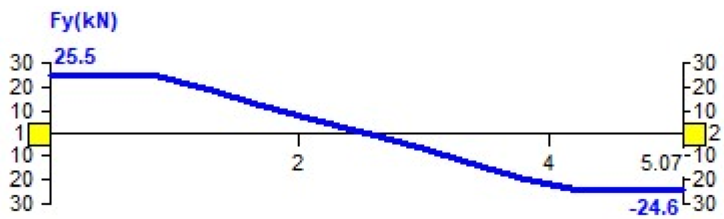
F = 1.4gk+1.6qk = 1.4(2.3 x 1.118) +1.4(5.04) + 1.6(3) = 15.46kN/m^2

For second flight

Span = (3300) + 0.5(1730 +1800) = 5065mm







M_{max} = 43.1kNm/m

b=1000mm, Cover = 20mm, $\emptyset = 16\text{mm}$

d = 190 -20 – (16/2) =162mm

$K = M / (bd^2 fcu) = (43.1x10^6) / (1000 \times 162^2 \times 25) = 0.066 < 0.156$

Compression reinforcement isn't required.

$Z = d \{0.5 + \sqrt{[0.25-(0.066/0.9)]}\} = 0.921d < 0.95d$

$As = M / (0.95fyZ) = 43.1 \times 10^6 / (0.95 \times 410 \times 0.921 \times 162) = 741.86mm^2$

Provide Y16 bars at 150c/c (1340mm^2) at bottom of waist slab

DEFLECTION

$$\frac{\text{Span}}{\text{d}} = \frac{3300 + 865 + 900}{162} = 31.3$$

$$f_s = \frac{2 \times 410 \times 741.86}{3 \times 1340} = 151.3\text{N/mm}^2$$

$$\frac{\text{M}}{\text{bd}^2} = \frac{43.1 \times 10^6}{1000 \times 162^2} = 1.64$$

$$\text{MF} = 0.55 + \frac{477 - 151.3}{120(0.9 + 1.64)} = 1.62$$

$$\frac{\text{Modified Span}}{d} = 1.62 \times 20 = 32.4$$

31.3 < 32.4

Deflection is Ok.

CRACK CONTROL

BS 8110 3.12.11.2.4

Clear spacing = $\frac{47,000}{F_s} \leq \mathbf{300}$

$F_s = 151.3$

Clear spacing = 47,000/151.3 = 310.6> 174

Crack control is Ok.

HALF LANDING SLAB DESIGN

Depth of landing = 150mm, diameter of main bar = 20

d=150 - 20 – 10 = 120mm

Span = 1500 + $\frac{230}{2} = 1615$

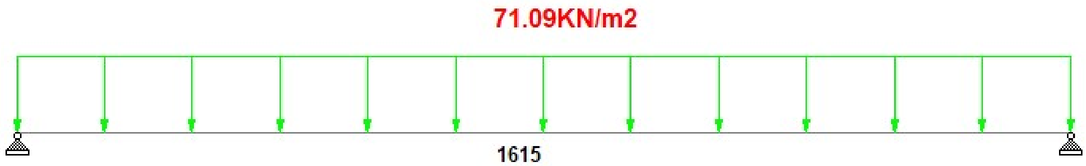
Own load=0.15 x 24 = 3.6kN/m^2

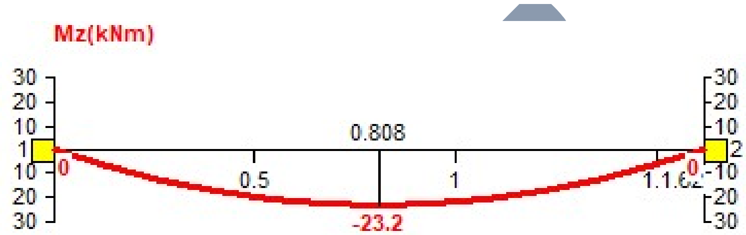
Finishes=1.0kN/m^2

Live=3kN/m^2

Total g_k= 4.6kN/m^2

Design Load = 1.4(4.6) + 1.6(3) +14.4(1.5) + 25.5(1.5) = 71.09kN/m^2





M = 0.125 x 71.09 x 1.615^2 =23.17kNm

K = M/(bd^{2}fcu) = [(23.17x10^6)/(1000 x 25 x 120^2)]=0.064

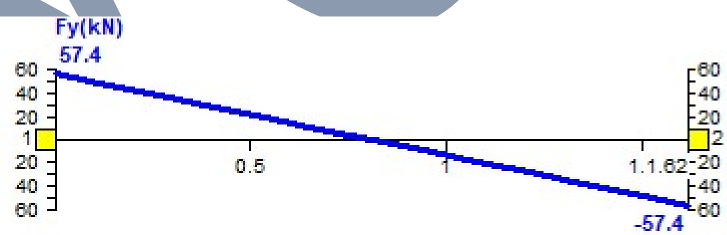
Compression reinforcement isn't required.

Z = 125{0.5 + √[0.25-(0.064/0.9)]} = 0.922d

As = (M/0.95fyZ) = (23.17 x 10^6/0.95 x 410 x 0.922 x 120) =537.4mm^2

Provide Y20 bars at 300c/c (1050mm^2) at bottom

SHEAR STRESS CHECK



Vmax = 57.4kN

$$v = \frac{Vmax}{b \times d} = \frac{57.4 \times 10^3}{1000 \times 120} = 0.48N/mm2$$

$$v_c = 0.79 \times \left\{\frac{100As}{bv \times d}\right\}^{\frac{1}{3}} \times \left(\frac{400}{d}\right)^{\frac{1}{4}} \div ym$$

$$v_c = 0.79 \times \left\{\frac{100 \times 1050}{1000 \times 120}\right\}^{\frac{1}{3}} \times \left(\frac{400}{120}\right)^{\frac{1}{4}} \div 1.25$$

$$\boldsymbol{v_c} = 0.82N/mm2$$

$$0.5v_c = 0.5 \times 0.82 = 0.41$$

$$v > 0.5v_c$$

Design shear inadequate

Change Reinforcement requirement

Provide Y20 bars at 150c/c (2510mm^2) at bottom

$$v_c = 0.79 \times \left\{\frac{100As}{bv \times d}\right\}^{\frac{1}{3}} \times \left(\frac{400}{d}\right)^{\frac{1}{4}} \div ym$$

$$v_c = 0.79 \times \left\{\frac{100 \times 2510}{1000 \times 120}\right\}^{\frac{1}{3}} \times \left(\frac{400}{120}\right)^{\frac{1}{4}} \div 1.25$$

$$\boldsymbol{v_c} = 1.09N/mm2$$

$$0.5v_c = 0.5 \times 1.09 = 0.55$$

$$v < 0.5v_c$$

Design shear adequate

DEFLECTION

$$\frac{\text{Span}}{\text{d}} = \frac{1615}{120} = 13.5$$

$$\mathrm{f}_s = \frac{2 \times 410 \times 537}{3 \times 2510} = 58.5\mathrm{N/mm}^2$$

$$\frac{M}{bd^2} = \frac{23.17\times10^6}{1000\times120^2} = 1.61$$

$$MF = 0.55 + \frac{477 - 58.5}{120(0.9 + 1.61)} = 1.94$$

$$\frac{\text{Modified Span}}{d} = 1.94 \times 20 = 38.8$$

13.5 < 32.4

Deflection is Ok.

CRACK CONTROL

BS 8110 3.12.11.2.4

Clear spacing = $\frac{47,000}{F_s} \leq \mathbf{300}$

$F_s = 58.5$

Clear spacing = 47,000/58.5 = 803> 130

Crack control is Ok.

FULL LANDING SLAB

Depth of landing = 150mm,

d=150 - 20 – 10 = 120mm

Span = 1615mm

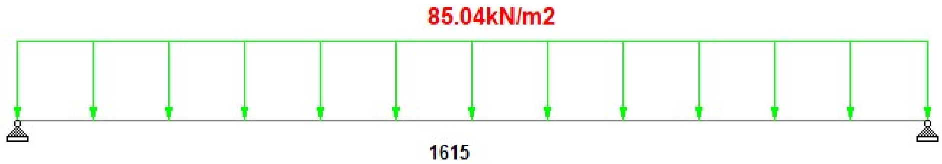
Own load=0.15 x 24= 3.6kN/m^2

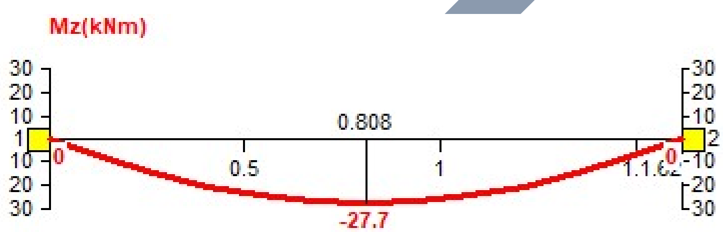
Finishes=1.0kN/m^2

Live=3kN/m^2

Total g_k= 4.6kN/m^2

Design Load = 1.4(4.6) + 1.6(3) +24.6(3) = 85.04kN/m^2





M = 0.125 x 85.04 x 1.615^{2}= 27.73kNm

K = M / (bd^2fcu) = [(27.73x10^6)/(25x120^2x1000)] = 0.077

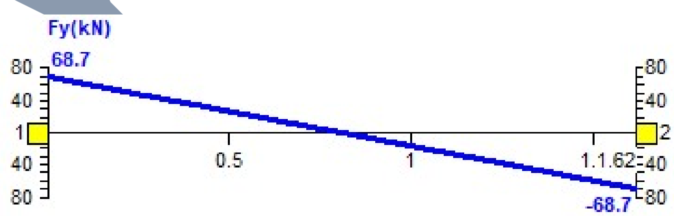
Compression reinforcement isn't required.

Z = d {0.5 + √[0.25-(0.077/0.9)]} = 0.905d

As = (M/0.95fyZ) = (27.73 x 10^6/ 0.95 x 410 x 0.905 x 120) =655.6mm^2

Provide Y20 bars at 300c/c (1050mm^2) at bottom

SHEAR STRESS CHECK



Vmax = 68.7kN

$$v = \frac{Vmax}{b \times d} = \frac{68.7 \times 10^3}{1000 \times 120} = 0.57N/mm2$$

$$v_c = 0.79 \times \left\{\frac{100As}{bv \times d}\right\}^{\frac{1}{3}} \times \left(\frac{400}{d}\right)^{\frac{1}{4}} \div ym$$

$$v_c = 0.79 \times \left\{\frac{100 \times 1050}{1000 \times 120}\right\}^{\frac{1}{3}} \times \left(\frac{400}{120}\right)^{\frac{1}{4}} \div 1.25$$

$$\boldsymbol{v_c} = 0.82N/mm2$$

$$0.5v_c = 0.5 \times 0.82 = 0.41$$

$$v > 0.5v_c$$

Design shear inadequate

Change Reinforcement requirement

Provide Y20 bars at 100c/c (3140mm^2) at bottom

$$v_c = 0.79 \times \left\{\frac{100As}{bv \times d}\right\}^{\frac{1}{3}} \times \left(\frac{400}{d}\right)^{\frac{1}{4}} \div ym$$

$$v_c = 0.79 \times \left\{\frac{100 \times 3140}{1000 \times 120}\right\}^{\frac{1}{3}} \times \left(\frac{400}{120}\right)^{\frac{1}{4}} \div 1.25$$

$$\boldsymbol{v_c} = 1.18N/mm2$$

$$0.5v_c = 0.5 \times 1.18 = 0.59$$

$$v < 0.5v_c$$

Design shear adequate

DEFLECTION

$$\frac{\text{Span}}{\text{d}} = \frac{1615}{120} = 13.5$$

$$f_s = \frac{2 \times 410 \ \times 655.6}{3 \times 3140} = 57.1\mathrm{N/mm^2}$$

$$\frac{\mathrm{M}}{\mathrm{bd^2}} = \frac{27.73\times10^6}{1000\times120^2} = 1.93$$

$$\mathrm{MF} = 0.55 + \frac{477 - 151.3}{120(0.9 + 1.64)} = 1.93$$

$$\frac{\text{Modified Span}}{d} = 1.93 \ \times 20 = 38.6$$

13.5 < 32.4

Deflection is Ok.

CRACK CONTROL

BS 8110 Clause 3.12.11.2.4

Clear spacing = $\frac{47{,}000}{F_s} \leq \mathbf{300}$

$F_s = 57.1$

Clear spacing = 47,000/57.1 = 823> 134

Crack control is Ok.

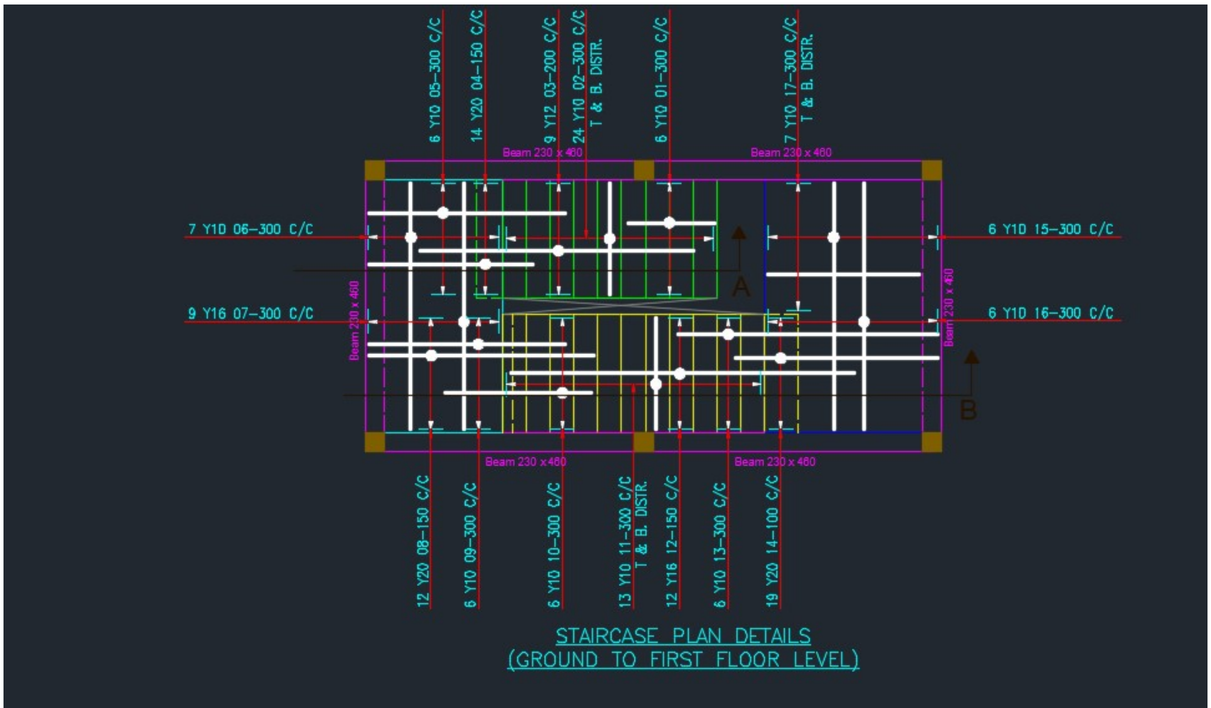
MINIMUM REINFORCEMENT

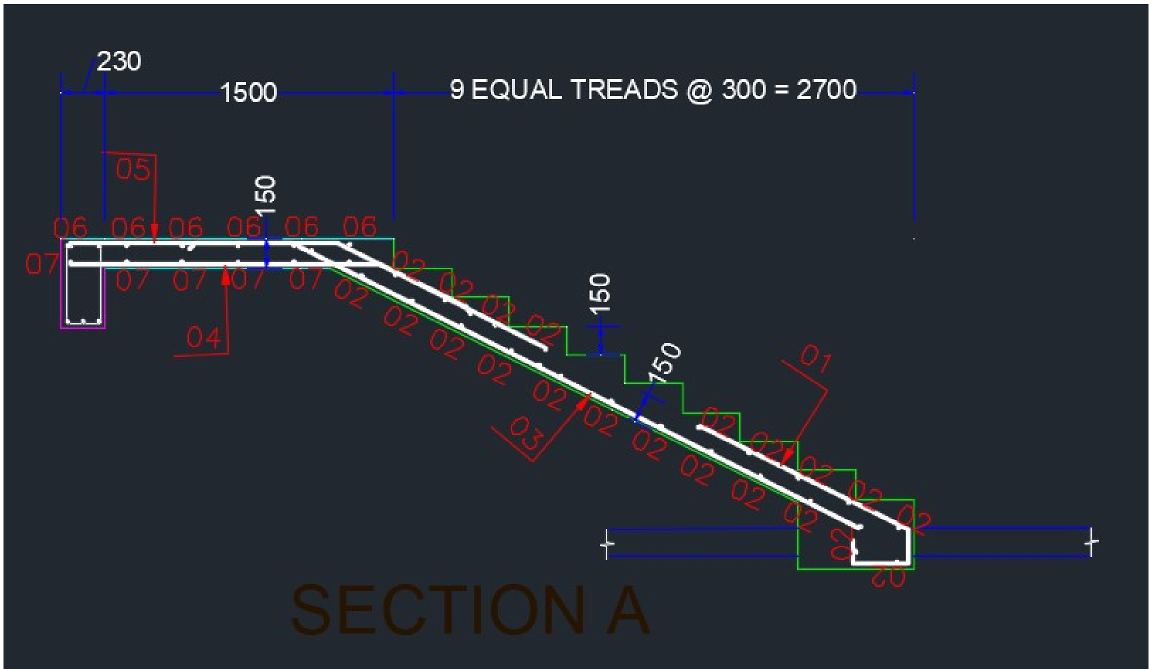
$$\frac{100 \ \times A_s}{A_c} = 0.13$$

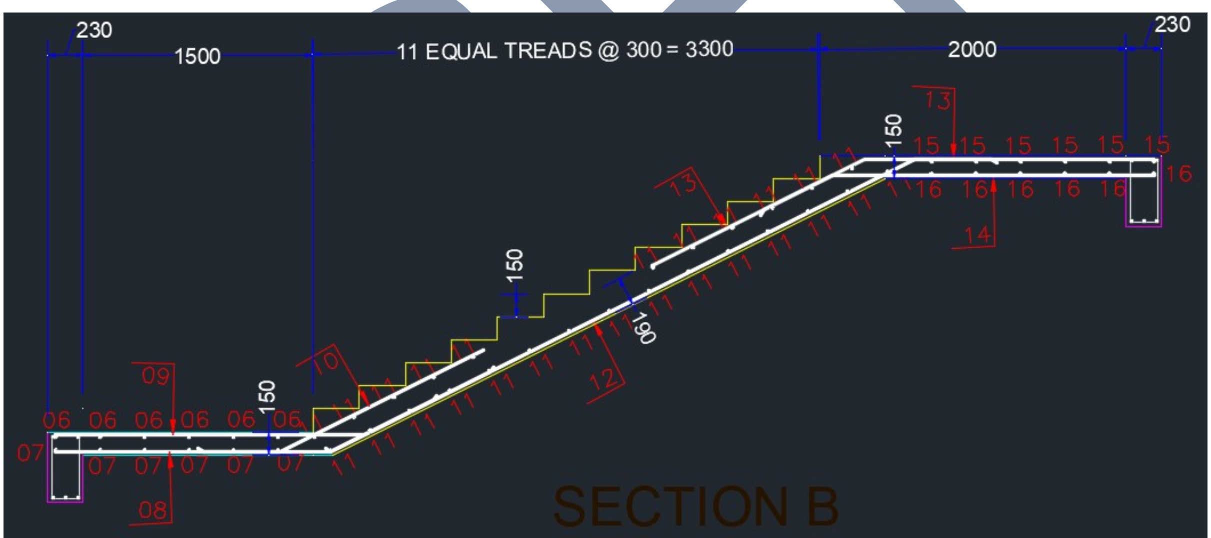
$$As = \frac{0.13 \times 1000 \times 150}{100} = 195$$

Y12@300 c/c 377mm2

STRUCTURAL DETAIL OF STAIRCASE




230
1500
9 EQUAL TREADS @ 300 = 2700
150
150
150
SECTION A


230
1500
11 EQUAL TREADS @ 300 = 3300
2000
230
150
150
150
SECTION B