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RC STAIRCASE DESIGN

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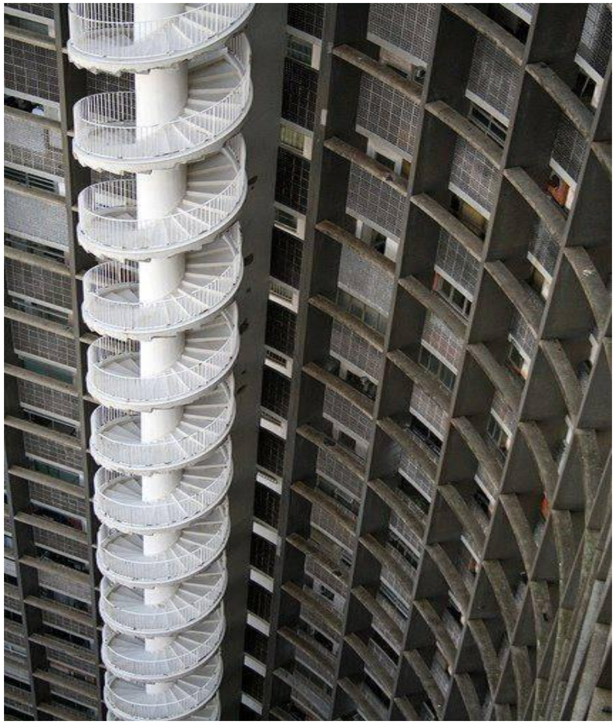
FKAAS
FAKULTI KEJURUTERAAN AWAM DAN ALAM SEKITAR

Introduction



Staircase

vs

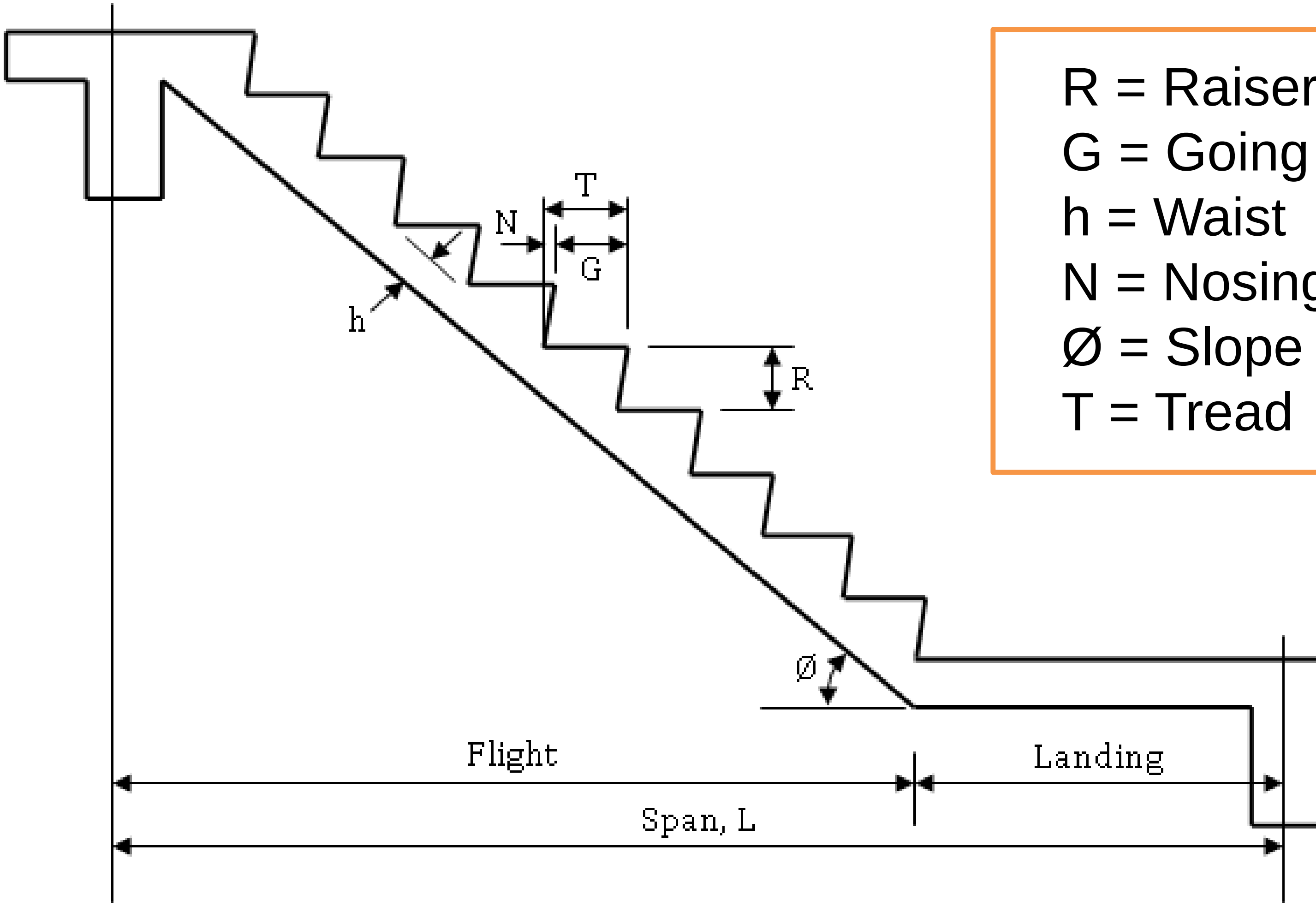
Lift/ Elevator/ Escalator

Why we still need staircase?

Introduction

- A stair is a convenient means of access between the floors of a building.
- It is constructed to provide ready, easy, comfortable and safe ascent/descent.
- It consists of a flight of steps, usually with one or more intermediate landings provided between the floor levels.
- Concrete staircase has requisite fire resisting qualities, durable, strong and pleasing in appearance, as well as favorable choice in framed structures.

Introduction



R = Raiser
G = Going
h = Waist
N = Nosing
Ø = Slope
T = Tread

The basic terminology of stairs

Introduction

- The dimension of stair should be such as to give the maximum comfort to the users, which depends on the use of the building.

- Basic guideline:

  - Public buildings: R is not more than 180mm, G shall not be less than 255mm, whereas

  - Private buildings: R is not more than 200mm, G are varies between 250mm to 400mm.

  - For comfort, R and G can be proportioned according to the following formula;

$$(2 \times R) + G = 600\text{mm} \quad \textbf{\textit{(BS 5395)}}$$

Introduction

- For optimum requirement:

Stair	Rise (mm)			Going (mm)			Pitch (°)		Unobstructed width (mm)	
	Min.	Opt.	Max.	Min.	Opt.	Max.	Opt.	Max.	Min.	Reduced min. where stair has limited use
Private stair	100	175	190	225	250	300	35	40	800	600
	220 absolute max.						42 absolute max.			
Semi-public stair (factories, offices, shops, schools, etc.)	100	165	190	250	275	350	31	38	1000	800
Public stair (cinema, theatre, stadium, hospitals, etc.	100	150	180	280	300	350	27	33	1000	-
									Hospitals 1200	

Classification of Staircase

- Two main classifications of staircase related to the design method:

Transverse span staircase	Longitudinal span staircase
▪ Staircases which spans perpendicular to the stair flight.	▪ It spans parallel to the stair flight. ▪ Two supports at upper and lower of stair flight with no lateral flight support.
▪ Design: one unit of step is taken as a beam. ▪ Area of reinforcement is determined like a beam.	▪ Design: similar to the design of one-way spanning slab.

- Transverse-span staircase are further subdivided to the following:

Transverse span staircase		
Cantilever staircase from wall on one side	Staircase span between support on both left and right	Cantilever staircase from the middle beam

Classification of Staircase

- Transverse span staircase – cantilever staircase

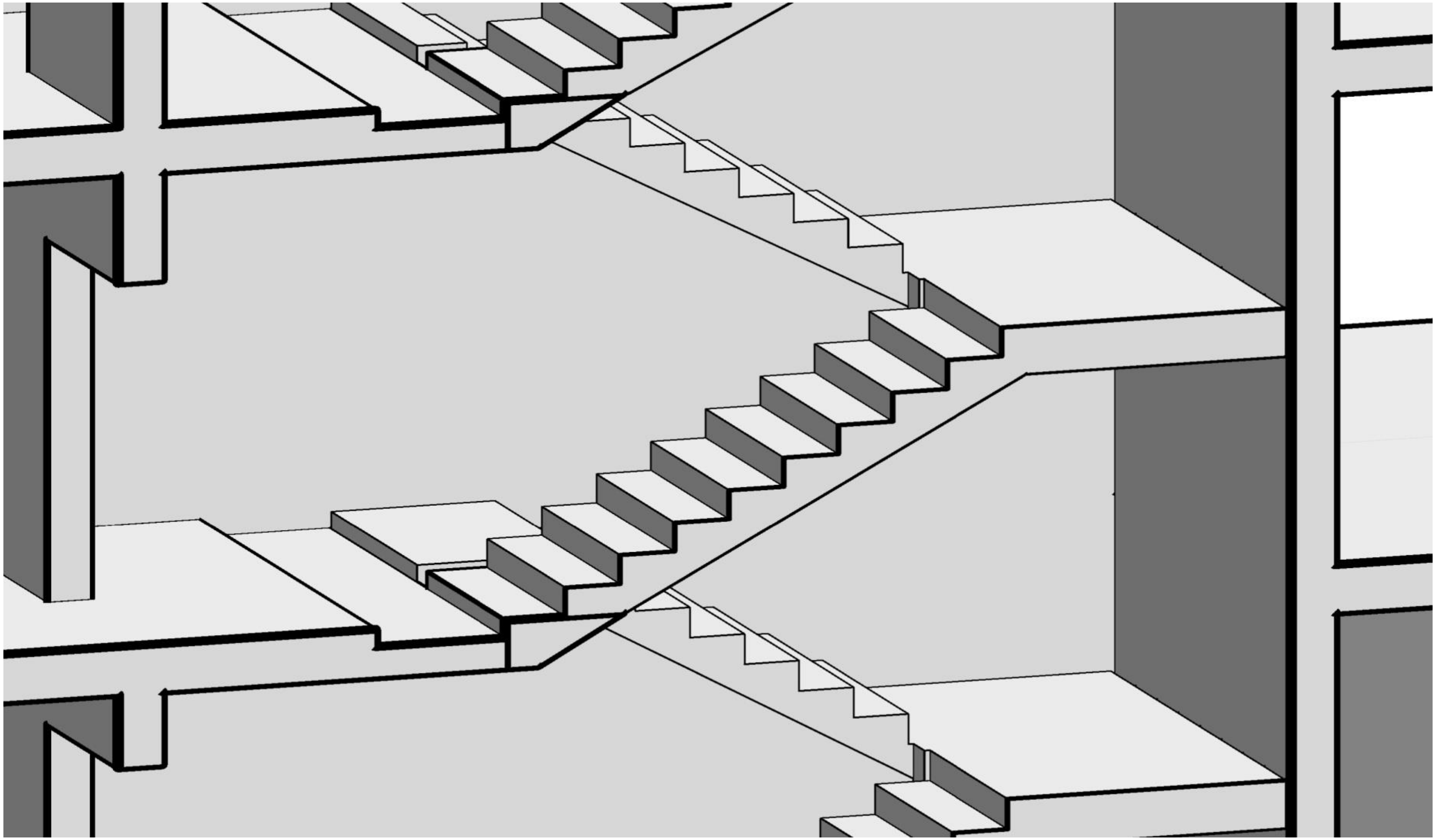
- Longitudinal-span staircase are further subdivided to the following:

Longitudinal span staircase

- Monolithic staircase
- Staircase with landing supported by beam/wall
- Staircase and landing built into the wall
- Staircase supported by landing perpendicular to the stair flight
- Staircase surrounding openings

Classification of Staircase

- Longitudinal span staircase



Classification of Staircase

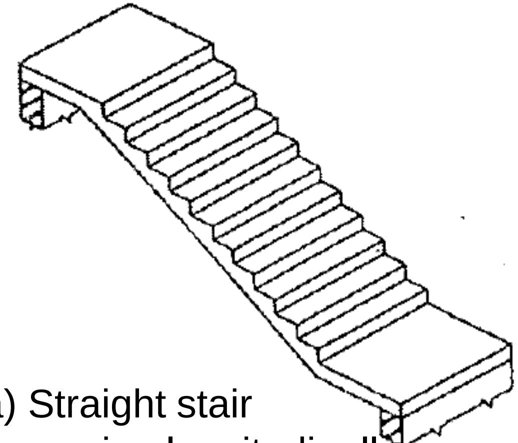
- Longitudinal span staircase

Type of Staircase

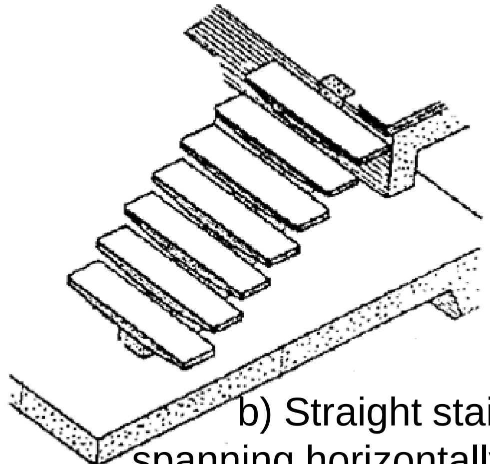
- Depend mainly on the type and function of the building, and on architectural requirements.

- Type of staircase:
  - **Straight flight** (floor to floor, with/out landing, used where space is limited)
  - **Quarter turn** (rises to landing between floors, turn to 90°, space saving)
  - **Half turn/dog-legged** (rises to landing between floors, turn to 180°, used in most building)
  - **Geometrical** (spiral, elliptical, extravagant, used in prestigious building)

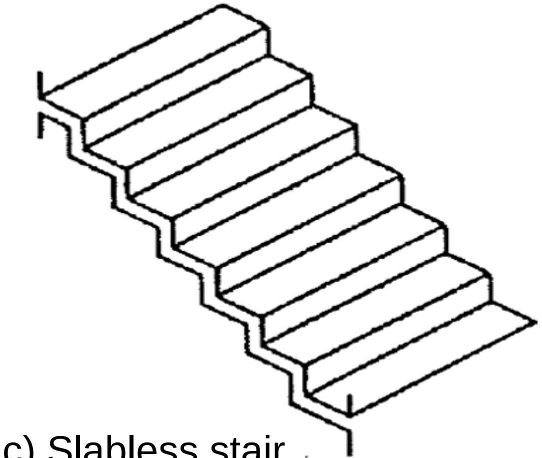
Type of Staircase



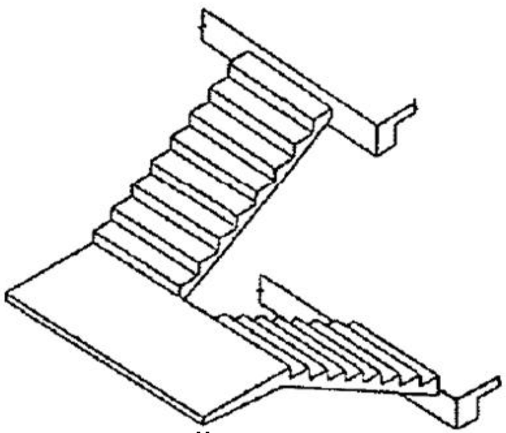
a) Straight stair spanning longitudinally



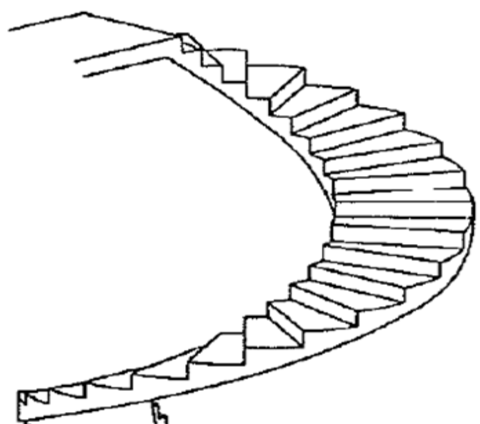
b) Straight stair spanning horizontally



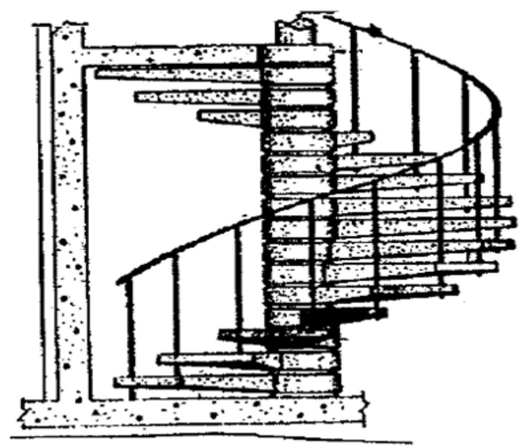
c) Slabless stair



d) Free standing



f) Helical stair

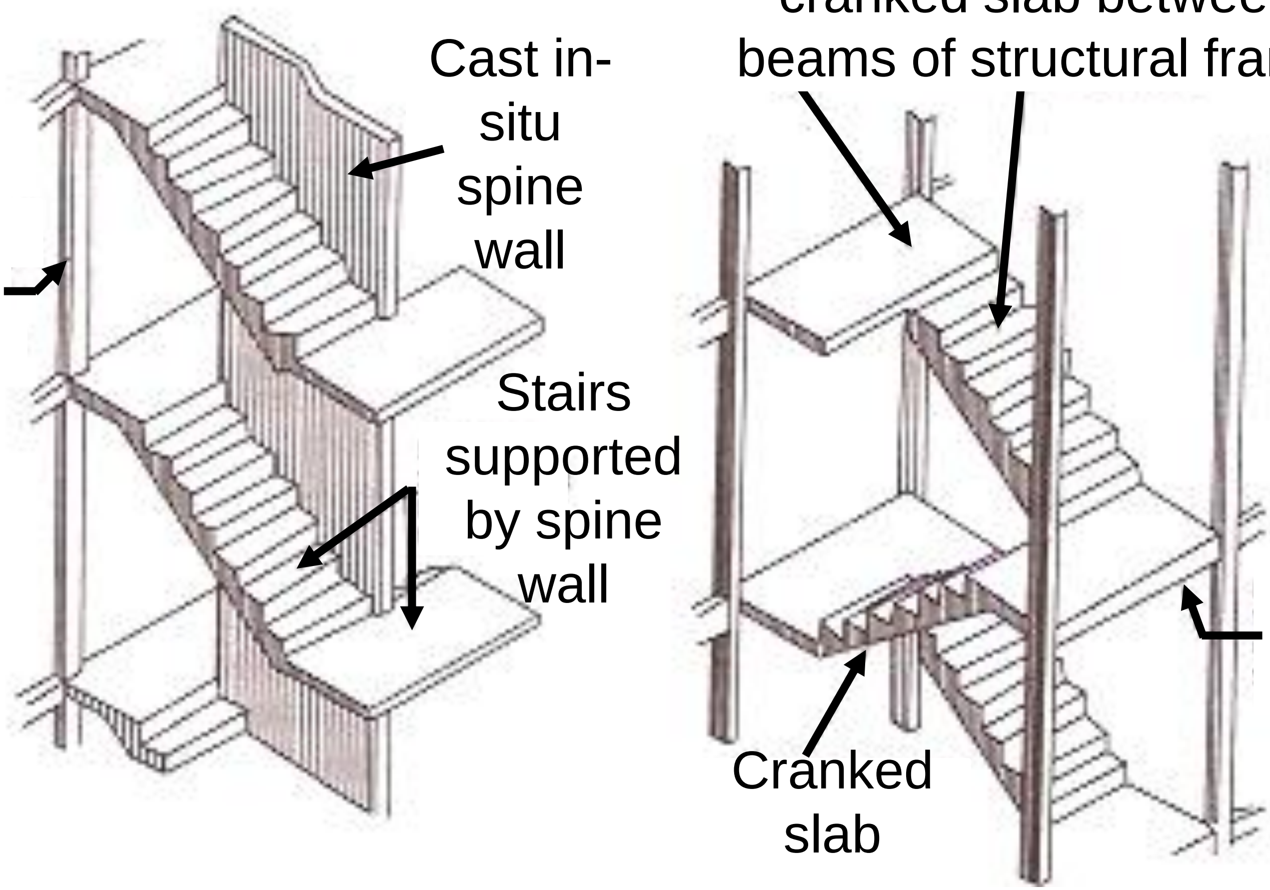


f) Spiral stair

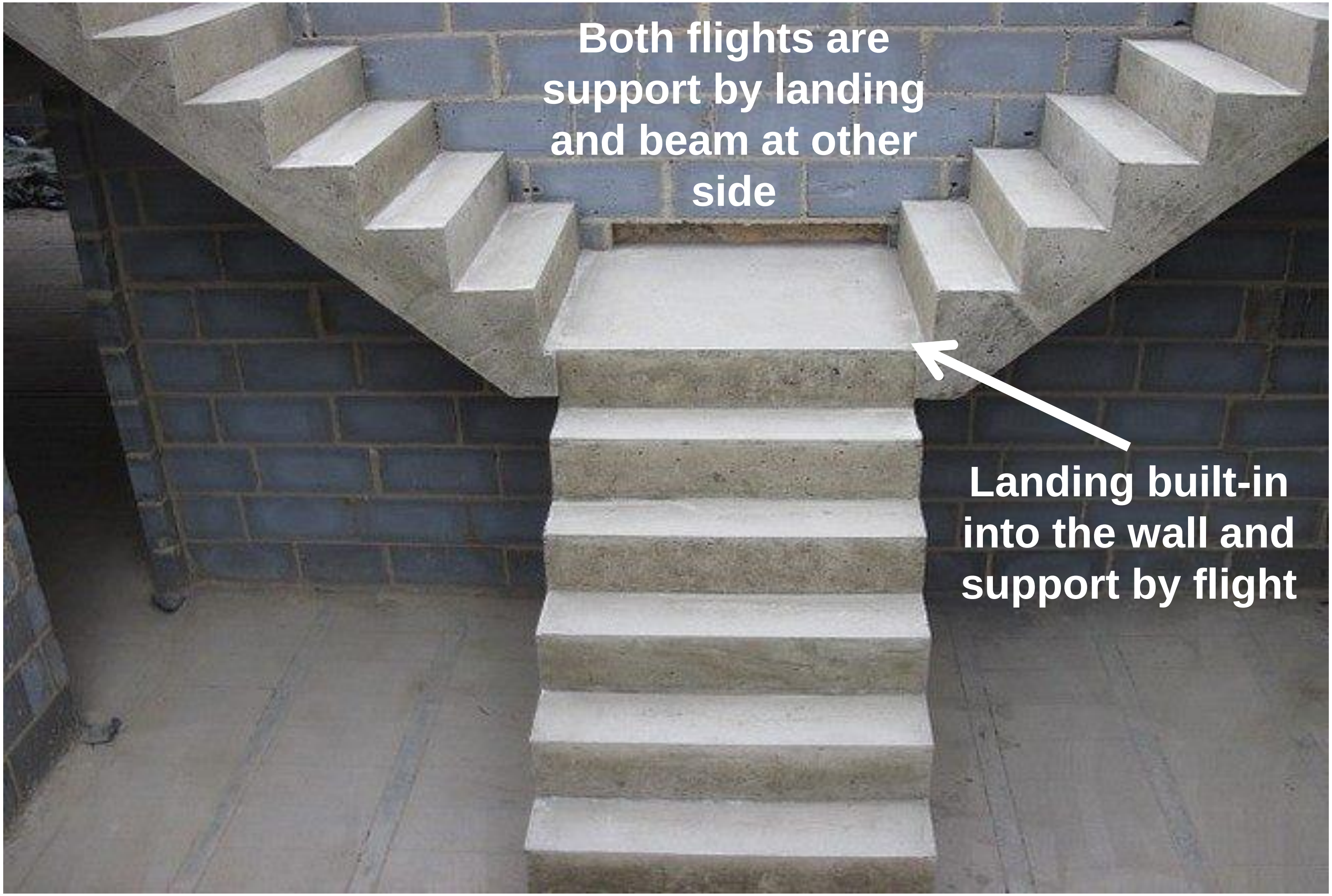
Support Condition

Many cases of staircase are supported by beam or wall

Support Condition



Support Condition



Support Condition

Design Consideration

- The reinforced concrete stairs should be designed generally similar to reinforced concrete slabs, except as indicated otherwise.

1. **Actions**

    When considering the permanent load for the flights of stair, care should be taken to ensure that a sufficient allowance is made to cater the weight of the steps and finishes as well as the increase loading on plan occasioned by the inclination of the waist.

    Where stair with open wells have two intersecting landings at right-angles to each other, the actions on the areas common to both spans may be divided equally between the spans.

Design Consideration

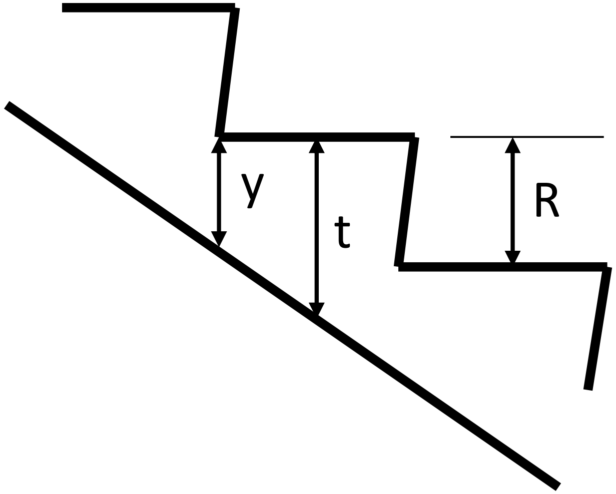
Selfweight of landing and flight can be calculated by considering overall waist (h_L) and average thickness (t).

For landing, the selfweight is considered as:
g_k (landing) = 25 kN/m^3 x overall waist

For flight, the selfweight is considered as:
g_k (flight) = 25 kN/m^3 x average thickness

$$y = h\left[\frac{\left(G^2 + R^2\right)^{1/2}}{G}\right]$$

$$t = y + \left(\frac{R}{2}\right)$$



Design Consideration

2. Bending moment and shear force

Stair slabs and landings should be designed to support the most unfavorable arrangements of design loads.

For example, where a span is adjacent to a cantilever of length exceeding one third of the span of the slab, the case should be considered of maximum load on the cantilever and minimum load on the adjacent span.

Stairs which are continuous and constructed monolithically with supporting slabs or beams can be designed for a bending moment of FL/10, where F is the total ultimate load. For a simply supported staircase, bending moment is consider as FL/8.

3. Effective span

The effective span of stairs spanning between beams or walls is the distance between centre-line of supporting beams or walls.

The effective span of stairs spanning between landing slabs is the distance between centre-line of supporting landing slabs, or the distance between the edges of the supporting slabs plus 1.8 m, whichever is the smaller.

Given the rise, going and the number of steps, the span and overall height can be determined:
Span = no. steps x going, Height = no. steps x rise
Slope length = $\sqrt{(\text{Span}^2 + \text{Height}^2)}$

4. Detailing

The reinforcement arrangement in stair flights follows a standard pattern. Deviation from this 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.

Strength requirements are not always critical for stair slabs. It is therefore essential that the other limit states are checked:

a. Deflection
b. Cracking
c. Min. % As

5. Bar arrangement

Reinforcement should also be provided in the compression zone with distance $0.3L_{eff}$ for flight and $0.2L_{eff}$ for landing (from support).

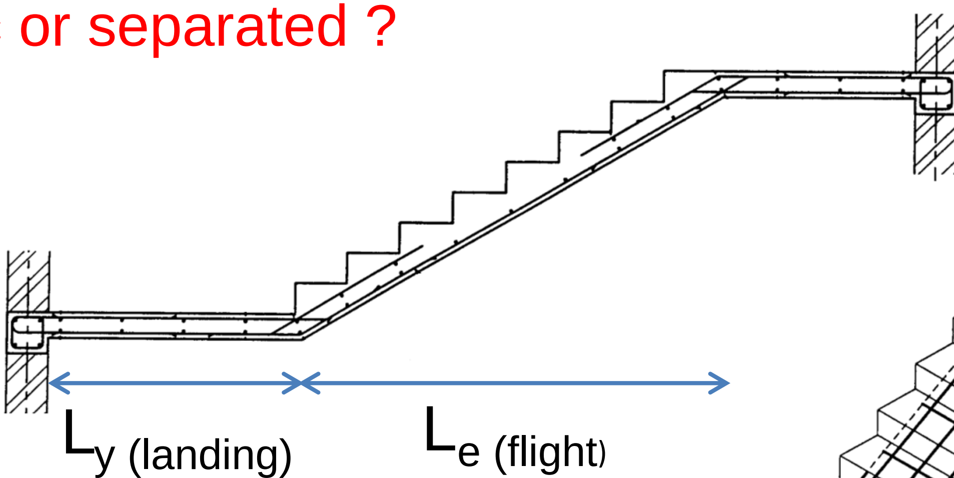
Concept of Design

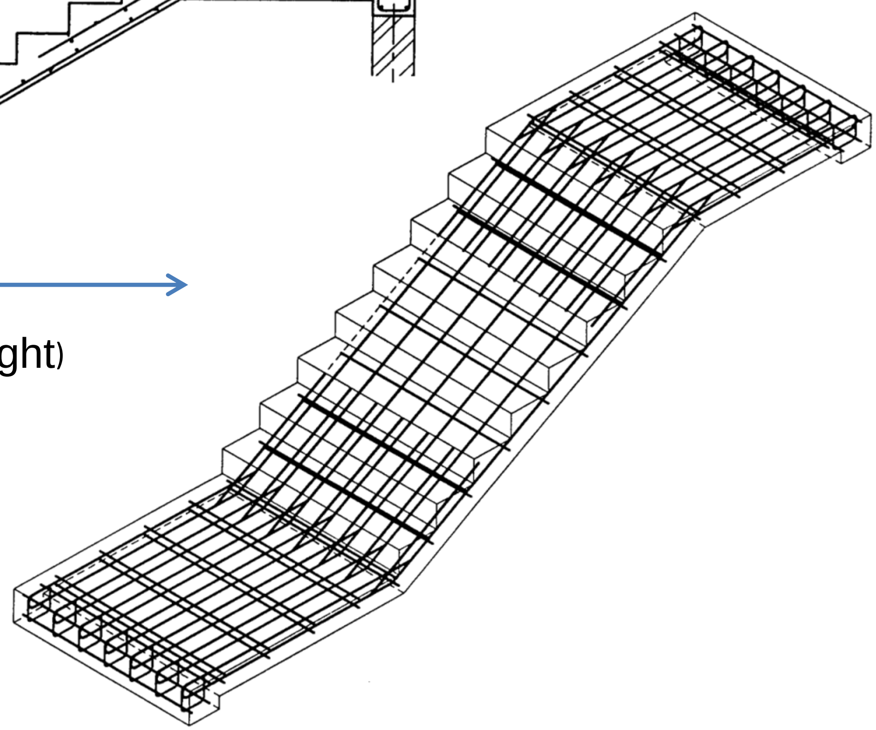
Flight and landing monolithically	**Flight and landing separately**
❑ Simply supported stair ❑ 1 flight + 1 landing ❑ Flight perpendicular to landing in L_x ❑ Condition of support at landing is simply support	❑ Flight perpendicular to landing in the direction of load distribution (L_y) ❑ Sharing spanning landing ❑ Condition of support at landing is 3-edge-support
Example: Half-turn	Example: U-turn, parallel flights

Concept of Design

Exact design should be based on the requirement of reinforcements

Monolithic or separated ?

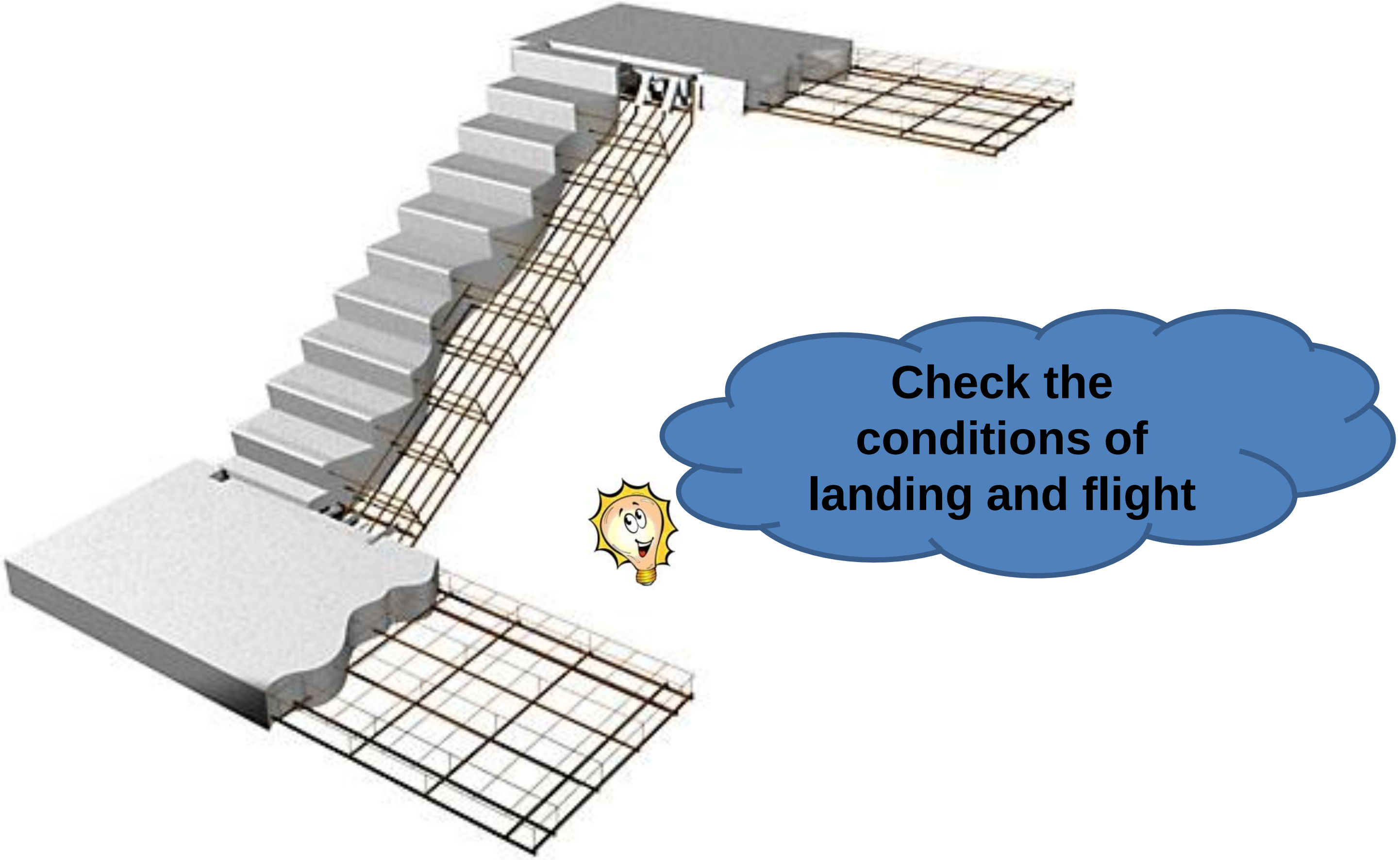




Check direction of main reinforcement and deflection control

Concept of Design

Monolithic or separated ?



Procedure of Design

Identify type of staircase	→	Monolithic/separated
Determine R, G, h_f, h_L	→	Comfort requirement & T4.7N
Calculate average thicknesses	→	y and t
Calculate actions	→	G_k, Q_k, n_k for flight/landing
Calculate moment and shear	→	Simple support/with cantilever
Design main reinforcement	→	d, k, z, As, As_{max}, As_{min}, As_{sec}
Check shear resistance	→	k, ρ_1, $V_{Rd,c}$, V_{min}
Check deflection	→	ρ, ρ_o ,l/d, $f_{modification}$
Check cracking	→	h, $S_{max,slab}$, max. bar spacing
Detailing	→	main/secondary

Example of Design

1) Example 1:
   Stair Spanning Longitudinally Continuous Over Supports

2) Example 2:
   Stair Spanning Longitudinally with Landing and Continuous at One End

3) Example 3:
   Staircase Spanning Parallel to Flight with Landings

4) Example 4:
   Stair Supported by Landing Spanning Perpendicular to Stair Flight (Half Turn)

5) Example 5:
   Stair Supported by Landing Spanning Perpendicular to Stair Flight (Quarter Turn)