# Module 9

# Staircases

# Lesson 20

# Types and Design of Staircases

Version 2 CE IIT, Kharagpur

## Instructional Objectives:

At the end of this lesson, the student should be able to:

- classify the different types of staircases based on geometrical configurations,
- name and identify the different elements of a typical flight,
- state the general guidelines while planning a staircase,
- determine the dimensions of trade, riser, depth of slab etc. of a staircase,
- classify the different staircases based on structural systems,
- explain the distribution of loadings and determination of effective spans of stairs,
- analyse different types of staircases including the free-standing staircases in a simplified manner,
- design the different types of staircases as per the stipulations of IS 456.

## 9.20.1 Introduction

Staircase is an important component of a building providing access to different floors and roof of the building. It consists of a flight of steps (stairs) and one or more intermediate landing slabs between the floor levels. Different types of staircases can be made by arranging stairs and landing slabs. Staircase, thus, is a structure enclosing a stair. The design of the main components of a staircase-stair, landing slabs and supporting beams or wall – are already covered in earlier lessons. The design of staircase, therefore, is the application of the designs of the different elements of the staircase.

## 9.20.2 Types of Staircases

**Fig. 9.20.1(a)**: Single flight staircase

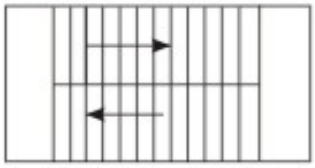

**Fig. 9.20.1(b)**: Two flight staircase

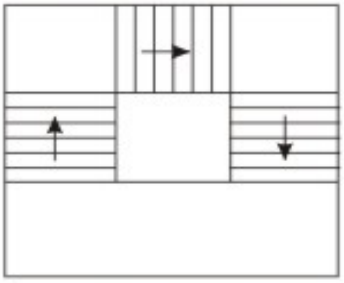

**Fig. 9.20.1(c)**: Open-well staircase

**Fig. 9.20.1**: Types of staircases

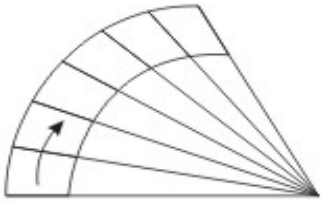

**Fig. 9.20.1(e)**: Helicoidal staircase

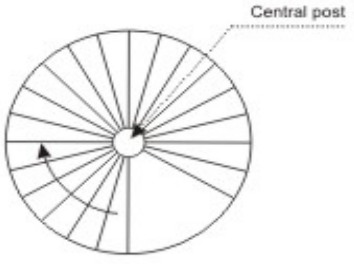


**Fig. 9.20.1(d)**: Spiral staircase

**Fig. 9.20.1**: Types of staircases

Figures 9.20.1a to e present some of the common types of staircases based on geometrical configurations:

(a) Single flight staircase (Fig. 9.20.1a)

(b) Two flight staircase (Fig. 9.20.1b)
(c) Open-well staircase (Fig. 9.20.1c)
(d) Spiral staircase (Fig. 9.20.1d)
(e) Helicoidal staircase (Fig. 9.20.1e)

Architectural considerations involving aesthetics, structural feasibility and functional requirements are the major aspects to select a particular type of the staircase. Other influencing parameters of the selection are lighting, ventilation, comfort, accessibility, space etc.

## 9.20.3 A Typical Flight

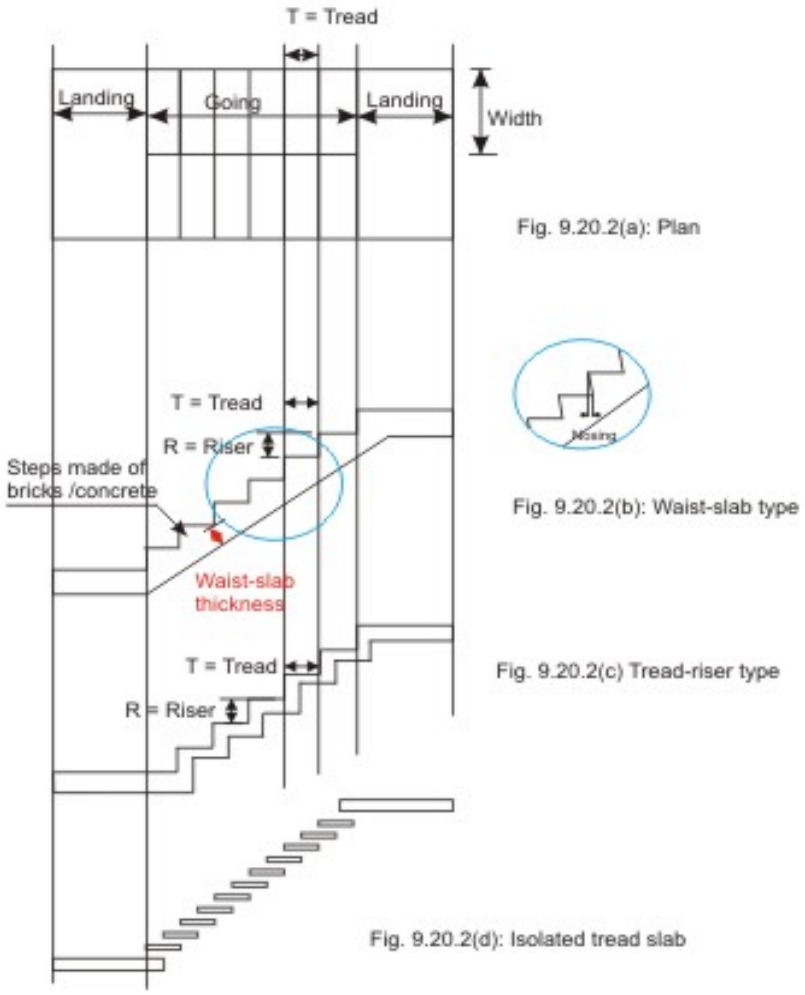


**Fig. 9.20.2**: A typical flight

Figures 9.20.2a to d present plans and sections of a typical flight of different possibilities. The different terminologies used in the staircase are given below:

(a) Tread: The horizontal top portion of a step where foot rests (Fig.9.20.2b) is known as tread. The dimension ranges from 270 mm for residential buildings and factories to 300 mm for public buildings where large number of persons use the staircase.

(b) Nosing: In some cases the tread is projected outward to increase the space. This projection is designated as nosing (Fig.9.20.2b).

(c) Riser: The vertical distance between two successive steps is termed as riser (Fig.9.20.2b). The dimension of the riser ranges from 150 mm for public buildings to 190 mm for residential buildings and factories.

(d) Waist: The thickness of the waist-slab on which steps are made is known as waist (Fig.9.20.2b). The depth (thickness) of the waist is the minimum thickness perpendicular to the soffit of the staircase (cl. 33.3 of IS 456). The steps of the staircase resting on waist-slab can be made of bricks or concrete.

(e) Going: Going is the horizontal projection between the first and the last riser of an inclined flight (Fig.9.20.2a).

The flight shown in Fig.9.20.2a has two landings and one going. Figures 9.2b to d present the three ways of arranging the flight as mentioned below:

(i) waist-slab type (Fig.9.20.2b),
(ii) tread-riser type (Fig.9.20.2c), or free-standing staircase, and
(iii) isolated tread type (Fig.9.20.2d).

## 9.20.4 General Guidelines

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

- The respective dimensions of tread and riser for all the parallel steps should be the same in consecutive floor of a building.
- The minimum vertical headroom above any step should be 2 m.
- Generally, the number of risers in a flight should be restricted to twelve.
- The minimum width of stair (Fig.9.20.2a) should be 850 mm, though it is desirable to have the width between 1.1 to 1.6 m. In public building, cinema halls etc., large widths of the stair should be provided.

## 9.20.5 Structural Systems

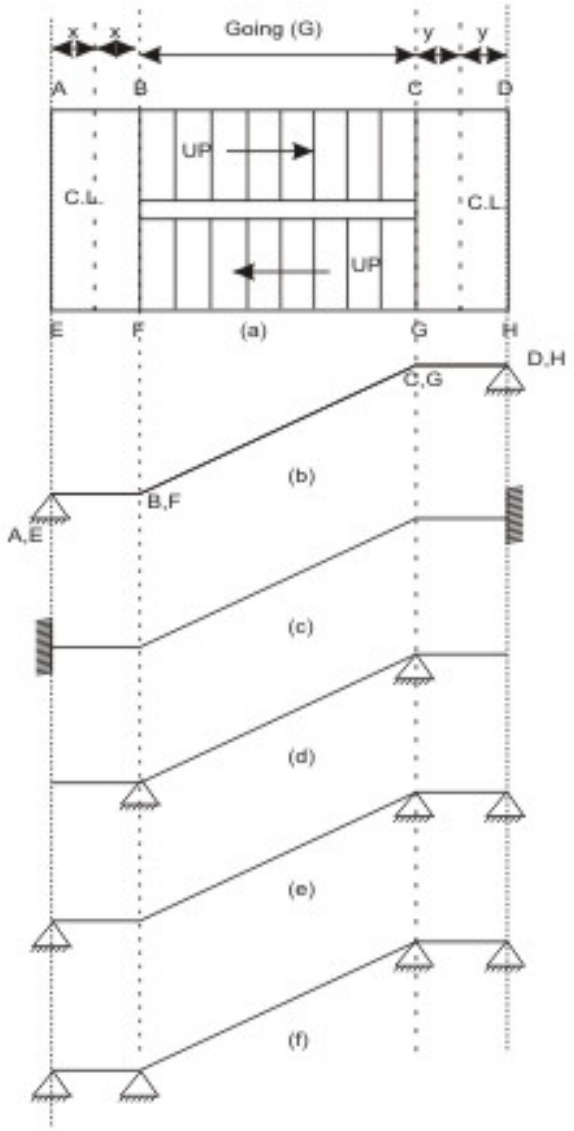


**Fig. 9.20.3**: Longitudinally spanning staircases

Different structural systems are possible for the staircase, shown in Fig. 9.20.3a, depending on the spanning direction. The slab component of the stair spans either in the direction of going i.e., longitudinally or in the direction of the steps, i.e., transversely. The systems are discussed below:

### (A) Stair slab spanning longitudinally

Here, one or more supports are provided parallel to the riser for the slab bending longitudinally. Figures 9.20.3b to f show different support arrangements of a two flight stair of Fig.9.20.3a:

(i) Supported on edges AE and DH (Fig.9.20.3b)
(ii) Clamped along edges AE and DH (Fig.9.20.3c)
(iii) Supported on edges BF and CG (Fig.9.20.3d)
(iv) Supported on edges AE, CG (or BF) and DH (Fig.9.20.3e)
(v) Supported on edges AE, BF, CG and DH (Fig.9.20.3f)

Cantilevered landing and intermediate supports (Figs.9.20.3d, 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.

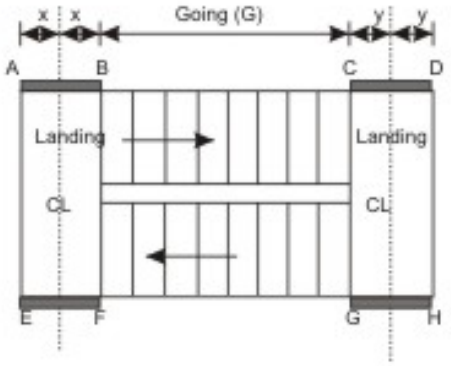


**Fig. 9.20.4(a)**: Beams at two ends of landings

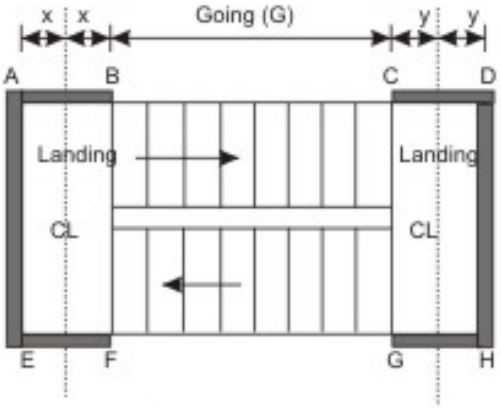


**Fig. 9.20.4(b)**: Beams at three ends of landings

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

In the case of two flight stair, sometimes the flight is supported between the landings which span transversely (Figs.9.20.4a and b). 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.

Longitudinal spanning of stair slab is also possible with other configurations including single flight, open-well helicoidal and free-standing staircases.

## (B) Stair slab spanning transversely

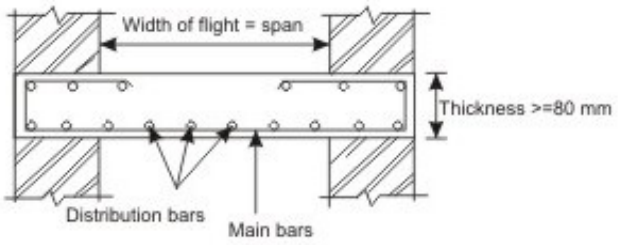


**Fig. 9.20.5(a)**: Slabs supported between two stringer beams or walls

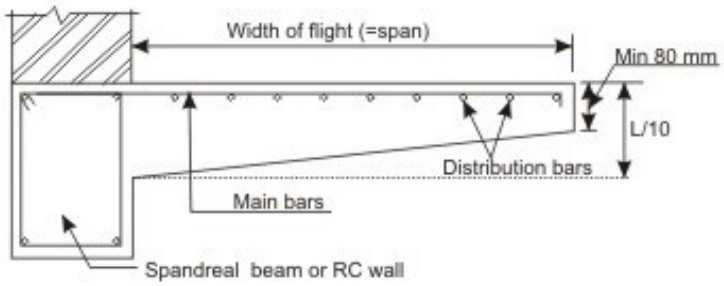


**Fig. 9.20.5(b)**: Cantilever slab from a spandreal beam or wall

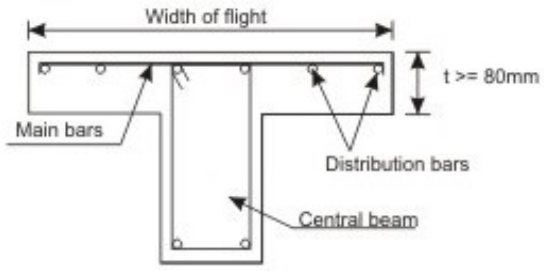


**Fig. 9.20.5(c)**: Doubly cantilever slab from a central beam

**Fig. 9.20.5**: Transversely spanning staircases

Here, either the waist slabs or the slab components of isolated tread-slab and trade-riser units are supported on their sides or are cantilevers along the width direction from a central beam. The slabs thus bend in a transverse vertical plane. The following are the different arrangements:

(i) Slab supported between two stringer beams or walls (Fig.9.20.5a)
(ii) Cantilever slabs from a spandreal beam or wall (Fig.9.20.5b)
(iii) Doubly cantilever slabs from a central beam (Fig.9.20.5c)

## 9.20.6 Effective Span of Stairs

The stipulations of clause 33 of IS 456 are given below as a ready reference regarding the determination of effective span of stair. Three different cases are given to determine the effective span of stairs without stringer beams.

(i) The horizontal centre-to-centre distance of beams should be considered as the effective span when the slab is supported at top and bottom risers by beams spanning parallel with the risers.

(ii) The horizontal distance equal to the going of the stairs plus at each end either half the width of the landing or one meter, whichever is smaller when the stair slab is spanning on to the edge of a landing slab which spans parallel with the risers. See Table 9.1 for the effective span for this type of staircases shown in Fig.9.20.3a.

Table 9.1 Effective span of stairs shown in Fig.9.20.3a

| Sl. No. | *x* | *y* | Effective span in metres |
|---|---|---|---|
| 1 | < 1 m | < 1 m | $G + x + y$ |
| 2 | < 1 m | ≥ 1 m | $G + x + 1$ |
| 3 | ≥ 1 m | < 1 m | $G + y + 1$ |
| 4 | ≥ 1 m | ≥ 1 m | $G + 1 + 1$ |

Note: *G* = Going, as shown in Fig. 9.20.3a

## 9.20.7 Distribution of Loadings on Stairs

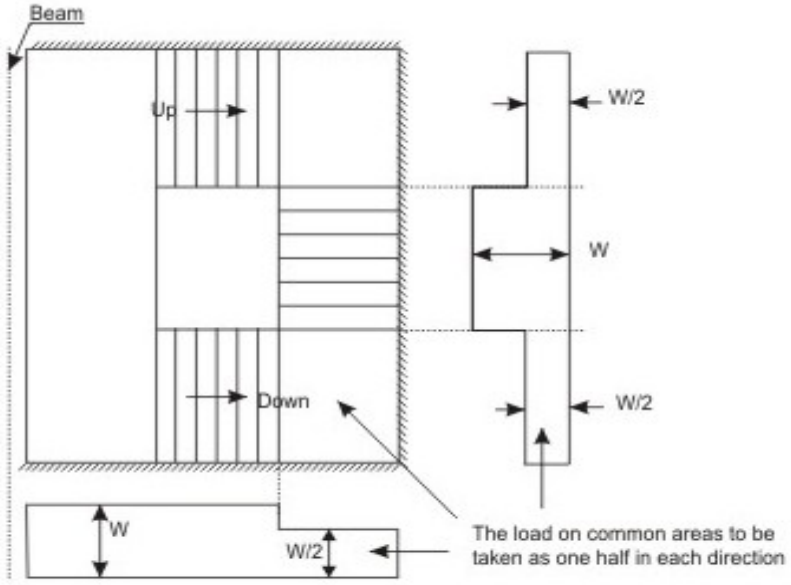


**Fig. 9.20.6**: Loadings on open-well staircases

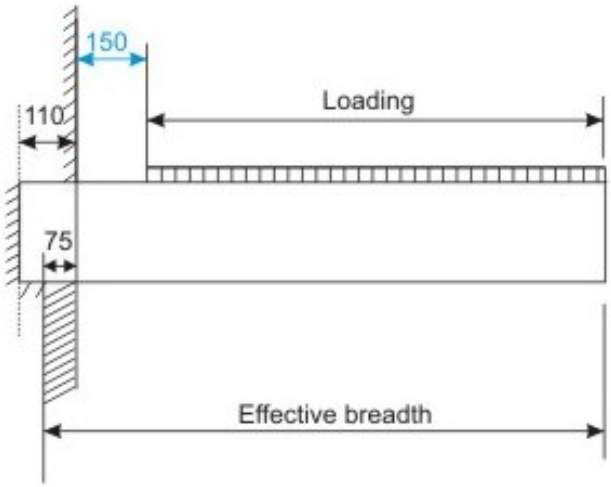


**Fig. 9.20.7**: Loading on staircases built into walls

Figure 9.20.6 shows one open-well stair where spans partly cross at right angle. The load in such stairs on areas common to any two such spans should be taken as fifty per cent in each direction as shown in Fig.9.20.7. Moreover, one 150 mm strip may be deducted from the loaded area and the effective breadth of the section is increased by 75 mm for the design where flights or landings are embedded into walls for a length of at least 110 mm and are designed to span in the direction of the flight (Fig.9.20.7).

## 9.20.8 Structural Analysis

Most of the structural systems of stair spanning longitudinally or transversely are standard problems of structural analysis, either statically determinate or indeterminate. Accordingly, they can be analysed by methods of analysis suitable for a particular system. However, the rigorous analysis is difficult and involved for a trade-riser type or free standing staircase where the slab is repeatedly folded. This type of staircase has drawn special attraction due to its aesthetic appeal and, therefore, simplified analysis for this type of staircase spanning longitudinally is explained below. It is worth mentioning that certain idealizations are made in the actual structures for the applicability of the simplified analysis. The designs based on the simplified analysis have been found to satisfy the practical needs.

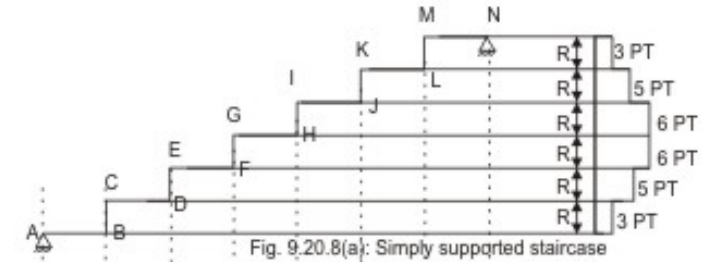


Fig. 9.20.8(a): Simply supported staircase

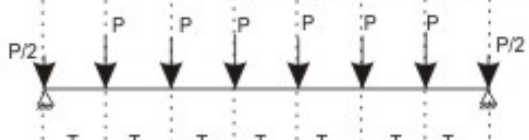


Fig. 9.20.8(e): BM diagrams along riser

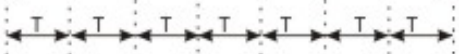


Fig. 9.20.8(b): Loadings

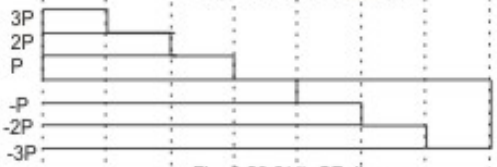


Fig. 9.20.8(d): SF diagram

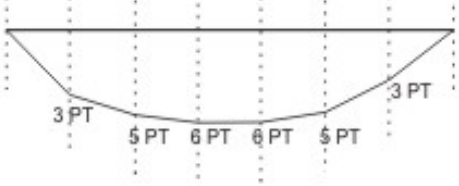


Fig. 9.20.8(c): BM diagrams along treads


Fig. 9.20.8(h): FBD of trade slab EF

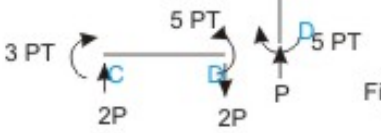


Fig. 9.20.8(g): FBD of riser slab DE

Fig. 9.20.8(f): FBD of trade slab CD

**Fig. 9.20.8**: Structural analysis of simply supported trade-riser staircase

Figure 9.20.8a shows the simply supported trade-riser staircase. The uniformly distributed loads are assumed to act at the riser levels (Fig.9.20.8b). The bending moment and shear force diagrams along the treads and the bending moment diagram along the risers are shown in Figs.9.20.8c, d and e, respectively. The free body diagrams of CD, DE and EF are shown in Figs.9.20.8f, g and h, respectively. It is seen that the trade slabs are subjected to varying bending moments and constant shear force (Fig.9.20.8f). On the other hand the riser slabs are subjected to a constant bending moment and axial force