G. PULLAIAH COLLEGE OF ENGINEERING AND TECHNOLOGY
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Nandikotkur Road, Venkayapalli, Kurnool – 518452

Department of Civil Engineering

Bridge Course
On
Design & Drawing of Reinforced Concrete Structures

Concrete:

Concrete is a stone like substance obtained by permitting a carefully proportioned mixture of cement, sand and gravel or other aggregate and water to harden in forms of the shape and of dimensions of the desired structure.

Reinforced cement concrete:

Since concrete is a brittle material and is strong in compression. It is weak in tension, so steel is used inside concrete for strengthening and reinforcing the tensile strength of concrete. The steel must have appropriate deformations to provide strong bonds and interlocking of both materials. When completely surrounded by the hardened concrete mass it forms an integral part of the two materials, known as "Reinforced Concrete".

Reinforced Concrete is a structural material, is widely used in many types of structures. It is competitive with steel if economically designed and executed.

Advantages of reinforced concrete:

- The combination of steel & concrete is economical because compressive forces are borne by concrete and tensile forces by steel.
- The combination of steel and concrete provides a monolithic character and provides much rigidity to the structure. RCC structures resist earthquake effectively.
- RCC structures require less cost of maintenance because these are not attacked by termites.
- RCC structures are durable and fire resisting.
- RCC structures are almost impermeable to moisture.
- Ingredients of RCC are easily available.
- Due to plastic properties of RCC, the RCC structures can be constructed in any desirable shape.

Less skilled labour is required for erection of structures as compared to other materials such as structural steel.

Working Stress Method (WSM):

This method is based on linear elastic theory. This method ensures adequate safety by suitably restricting the stresses in the materials (i.e. concrete & steel) induced by the expected working loads on the structure. The assumption of linear elastic behaviour is considered justifiable since the specified permissible or allowable stresses are kept well below ultimate strength of the material. The ratio of yield stress of the steel reinforcement or the cube strength of the concrete to the corresponding permissible or working stress is usually called the factor of safety. The WSM uses a factor of safety of about 3 with respect to the cube strength of the concrete and a factor of safety of about 1.8 with respect to the yield strength of the steel.

Reinforced concrete is a composite material. The WSM assumes strain compatibility, whereby the strain in the reinforcing steel is assumed to be equal to that in the adjoining concrete to which it is bonded. Consequently the stress in steel is linearly related to the stress in adjoining concrete by a constant factor, called the modular ratio defined as the ratio of the modulus of elasticity of steel to that of concrete. The WSM is therefore also known as the modular ratio method.

Limit State Method (LSM):

This method is the one which takes into account not only the ultimate strength of the structure but also the serviceability and durability requirements. In this method, structure is designed for safety against collapse (i.e. for ultimate strength to resist ultimate load) and checked for its serviceability at working loads, thus rendering the structure fit for its intended use. Thus, the LSM includes consideration of a structure at both the working and the ultimate load levels with a view to satisfy the requirements of safety and serviceability.

The acceptable limit of safety and serviceability requirements, before failure occurs is called a limit state. A limit state is a state of impending failure, beyond which a structure ceases to perform its intended function satisfactorily, in terms of either safety or serviceability, i.e. it either collapse or becomes unserviceable. The aim of design is to acceptable probabilities that the structure will not become unfit for the use for which it is intended that is, it will not reach a limit state.

Beam:

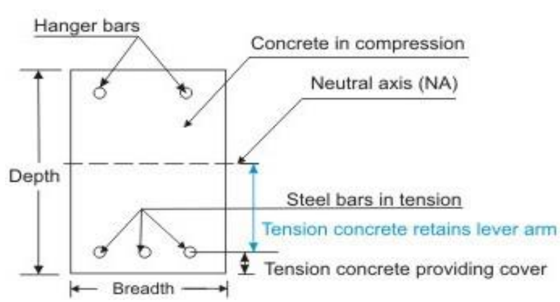
A beam is a structural element that primarily resists loads applied laterally to the beam's axis. Its mode of deflection is primarily by bending.

Types of beams:

The beams are classified into two types are as follows:

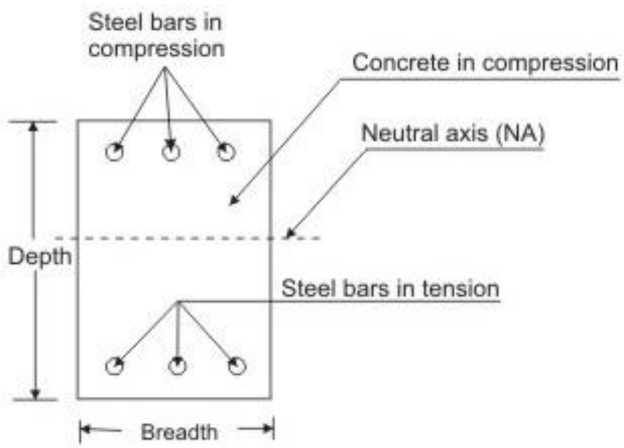
Singly reinforced beam:

A singly reinforced beam is a beam provided with longitudinal reinforcement in the tension zone only. Compressive forces are handled by the concrete in the beam.



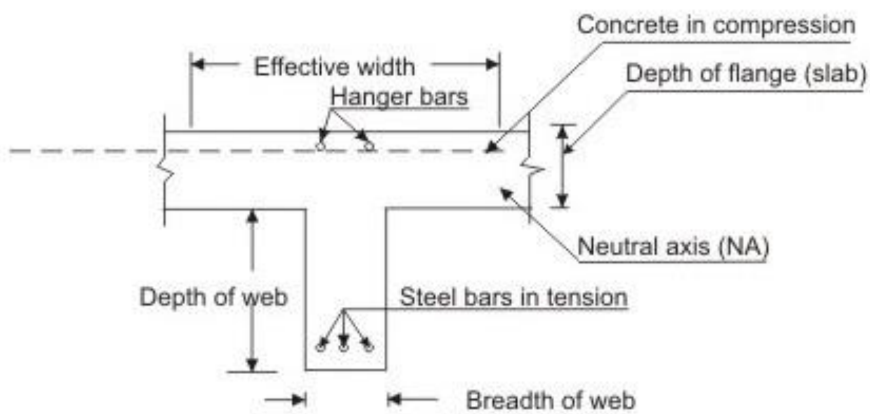
Doubly reinforced beam:

Beams reinforced with steel in compression and tension zones are called doubly reinforced beams. This type of beam will be found necessary when due to head room consideration or architectural consideration the depth of the beam is restricted.



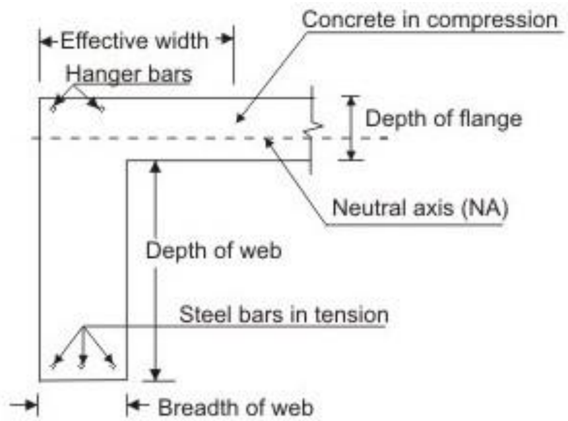
T - Beam:

A T-beam (or tee beam), used in construction, is a load-bearing structure of reinforced concrete, wood or metal, with a t-shaped cross section. The top of the t-shaped cross section serves as a flange or compression member in resisting compressive stresses.



L – Beam:

An L-beam is a load-bearing section made of reinforced concrete, wood or metal, with a L-shaped cross section. The top of the L-shaped cross section serves as a flange or compression member in resisting compressive stresses acts in one side of flange.



Balanced section:

In the balanced section, the strain in steel & strain in concrete reach their maximum values simultaneously. The depth of neutral axis is

$$x_u = x_{u,\,max.}$$

Under reinforced section:

An under reinforced section is the one in which steel percentage is less than critical or limiting percentage. Due to this, the actual neutral axis is above the balance neutral axis.

$$x_u < x_{u,\,max.}$$

Over reinforced section:

In an over reinforced section, the steel percentage is more than limiting percentage due to which neutral axis falls below the balanced neutral axis.

$$x_u > x_{u,\,max.}$$

Where, x_u is the depth of neutral axis

$x_{u,\,max.}$ is the limiting or critical value of depth of neutral axis

Shear:

Bending is usually accomplished by shear. The combination of shear and bending stresses produces the principle stress which causes diagonal tension in the beam section. The diagonal tensile stress caused by the shear and combination of shear and combination of shear and bending is likely to cause failure of the section by producing cracks.

Shear stress:

The nominal shear stress in beams of uniform depth shall be obtained by the following equation:

$$\tau_v = \frac{V_u}{bd}$$

Shear failure:

Shear failure observed in reinforced concrete structures are diagonal tension failure, flexural shear failure, shear compression failure and shear bond failure.

Bending failure:

Flexure or bending failure is commonly encountered in structural elements of reinforced cement concrete. Example: Beams and Slabs, which are transversely loaded, Flexure usually occurs in combination with transverse shear and sometimes with axial compression or shear.

Shear reinforcement:

Shear reinforcement has to be provided against diagonal tensile stresses caused by the shear force. The longitudinal bars do not prevent the diagonal tension failure. The inclined shear crack stars at the bottom near the support and extend towards compression zone.

Bent–up bars:

Some of longitudinal bars can be bent up near the supports as the bending moment to be resisted near the supports is very little. Such bent up bars resist diagonal shear.

Bond:

The force which prevents the slippage between the two constituent materials is known as bond**.** The important assumption made in the theory of reinforced concrete is that there is a perfect bond between steel and concrete. They have to act together without any slip. Due to bond only the force will be transferred to the steel from the surrounding concrete and to concrete from steel.

Bond stress:

When steel bars are embedded in concrete, the concrete, after setting, adheres to the surface of the bar and thus resist any force that tends to pull or push this rod. The intensity of adhesive force is called bond stress.

Flexural bond:

Flexural bond is one which arises from the change in tensile force carried by the bar, along its length, due to change in bending moment along the length of the member. Evidently, flexural bond is critical at points where the shear is significant. Since this occurs at a particular section, flexural bond stress is known as local bond stress.

Anchorage bond:

Anchorage bond is that which arises over the length of anchorage provided for a bar. It also arises near the end or cut off point of a reinforcing bar. The anchorage bond resist the 'pulling out' of the bar if it is in tension or 'pushing in' of the bar if it is in compression.

Anchorage length:

Anchorage length is defined as the length of bar necessary to develop the full strength of the bar.

Development length:

The development length (L_d) is defined as the length of the bar required on either side of the section under consideration, to develop the required stress in steel at that section through bond. As per IS 456: 2000 clause 26.2.1 the development length (L_d) is given by

$$L_d = \frac{\phi \sigma_s}{4\tau_{bd}}$$

Torsion:

The torsion reinforcement consists of closely spaced closed stirrups or hoops with good anchorage being provided by hooking the stirrup bar ends around the longitudinal reinforcement.

Slab:

Slabs are plane structural members whose thickness is small as compared to its length and breadth. Slabs are more frequently used as roof coverings and floors in various shapes such as square, rectangular, triangular etc. in buildings.

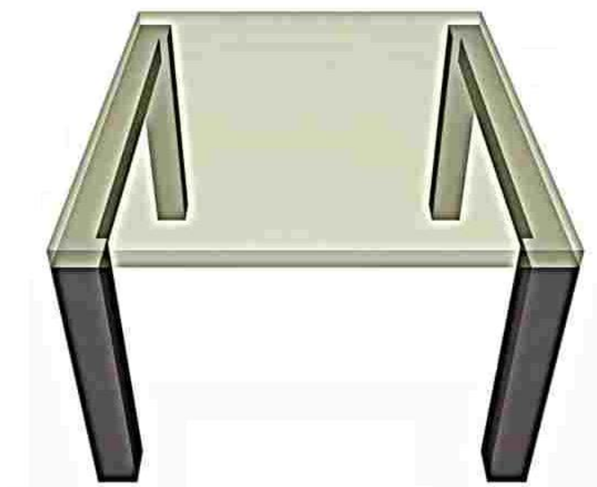
Types of slabs:

Depending upon the ration of longer span to short span (L_y/L_x), the slabs are classified into:

1. One-way slab
2. Two-way slab

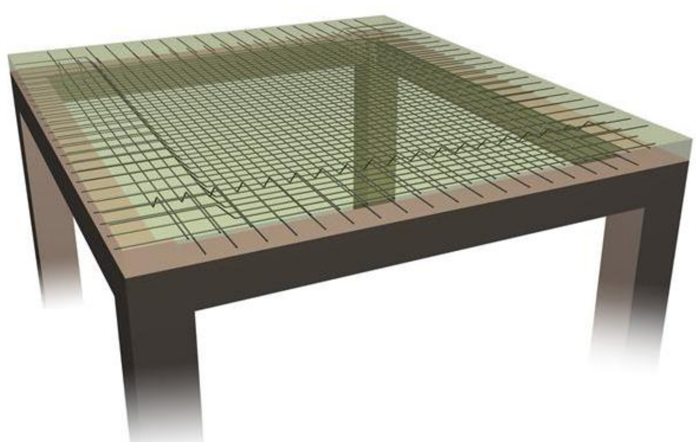
One-way slab:

One way slab is a slab which is supported by beams on the two opposite sides to carry the load along one direction. In one way slab, the ratio of longer span (l) to shorter span (b) is equal or greater than 2, i.e. longer span (l)/Shorter span (b) > 2.



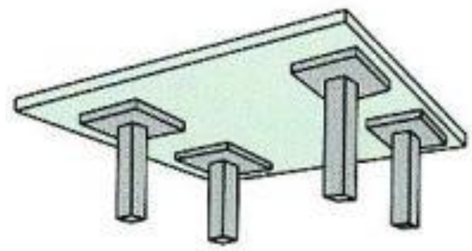
Two-way slab:

In two way slab, the ratio of longer span (l) to shorter span (b) is less than 2. In two way slabs, load will be carried in both the directions. So, main reinforcement is provided in both directions for two way slabs.



Flat slabs:

A slab supported directly on the columns without any intermediate beams is called as flat slab. Depending upon the support conditions, the slabs may be divided into simply supported slabs, cantilever slabs, etc.



Column:

A vertical member whose effective length is greater than 3 times its least lateral dimension carrying compressive loads is called as column. Columns transfer the loads from beams or slabs to the footings or foundation. Generally the column may be square, rectangular or circular in shape.

Strut:

The inclined member carrying compressive loads in case of frames and trusses is called as struts.

Pedestal:

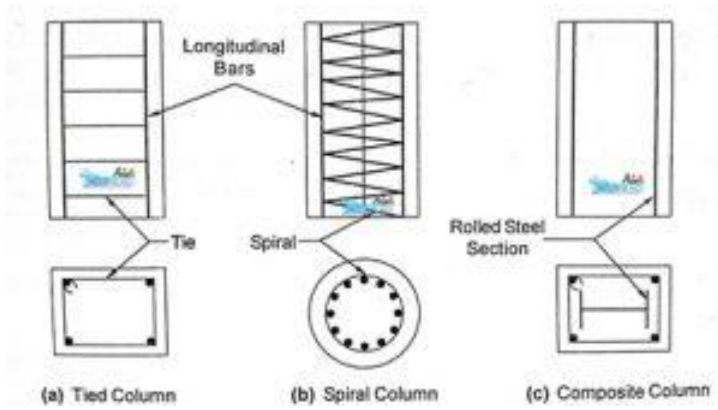
The vertical compression member whose effective length is less than 3 times its least lateral dimension is called as pedestal.

Types if columns:

1. Based on type of reinforcement: Depending upon the type of reinforcement used, reinforced columns are classified into

- **Tie columns**: When the main longitudinal bars of the column are confined with I closely spaced lateral ties, it is called as tied column.
- **Spiral column**: When the main longitudinal bars of the column are enclosed with in closely spaced and continuously wound spiral reinforcement, it is called as spiral column.

- **Composite column**: When the longitudinal reinforcement is the form of structural steel section or pipe with or without longitudinal bars, it is called as composite column.



2. Based on type of loading: Depending upon the type of loading, columns may be classified into the following three types

- **Axially loaded column:** when the line of action of the resultant compressive force coincides with the centre of gravity of the cross section of the column, it is called as axially loaded column.

- **Eccentrically loaded columns (Uniaxial or biaxial):** When the line of action of the resultant compressive force doesn't coincide with the centre of gravity of the cross section of the column, it is called as eccentrically loaded columns. Eccentrically loaded columns.

3. Based on slenderness ratio: Depending upon the slenderness ratio (ratio of effective length to least lateral dimension of the column), the columns are classified as

- **Short column:** When the ratio of effective length of the column to the least lateral dimension is less than 12, the column is called Short column. It fails by crushing (Compressive failure).

- **Long column:** When the ratio of effective length of the column to the least lateral dimension is exceeds 12, the column is called Long column. It fails by bending or buckling.

Foundation:

Foundation is an important part of the structure which transfers the load of the super structure to foundation soil. The foundation distributes the load over a larger area so that the pressure on the soil does not exceed its allowable bearing capacity and restricts the settlement of the structure with in the permissible limits. Foundation increases the stability of the structure.

Footings:

Footings are shallow foundations which are provided when the soil of adequate bearing capacity is available at a relatively short depth below the ground level. Footings may be of masonry, plain concrete or reinforced concrete.

Types of footings:

The most common types of footings used for the concrete structures are

- **Isolated footings**: Footings which are provided under each column independently are called as isolated footings. Isolated footings comprise of a thick slab which may be flat or stepped or sloped.
- **Combined footings**: Combined footings support two or more columns. These footings are provided when the isolated footings of adjacent columns overlap each other and when the exterior column is close to the boundary or property line and hence there is no scope to project footing much beyond the column face.
- **Strap footing**: it is also one of the types of combined footings. It consists of an isolated footing of two columns connected by a beam called strap beam.
- **Raft or Mat footing:** when the column loads are heavy or the safe bearing capacity of soil is very low, the required footing area become very large and the footings of adjacent column may overlap.

Depth of foundation:

Rankin's formula is used to determine the minimum depth of foundation which is given below

$$h = \frac{p}{w}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$$

Where h = minimum depth of foundation below ground level

P = safe bearing capacity of soil

W = unit weight of soil

ϕ = angle of repose

As per IS: 1080-1962, the minimum depth of foundation in all types of soils is 500mm.

Causes of failure of foundation:

The common failure causes of foundation are as follows:

- Unequal settlement of the subsoil.
- Lateral movement of the soil close to the structure.
- Shrinkage of soil below the foundation due to with drawl of moisture.
- Maximum pressure below the foundation exceeding the safe bearing capacity of the soil.

Stair case:

Stairs provide for the various floors of building. The stair consists of series of steps with landings at the appropriate intervals. The stretch between the two landings is called flight. The room or space where stairs are provided is called stairs case.

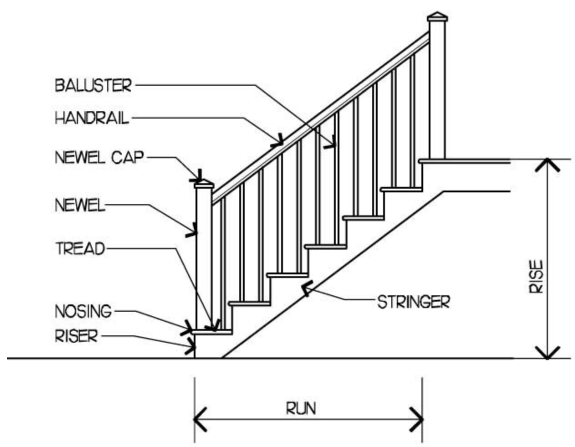
Types of stair cases:

The stairs are classified into the following categories depending upon the geometry

- **Single flight stair case:** This type of stair is used in cellars or where the height between the floors is small and the frequency of its use is less.
- **Quarter turn stair case**: In this stair, flights run adjoining the walls and provide uninterrupted space at the centre of the room. Generally, quarter turn stair case is used in domestic houses where floor heights are limited to 3m.
- **Doglegged stair case:** The most common type of stairs arranged with two adjacent flights running parallel with a mid landing. Where space is less, dog legged stair case is generally provided resulting in economical utilization of available space.
- **Open well stair case:** In public buildings where large spaces are available, open well stair case is generally preferred due to its better accessibility, comfort and ventilation due to its smaller flights with an open well at the centre.
- **Geometrical stair case:** It is aesthetically superior compared to other types and is generally used in the entrance of cinema theatres and shopping malls.
- **Spiral stair case**: In congested locations, where space available is small, spiral stairs are ideally suited. It comprises a central post with precast treads anchored to the central column.

Terminology used in stair case:

- **Tread:** Tread means the horizontal upper portion of the step.
- **Riser:** Riser is the vertical portion of a step.
- **Nosing:** Nosing is the outer projecting edge of a tread.
- **Newel:** Newel is the supporting pillar of a staircase
- **Handral:** A **handrail** is a rail that is designed to be grasped by the hand so as to provide stability or support.
- **Baluster:** A baluster also called as spindle or stair stick is a moulded shaft supporting the coping of a parapet or the handrail of a staircase.
- **Flight:** Flight is the length of the staircase situated between two landings.
- **Line of Nosing:** Line of nosing is a straight line touching the nosings of the various steps and parallel to the slope of the stair.



Staircase Terminology