3 - Types of Beams in building construction

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❖ Introduction

As we all know in a field of construction, where towering skyscrapers kiss the sky and majestic bridges span vast chasms, one element stands out as the unsung hero – the beam. Beams are simple structural members that literally carry the weight of our architectural dreams. They are the silent sentinels who ensure that buildings and bridges do not collapse under the test of time and the relentless forces of nature.

As we understand through the above paragraph, Beam is like a diverse family member playing a unique role. in construction. In this article we will classify a beam into three different categories, each bringing its own character and capabilities, ensuring that structures are not only static, but also tailored to their specific purposes.

❖ Some important definitions -

Beam: - A Beam is a structural member which is subjected to transverse to its longitudinal axis, Joists: Joists are beams commonly used to support roofs in buildings.

Girder: In the context of larger beams supporting joists, they are referred to as girders.

Spandrels: Beams located at the floor level of a building that carry part of the floor load, especially those adjacent to exterior walls, are known as spandrels.

Purlins: Beams that carry the load of the roof in truss structures are called purlins.

Lintels: Lintels are beams that support the load from masonry over openings, such as doors or windows.

Girt: A girt is a horizontal beam that spans the wall columns in industrial buildings. Its purpose is to support wall coverings.

Beam Column: A beam column is a structural member that can experience bending stress when subjected to large axial compressive loads.

❖ Classification of Beams

1. **Types of Beams based on geometry:** Its unique design and geometry make it a game changer in specific construction scenarios.

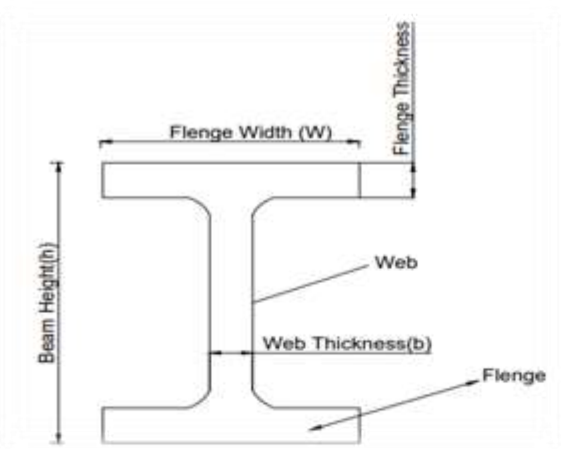
2. **Types of Beams Based on equilibrium conditions:** Its distinctive features and equilibrium properties set it apart as an essential component in engineering marvels.
3. **Types of Beams Based on support:** based on support challenges traditional practices while pushing the boundaries of structural design and engineering.

1. Types of Beams Based on their geometry

I. I-Beams

I-Beams, also called H-Beams, are among the most common and versatile types of beams used in Construction. made up of a wide, flange on either side of a narrow web. The flanges are responsible for carrying most of the bending moment, while the web resists shear forces.

I - Beam Design provide the good strength and stiffness to the structure, and due to this making, them ideal for supporting heavy load and longer span



Applications: -

- ❖ Skyscrapers and high-rise buildings
- ❖ Bridges
- ❖ Industrial structures

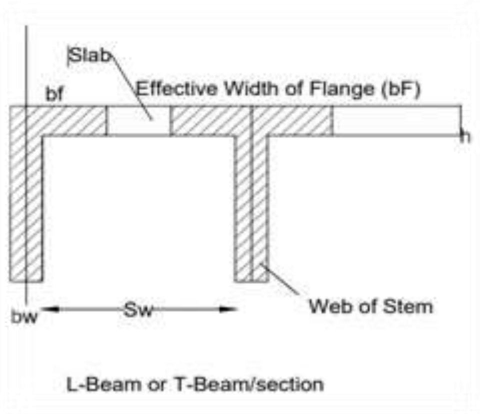
Advantages: -

- ❖ High load-bearing capacity
- ❖ Minimal deflection

❖ Cost-effective

II. T-Beams

T-beams are structural members or load bearing structures of reinforced concrete wood and metal with their T-shaped cross-section, with a wide top flange and a vertical web. T- shaped Beams are suitable for the wide range of applications due to their Specific geometry which provides good resistance to bending moments and shear stresses.



Applications: -

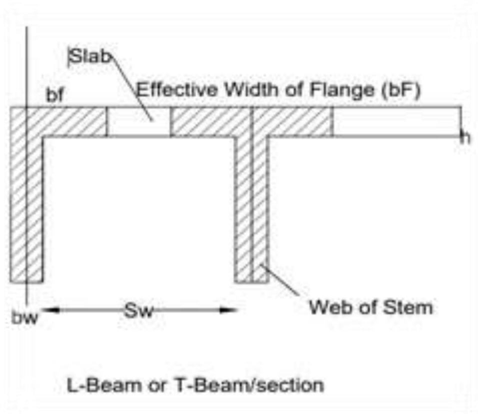
- ❖ Flooring systems
- ❖ Roofing structures
- ❖ Bridge decks

Advantages: -

- ❖ Efficient use of materials
- ❖ Good resistance to bending

III. L-beams

L-beams, also known as angle beams, have an L-shaped cross-section. They are mainly used to provide support and stability to structures, especially at corners or junctions where two beams meet at a right angle



Applications: -

- ❖ Building corners
- ❖ Structural connections
- ❖ Frameworks

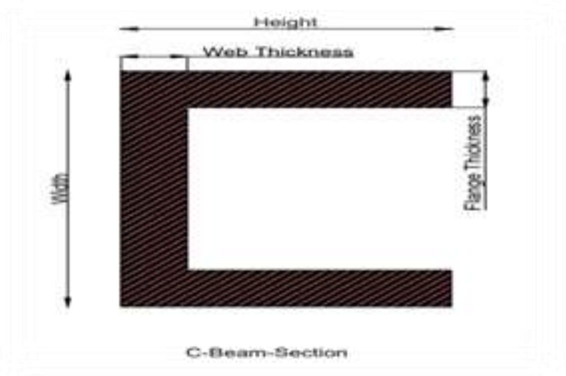
Advantages: -

- ❖ Excellent corner support

❖ Versatile applications

IV. C- Beams

C Beams are also known as channel beams, have C- Shaped Cross-section and are often used for structural and support purposes. C Beams are allowing a unique shape for efficient load distribution and makes them suitable for various framing applications.



<u>Applications: -</u>

❖ Building frames

❖ Bracing systems

❖ Conveyor systems

Advantages: -

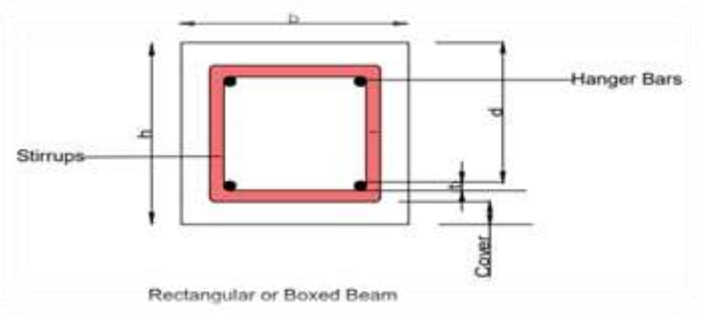
❖ Lightweight

❖ High resistance to torsion

❖ Easy installation

V. Box Beams

Box beams, also known as hollow structural sections (HSS), have a square or rectangular cross-section. They are designed to maximize strength while minimizing weight making them a popular choice for demanding structural applications.



Applications: -

- Architectural structures
- Truss systems
- Pedestrian bridges

Advantages: -

- High strength-to-weight ratio
- Aesthetic appeal

VI. Circular Beams

As the name suggests, circular beams have a circular cross-section. circular Beam shape provides a good resistance to torsion and bending making them suitable for special applications.

Applications

- Flag poles
- Roller coaster track
- Sculptural elements

Advantages

- Equal weight distribution
- Attractive appearance

2. Types of Beams based on the equilibrium

I. Statically determinant = 0

"A Structure is Said to be determinate; If conditions at static Equilibrium are sufficient to analyse the structure"

Or

A type of structured system in which all forces and reactions can be calculated using the principle of Equilibrium and equation of static

Sum of all forces and Sum of moments is Equal to Zero (= 0)

Here are some examples of statically determinate beams: -

- Simply supported beam
- Cantilever beam
- Overhanging beam
- Fixed end beam

II. Statically indeterminate beam > 0

Is a beam that has more unknown reaction forces than the number of equilibrium equations available. This means that the reactions cannot be determined solely by applying the laws of statics. In order to determine the reactions, it is necessary to make additional assumptions or to use more advanced methods of analysis.

Statically indeterminate beams can be analysed using a variety of methods, including

- Force method
- Moment distribution method:
- Stiffness method

The choice of method depends on the complexity of the beam and the accuracy required.

- Continuous beam with three supports
- Beam with one end fixed and the other end supported on a roller
- Beam with one end fixed and the other end restrained from rotating

Over determinate (Degree of Determinacy < 0) This is a rare situation where there are more equilibrium equations than unknowns. It implies that the s

In structural engineering, engineers rely on the principles of equilibrium, which state that for any structure to be in a state of balance, the following conditions must be met:

- The sum of all forces acting in the horizontal direction (ΣFx) must equal zero.
- The sum of all forces acting in the vertical direction (ΣFy) must equal zero.
- The sum of all moments (rotational forces) about any point must equal zero (ΣM = 0).

This means that the number of unknown reaction forces and moments can be determined using these equations.

Degree of Determinacy

The degree of determinacy of a structure is a measure of how many unknown forces can be determined by applying the laws of statics. A structure is said to be statically determinate if the number of unknown forces is equal to the number of equilibrium equations. If the number of unknown forces is greater than the number of equilibrium equations, then the structure is said to be statically indeterminate.

The degree of determinacy is denoted by the letter D. For a two-dimensional structure, the degree of determinacy can be determined using the following for

$$D = 3m - 2j - r$$

- m is the number of members
- j is the number of joints
- r is the number of support reactions

- **Here are some examples of the degree of determinacy of different types of structures -**

- Simply supported beam: Statically determinate (D = 1)
- Fixed beam: Statically indeterminate (D = 2)
- Continuous beam: Statically indeterminate (D > 2)
- Truss: Statically determinate (D = 2j – 3)

- Frame: Statically determinate or indeterminate (D = 3m – 2j – r)

Stabilities in 2-d structure: -

For a 2-D structures we need to make a note of the below some point,

- Maximum no of externally independent support reaction should be available for 2D structure, is R=3
- All Reaction should be non-Parallel
- All Reactions should be non-concurrent
- Reaction should be non-Trivial
- There Should be no condition of mechanism I.e no three collinear hinges

- **Procedure analysis or calculation steps for the beam**

I. Identify Supports and Joints: -

The first step is to Determine and identify the type of Support**,** whether it is Pin joint, fixed or Roller support. And then locate the joint where members meet.

II. Draw Free Body Diagrams (FBDs): -

Isolate each component of the structure (beams, trusses, etc.) and draw a free body diagram for each one. This involves representing the structure with all forces acting on it and applying equilibrium equations (ΣF = 0 and ΣM = 0) to find unknown forces and reactions.

III. Apply Equilibrium Equations: -

For each free body diagram, apply the equations of equilibrium

- ΣFx (sum of horizontal forces) = 0
- ΣFy (sum of vertical forces) = 0

- ΣM (sum of moments about a point) = 0

IV. **Solve for Unknowns forces: -**

Use the equilibrium equations to solve for unknown forces (e.g., internal member forces, support reactions). In statically determinate structures, you will have as many equations as unknowns, making it possible to solve for everything

Now Let's understand the above steps with an Examples, With the help of this calculation we can Draw a SFD and BMD for any Beam,

Example: Consider a simply supported beam with a point load 2000N applied at its centre.

Given data

- Point load (P) = 2000N
- Length of the beam (L) = 4m

Step 1: Identify Supports and Joints

In this example, we have a simply supported beam, which means it is supported at both ends by roller supports shown in Fig:1 (R1 and R2).

Locate the joint where the beam meets the support. In this case, we have two joints: one at the left end and one at the right end.

Step 2: Draw Free Body Diagrams (FBDs)

Isolate each component of the structure. In this case, we have the entire beam as one component.

Draw a free body diagram for the beam. Include all forces acting on it.

Step 3: Apply Equilibrium Equations

- To calculate the reaction forces, we can use the following equations:
- ΣFy = 0
- ΣMA = 0

where:

- ΣFy is the sum of all forces in the y-direction
- ΣMA (R1) is the sum of all moments about point A

Step 4: Solve for Unknowns forces

In this case, point A is the left support.

Substituting the forces and moments into the equations, we get:

- R1 + R2 = 2000 N
- -R1 * L/2 + 2000 N * L/2 = 0

Solving these equations, we get:

- R1 = 1000 N
- R2 = 1000 N

3. Types of Beams Based on Support

Beams can be classified into different types based on the way they are supported. Let us learn about these types in detail:

I. Simply supported beam

A simply supported beam is defined as the beam where both ends Are Fixed with the Supports one end is Fixed with the Hinge or Roler Lead and Other end is pinned connection

Important Note: -

a) The bending moment in a simply supported beam is zero at the support and maximum at the centre of the beam.

b) The shear force in a simply supported beam is zero at the support and maximum at the centre of the beam.

c) The deflection of a simply supported beam is parabolic in shape and is maximum at the centre of the beam.

Simply supported beams are the most common type of beam because they are easy to analyse and design. Their construction is also relatively economical.

Let's take a look at the important definitions that we will use in this topic

- ✓ **Supports -** The supports are called pin supports and roller supports. Pinned supports allow the beam to rotate freely, while roller supports only allow the beam to rotate horizontally.
- ✓ **BM -** The bending moment is due to the load applied on the beam. The maximum bending moment occurs at the point where the load is applied.
- ✓ **SF -** Shear force is due to the difference in load applied on the beam. The maximum shear force occurs at the point where the load is applied or where the beam changes direction.
- ✓ **Deflection -** Deflection is the amount of bending that occurs in the beam. Maximum deflection occurs at the point where the bending moment is maximum.

Here are some Practicable examples Floor beams

- ✓ Roof beams
- ✓ Bridge beams
- ✓ Machine tool beds
- ✓ Loading docks

II. Fixed Beam

A fixed beam is a beam supported by two supports that prevent it from rotating. The supports are called fixed supports, and they are usually made of concrete or masonry.

Fixed supports prevent the beam from rotating, which means that the beam is subjected to a moment at each support. The moment at each support is equal to the reaction force at the support times the distance from the support to the load. Fixed beams are stronger and stiffer than simply supported beams. This is because the fixed supports prevent the beam from rotating, thereby reducing the bending moment in the beam. Fixed beams are more difficult to manufacture than simply supported beams.

Let's look at the advantages of Fixed Beam.

a) Fixed beams are stronger and stiffer than simple supported beams.
b) They can take heavy loads easily. without any deflection.
c) Fixed beams are used where Rotation is needs to be prevented.

Let's look at the drawbacks of fixed beam

a) These are more difficult to fabricate than simply supported beams.
b) Construction of Fixed beams is more costly.

III. Cantilever Beam

Cantilever beams are fixed at one end and the other end is free. They are excellent for making hanging structures such as diving boards and balconies. The cantilever beam is subjected to a moment at the support and a shear force along its length. The moment at the support is equal to the weight of the beam times the length of the beam. Shear force is equal to the load exerted on the beam minus the moment at the support. Cantilever beams are less strong and rigid than fixed beams, but they require less material and are easier to manufacture. Cantilever beams are used in applications where it is not necessary to prevent the beam from rotating such as in the case of balconies.

Let's look at the advantages of Fixed Beam.

a) Cantilever beams are less difficult to manufacture than fixed beams.
b) Cantilever beams require less material to construct.
c) Cantilever beams are less expensive.
d) Cantilever beam can be used in applications where it is not necessary to prevent the beam from rotating.

IV. Propped Cantilever

A propped cantilever beam is a beam supported by two supports, one of which is a fixed support and the other is a roller support. Fixed supports prevent the beam from rotating, while roller supports allow the beam to rotate. A propped cantilever beam is a statically indeterminate beam, meaning that there are more unknown reaction forces than the equilibrium equations allow. This makes it more difficult to analyse a supported cantilever beam than simply supported beams or cantilever beams.

Propped cantilever beam can be analysed using the method, moment distribution force method or stiffness method. The force method is a graphical method to analyse propped cantilever beams. The design of a propped cantilever beam is also more complex than the design of a simply supported beam or cantilever beam. This is because the designer must consider the interaction of the beams at the supports. The designer must also consider the deflection of the beam, which may be more pronounced in simply supported cantilever beams than simply supported beams or cantilever beams.

v. Continuous Beams

Continuous beams have multiple supports along their length, making them suitable for long spans. They are commonly used in buildings and bridges where extended supports are required.

Continuous beams are more efficient than simply supported beams because they can distribute the load over multiple supports. It can reduce the bending moment and shear force in the beam, and it can also reduce the deflection of the beam.

- Continuous beams are used in bridges
  - ✓ Buildings
  - ✓ Bridges
  - ✓ parking garages
  - ✓ runway

Let's Look at some additional details Related to the continuous beam,

The analysis of continuous beams is more complex than the analysis of simply supported beams. This is because the reactions on the support are not known a priori. The reactions at the supports should be determined using an iterative method, such as the moment distribution method or the stiffness method.

The design of a continuous beam is also more complex than the design of a simply supported beam. This is because the designer must consider the interaction of the beams at the supports. The designer must also consider the deflection of the beam, which may be more pronounced in a continuous beam than in a simply supported beam.

Let's look at the advantages of Fixed Beam.

- More efficient than simple supported beams.
- They can Take heavy loads.
- They are less likely to deflect under load.

VI. Overhanging Beams

One end of an overhanging beam is supported, while the other extends beyond the support. These beams are ideal for building awnings and canopies

An overhanging beam is a beam that is supported by two or more supports, but one or more supports allow the beam to hang beyond the supports.

An overhang is that part of a beam that extends beyond the supports. Overhanging beams are more efficient than simply supported beams because they can distribute the load over a longer length. It can reduce the bending moment and shear force in the beam, and it can also reduce the deflection of the beam.

- **Overhanging beams are used in**
- ✓ Balcony
- ✓ Canopies
- ✓ Cornice
- ✓ Shelving
- ✓ Railing

Analysis of overhanging beams is more complex than analysis of simply supported beams. This is because the reactions on the support are not known a priori. The reactions at the supports should be determined using an iterative method, such as the moment distribution method or the stiffness.