

GOVERNMENT POLYTECHNIC, BHUBANESWAR



DEPARTMENT OF CIVIL ENGINEERING

LECTURE NOTE

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STRUCTURAL DESIGN -II

Chapter-1

Common steel structure:

Common steel structures include frame buildings for residential and commercial use, trusses for bridges and roofs, portal rigid frames for industrial buildings, and arch structures for bridges and domes. Other common types are grid structures for large-span roofs, space frames for domes, and cable structures used in suspension bridges.

Advantages of steel structures:

- 1)High Strength and Durability: Steel is incredibly strong, durable, and can withstand significant loads and forces.
- 2)Design Flexibility: It can be fabricated into a wide variety of shapes and forms, allowing for long spans and complex architectural designs.
- 3)Speed of Construction: Steel components can be prefabricated off-site, which significantly speeds up the construction process.
- 4)Pest and Weather Resistant: Steel is resistant to pests, insects, and moisture, which can be a problem for other building materials.
- 5)Recyclable: Steel is a sustainable material that can be recycled, making it more environmentally friendly than some alternatives.

Disadvantages of steel structures:

- 1)Corrosion: Steel is prone to rust and corrosion, which requires protective coatings and regular maintenance to prevent degradation.
- 2)Fire Susceptibility: While more fire-resistant than wood, steel can lose its structural integrity when exposed to high temperatures, leading to permanent deformation and collapse.
- 3)Buckling: Under compression, slender steel members are susceptible to buckling, which can cause a loss of strength and potentially lead to failure.
- 4)Thermal Conductivity: Steel conducts heat, which can be a disadvantage in certain climates and may require extensive insulation to maintain a comfortable temperature.
- 5)Costly Maintenance: The cost of maintenance, particularly the upkeep to prevent rust, can be high.

Types of steel

i)Mild steel

ii)HYSD Steel

Mild steel is a low-carbon steel that is strong, ductile, and easily weldable, making it suitable for general construction and fabrication.

High Yield Strength Deformed (HYSD) steel bars are a type of steel with high yield strength and surface deformations (like ridges) to improve bonding with concrete, and are commonly

used in structural applications for increased strength and corrosion resistance.

Properties of structural steel.

Physical properties

Unit mass: 7850kg/m³

Modulus of elasticity (E): 200GPa

Poisson's ratio (ν): 0.3 in elastic range.

Shear modulus (G): $0.769 \times 10^5 \text{ N/mm}^2$

Coefficient of thermal expansion (α): $12 \times 10^{-6} / ^\circ \text{C}$

Mechanical properties

Yield strength (f_y): The stress at which permanent deformation begins.

Tensile strength (f_u): The maximum stress the material can withstand before failure.

Ductility: The ability to deform under tensile stress before breaking. This is often measured by elongation and is important for seismic performance.

Toughness: The ability to absorb energy and resist fracture, especially at cracks.

Weldability: The ease with which steel can be welded, which is crucial for fabrication and assembly.

Rolled steel sections

The various types of rolled structural steel sections manufactured and used as structural

members are as follows:

1. Rolled Steel I-sections (Beam sections).
2. Rolled Steel Channel Sections.
3. Rolled Steel Tee Sections.
4. Rolled Steel Angles Sections.
5. Rolled Steel Bars.
6. Rolled Steel Tubes.
7. Rolled Steel Flats.
8. Rolled Steel Sheets and Strips.
9. Rolled Steel Plates

2.3 ROLLED STEEL BEAM SECTIONS

The rolled steel beams are classified into following four series as per BIS : (IS : 808-1989)

1. Indian Standard Joist/junior Beams ISJB
2. Indian Standard Light Beams ISLB
3. Indian Standard Medium Weight Beams ISMB
4. Indian Standard Wide Flange Beams ISWB

The rolled steel columns/heavy weight beams are classified into the following two series as per BIS (IS : 808-1989)

1. Indian Standard Column Sections ISSC
2. Indian Standard Heavy Weight Beams ISHB

ROLLED STEEL CHANNEL SECTIONS

The rolled steel Channel sections are classified into four categories as per ISI, namely,

1. Indian Standard Joist/Junior Channels ISJC

2. Indian Standard Light Channels ISLC
3. Indian Standard Medium Weight Channels ISMC
4. Indian Standard Medium Weight Parallel Flange Channels ISMCP

ROLLED STEEL TEE SECTIONS

The rolled steel tee sections are classified into the following five series as per ISI:

1. Indian Standard Normal Tee Bars ISNT
2. Indian Standard Wide flange Tee Bars ISHT
3. Indian Standard Long Legged Tee Bars ISST
4. Indian Standard Light Tee Bars ISLT
5. Indian Standard Junior Tee Bars ISJT

2.6 ROLLED STEEL ANGLE SECTIONS

The rolled steel angle sections are classified in to the following three series.

1. Indian Standard Equal Angles ISA
2. Indian Standard Unequal Angles ISA
3. Indian Standard Bulb Angles ISBA

2.7 ROLLED STEEL BARS

The rolled steel bars are classified in to the following two series:

1. Indian Standard Round Bars ISRO
2. Indian Standard Square Bars ISSQ

ROLLED STEEL TUBES

The rolled steel tubes are used as columns and compression members and tension members in

tubular trusses. The rolled steel tubes are efficient structural sections to be used as compression members. The steel tube sections have equal radius of gyration in all directions.

2.9 ROLLED STEEL FLATS

The rolled steel flats are used for lacing of elements in built up members, such as columns and are also used as ties.

2.10 ROLLED STEEL SHEETS AND STRIPS

The rolled steel sheet is designated by abbreviated reference symbol SH followed by length in mm x width in mm x thickness in mm of the sheet. The rolled steel strip is designated as ISST followed by width in mm x thickness in mm, e.g., SH 2000 x 600 x 8 and ISST 250 x 2.

2.11 ROLLED STEEL PLATES

The rolled steel plates are designated by abbreviated reference symbol PL followed by length in mm x width in mm x thickness in mm of the plates, e.g., PL 2000 x 1000 x 6

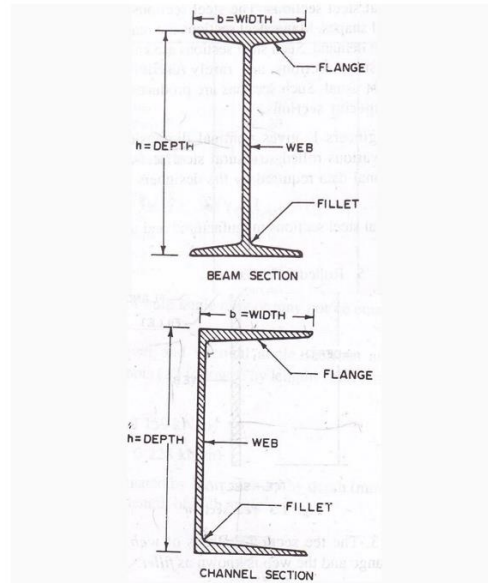


Fig. 2.1 Beam section

Fig. 2.2 Channel section

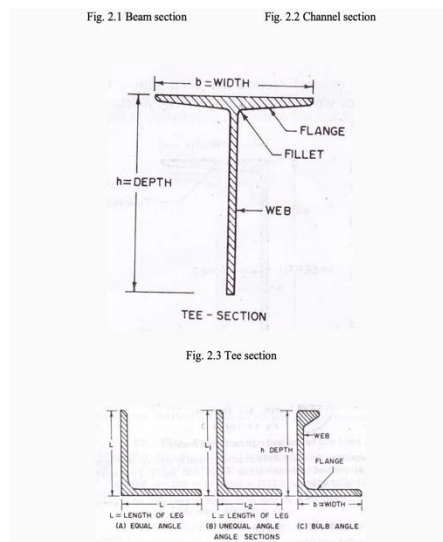
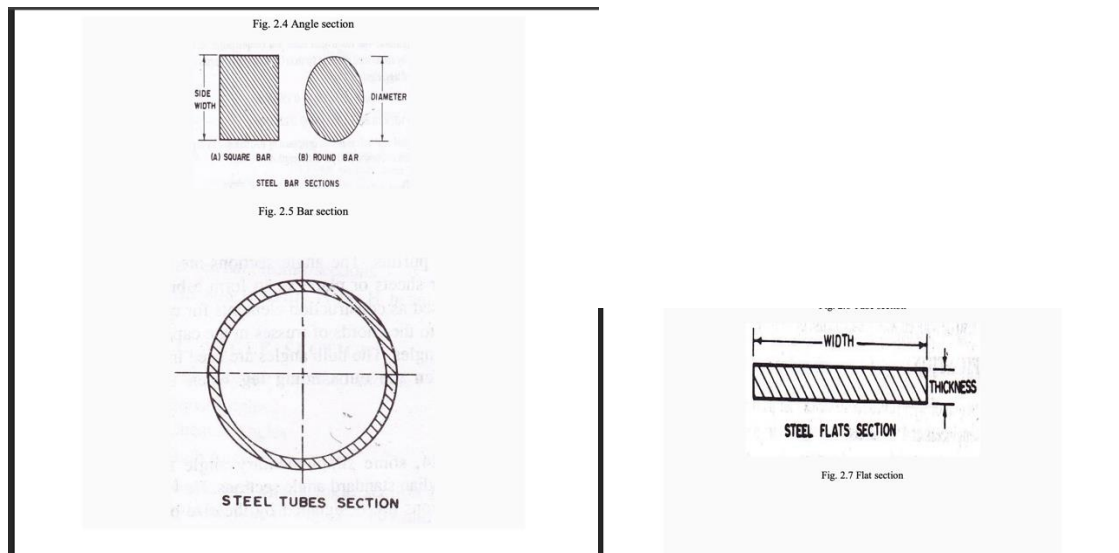


Fig. 2.3 Tee section



Special considerations in steel design:

Structural integrity and performance

Strength and stiffness: Design members to withstand loads without failure and to prevent excessive deflection or vibration.

Buckling and stability: Members, especially compression members, must be designed to prevent buckling.

Ductility and flexibility: Steel's inherent ductility and flexibility are beneficial, particularly in seismic applications, but connections must be designed carefully to prevent instability.

Environmental factors

Corrosion: Protect steel from corrosion using coatings, galvanizing, or paint to prevent premature failure and ensure long-term durability.

Fire resistance: Steel loses strength at high temperatures, so fireproofing measures like sprays, wraps, or intumescent coatings are often necessary.

Thermal movement: Account for the expansion and contraction of steel due to temperature changes, often by incorporating expansion joints.

Loading and connections

Loading conditions: Accurately calculate all loads, including dead, live, wind, snow, and earthquake loads.

Seismic design: Design with seismic activity in mind, ensuring the structure can withstand deformation.

Connections are particularly critical during earthquakes, and proper detailing is essential.

Connections: Connections are a critical failure point.

Design them carefully to distribute loads effectively.

Choice of connection type (bolted or welded) and specific details are crucial for stability.

Material and design principles

Material selection: Choose the appropriate grade of steel with the correct mechanical properties for the project requirements.

Connection and element design: Design individual components and their connecting elements (e.g., welds, bolts, base plates, anchor rods) to ensure proper load transfer.

Avoid overdesign: Don't over-engineer the structure by adding unnecessary complexity or material, which

increases cost and embodied carbon. Design efficiently and utilize structural benefits.

Loads and load combinations.

Types of loads

Dead Load (DL): The weight of the structure itself, including steel members, slabs, and other permanent components.

Live Load (LL): Loads that are not permanent, such as people, furniture, and equipment. They are also called imposed loads.

Wind Load (WL): Lateral force exerted by the wind on the structure. It's considered in different directions, such as transverse and longitudinal.

Earthquake Load (EL): Seismic forces that act on the structure due to an earthquake. These are also considered in different directions.

Other loads: These can include snow loads, thermal loads, and loads from erection. How are load combinations selected for the design of a steel building.

Common load combinations (examples based on IS 800 and ASCE 7)		
Scenario	Example Combination	Description
Dead and Live Load	$1.5(DL + LL)$	A combination for the limit state of collapse, ensuring safety under the combined effect of dead and live loads.
Dead Load + Wind Load	$0.9(DL) + 1.6(WL)$	Used for uplift or overturning checks, where the dead load is reduced and wind load is applied at a high factor.
Dead, Live, and Wind/Earthquake	$1.2(DL) + 1.6(LL) + 0.5(WL \text{ or } EL)$	A combination used for ultimate strength checks. It accounts for the structure being under dead load, live load, and a partial effect of wind or earthquake load.
Dead, Live, and Wind/Earthquake	$1.2(DL) + 1.6(WL \text{ or } EL) + 0.5(LL)$	Another combination for ultimate strength checks, this time giving more emphasis to wind or earthquake loads and less to the live load.
Dead and Wind/Earthquake	$0.9(DL) + 1.6(WL \text{ or } EL)$	This combination is for uplift or overturning conditions, as mentioned above.

Structural analysis and design philosophy

Structural analysis

Load estimation: Determine all anticipated loads, including dead, live, wind, and seismic forces.

Internal force calculation: Use structural analysis to find the internal forces (bending moments, shear forces, axial forces) within each member under the worst-case load combinations.

Method of analysis: Select a suitable analysis method, which can range from simpler assumptions (like pinned joints) to more complex models that account for semi-rigid connections.

Design philosophy and principles

Safety: The structure must be safe against failure under all anticipated load conditions throughout its lifespan.

This is achieved through:

Strength: Ensuring members can withstand the calculated internal forces without failure.

Stiffness: Preventing excessive deformation or deflection under service loads.

Stability: Designing against buckling and other forms of instability, especially in columns and slender members.

Serviceability: The structure should perform its intended function without discomfort or damage from issues like vibration or excessive sway under normal use.

Economy: Optimize the use of materials and consider fabrication, transportation, and erection costs.

Sustainability: Incorporate eco-friendly practices where possible.

Ductility: Utilize steel's inherent ductility to create more resilient structures. This involves ensuring connections have a large deformation capacity and designing so that yielding occurs in beams before columns to prevent sudden collapse.

Brief review of Principles of Limit State design.

Working Stress Method (WSM)

Principle: Assumes the material behaves elastically and linearly up to failure.

Design Load: Uses \"working\" or service loads.

Stress-Strain: Assumes linear stress-strain relationships for materials like steel and concrete.

Safety: Applies a single, large factor of safety to the yield or ultimate stress to get the permissible stress.

Outcome: Can lead to uneconomical designs because material strength is often underutilized.

Ultimate Load Method (ULM)

Principle: Designs for the ultimate load and considers the material's plastic behavior up to failure.

Design Load: Uses \"ultimate\" loads, which are higher than working loads.

Stress-Strain: Uses the actual stress-strain curves, including the plastic region.

Safety: Incorporates a factor of safety, but it is applied to the load.

Outcome: Can result in very economical designs, but the high strain and cracking at service loads can reduce the structure's service life, making it less desirable.

Limit State Method (LSM)

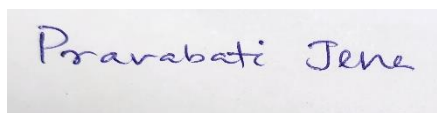
Principle: A probabilistic approach that ensures the structure will not reach a \"limit state\" (either of collapse or serviceability) during its service life.

Design Load: Considers both ultimate loads and serviceability conditions.

Stress-Strain: Accounts for the non-linear behavior of materials like concrete.

Safety: Applies partial safety factors to both loads and material strengths, which is a more rational and realistic approach.

Outcome: Considered the most accurate and modern method, leading to safe, economical, and durable structures that utilize material strength more effectively.



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