STRUCTURAL DESIGN II

LECTURE NOTES

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CHAPTER – 1

INTRODUCTION

1.0: Introduction

A structure is **an arrangement and organization of interrelated elements capable of withstanding external loads and transmitting them safely to the foundation. Steel structure** is a metal structure which is made of structural steel components connected with each other to carry loads and provide full rigidity. Because of the high strength grade of steel, this structure is reliable and requires less raw materials than other types of structure like concrete structure and timber structure.

In modern construction, steel structures is used for almost every type of structure including heavy industrial building, high-rise building, equipment support system, infrastructure, bridge, tower, airport terminal, heavy industrial plant, pipe rack, etc.

In our country concrete and steel are two major construction material used for most of the infrastructures. Concrete is casted at the site where as the steel is manufactured in the factory in an controlled environment.

Depending upon the orientation of the structures or the nature of application of loads the structures may be subjected to axial, bending, torsion or combined of all the forces. We design the building based on two aspects i.e; Functional aspects and Structural aspects. Functional aspect deals with purpose of the elements used in an infrastructure and Structural aspect deals with the structural requirement of a structure for safe transmission of the load.

1.1.1: Common Steel Structures

There are various types of steel structures like frame structure, truss structure, arch structure, pre stressed structure etc. . However broadly steel structures are classified into two categories:

a. Framed structures (Combination of beams, columns, ties, strut etc.)
b. Sheet structures (Made up of large plates or sheets)

1.1.2: Advantages and Disadvantages of Steel Structure

1.1.2.1: Advantages

1. Smaller weight to strength ratio: It has smaller weight to strength ratio, for which it results into light weight structures
2. Reliability: The reasons for this reliability include consistency and uniformity in properties, better quality control because of factory manufacture, large elasticity, and ductility
3. Industrial behaviour: as the rolled steel section sare factory manufactured hence the manual error reduces greatly, the speed of construction increases and the total cost reduces.
4. Gas and water tight joints: Steel structures provide completely impervious construction and structures like reservoirs, oil pipes, gas pipes, etc. are preferably made from structural steel.
5. Speed of erection: Because of the industrial nature of steel construction. Progress of the work is fast making the structures economical.
6. Scrap value: Steel has a scrap value even though it is not reusable in its existing form.
7. Possible reuse: Steel has a scrap value even though it is not reusable in its existing form.
8. Addition to existing Structures: Additions to existing steel structures are very easy to made. Connections between new and existing structures can be employed very effectively.

9. Ductility and warning before Failure: Steel being ductile material it can withstand extensive deformation without failure under high tensile stress. The ductile nature of steel enable sit to yield locally at various points, thus redistributing the stress and preventing failure.
10. Not combustible: Being a non combustible material steel structures doesn't catch fire.
11. Easy dismantling and transportation: BY using bolted connection steel structures can be easily dismantled and handled. Being light weight it can be easily transported to other sites.

1.1.2.2: Disadvantages

1. Suscpectible to Corrosion: When steel structures are Exposed to humid atmosphere they are susceptible to corrosion.
2. High maintenance cost: Steel structures requires regular maintenance to avoid corrosion and any other damages.
3. Fire and heat susceptibility: Steel is not combustible but when exposed to high temperature or fire a huge reduction in strength takes place. To avoid this it needs fire proof treatment.
4. Costly and liable to theft: Steel is a costly material and can be easily dismantled hence are liable to theft.
5. Susceptible to fatigue: when steel is subjected to large number of reversible stresses fatigue develops and there is a reduction in strength and ultimately it lead to failure.

1.2: Types of steel, Properties of Structural steel

1.2.1: Types of steel

Steel is mainly an alloy of Iron and carbon and few special properties can be impaired to it by addition of small quantity of manganese, phosphorus, chromium, nickel etc.. Carbon is the primary element which influences the property of steel. With the alteration of carbon percentage the strength and ductility of steel can be increased or decreased.

The structural steel can broadly be classified into two categories; (a) Mild steel (b) High tensile steel.

1.2.2: Properties of structural steel

1. Physical properties

a) Unit mass of steel, p = 7850 kg/m^3

b) Modulus of elasticity, E = 2.0x10^5 N/mm^2 (MPa)

c) Poisson ratio, p = 0.3

d) Modulus of rigidity, G = 0.769x10^5 N/mm^2 (MPa)

e) Coefficient of thermal expansion c_x.=12x10 $^{-6}/^0$C

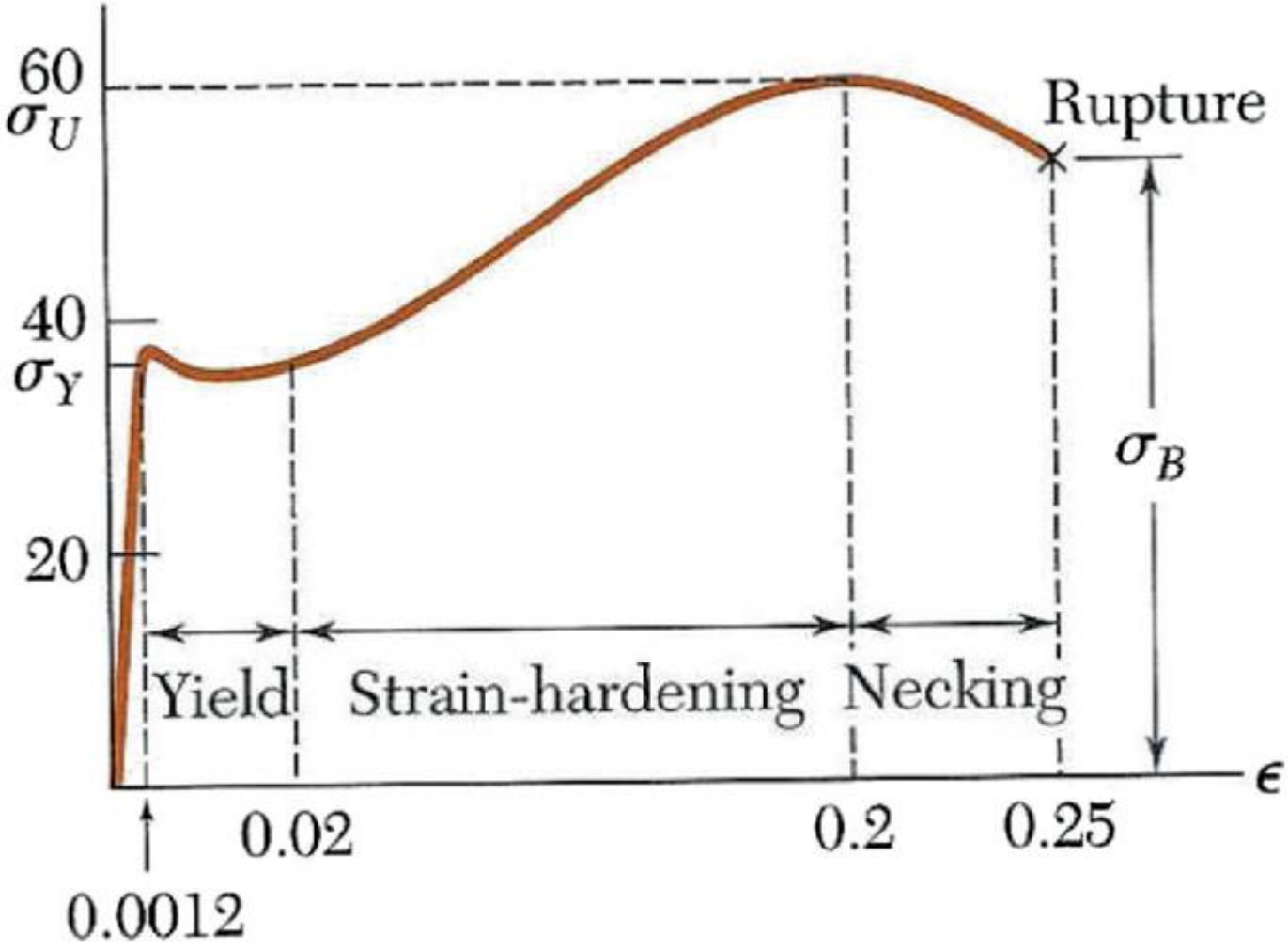
2.Mechanical Properties

The principal mechanical properties of the structural steel important in design, as detailed by the code IS 800:2007 in cl. 2.2.4.2, are the yield stress, f_y; the tensile or ultimate stress, f_u; the maximum percent elongation on a standard gauge length and notch toughness.

Tensile Properties of Structural Steel Products

IS Code	Grade	Yield stress (Mpa) min	Ultimate tensile	Elongation Percent

			(for d or t)		stress (MPa)	min
			<20	20 - 40	>40	min
E 165 (Fe 290)	165	165	165		290	23
E250(Fe410W)A	250	240	230		410	23
E250(Fe 410 W)B	250	240	230		410	23
E250(Fe 410 W)C	250	240	230		410	23
IS 2062						
E 300 (Fe 440)	300	290	280		440	22
E 350 (Fe 490)	350	330	320		490	22
E 410 (Fe 540)	410	390	380		540	20
E 450 (Fe 570) D	450	430	420		570	20
E 450 (Fe 590) E	450	430	420		590	20



Stress Strain Curve of Mild Steel

1.3: Rolled steel sections, special considerations in steel design

1.3.1: Rolled steel sections

The steel sections manufactured in rolling mills and used as structural members are known as rolled structural steel sections. These sections have standard shape and size.

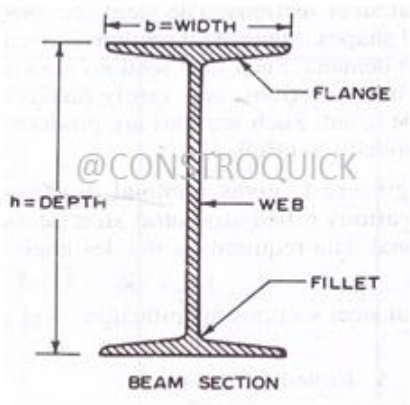
There are various steel sections as per the Bureau of Indian standard as listed below;

1) Rolled steel I-sections
2) Rolled steel channel sections
3) Rolled steel T-sections
4) Rolled steel angle sections
5) Rolled steel bars
6) Rolled steel tubes
7) Rolled steel plates
8) Rolled steel flats
9) Rolled steel sheets and strips

Rolled steel I-sections:

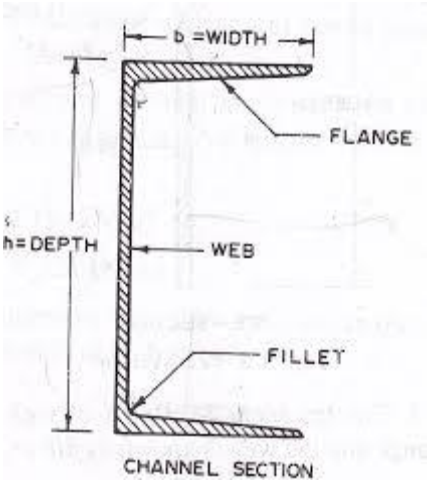
- The shape profile of this section looks similar to alphabet “I” or “H”. This section is used for all the types of load combinations, except pure rotation. This section is highly efficient to resist (in order) flexure, and compression.

- Most common usages of this section are beams/girder, columns in Buildings and Bridges.



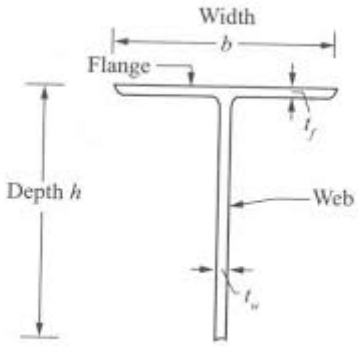
Rolled steel channel sections

- The shape profile of this section looks similar to alphabet “C”; hence they are also called as C-sections.
- This section is mostly used for uniformly distributed load applications with small moment/bending.
- Most common usages of C Shape/Channels as secondary structural member are transverse joists supporting floor, purlins for roof trusses, studs in the wall framing, supporting members for ceiling assemblies, etc.



Rolled steel T-sections

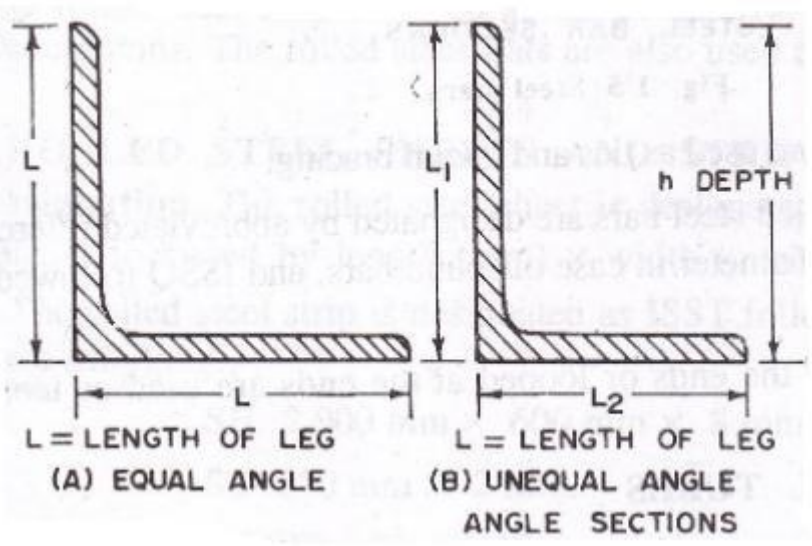
- The shape profile of this section looks similar to alphabet “T”; hence we call them T shape.
- This section can be used for all load applications similar to I-shape section.
- Most common usages of this section are connection member between I-shapes or other shapes, secondary beam members (lintels), Chord member in trusses and primary member of built-up member, End Diaphragm members in bridge girder system etc.



Rolled steel T-section.

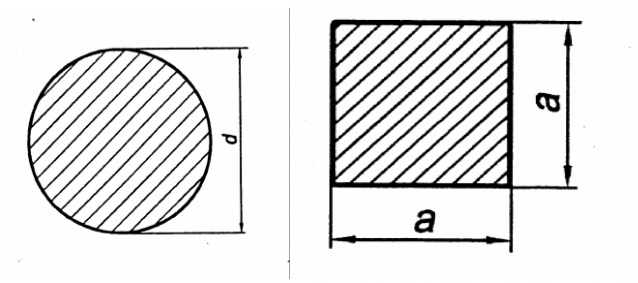
Rolled steel angle sections

- The shape profile of this section looks similar to alphabet “L”; hence we call them L Section. This section is also called as “Angle” due to its feasibility to accommodate angular connections.
- This section is highly used for point load applications to resist shear, tension and compression.
- This section is a perfect fit to be used as a connection member, primary component of a built-up member etc.
- Most common usages of this section are connection between I-shapes and/or other shapes, bracing in truss members, Chords, Battens and/or Laces of built-up member, Diaphragm members in bridge girder system, Web stiffening elements for I-shape sections, etc.



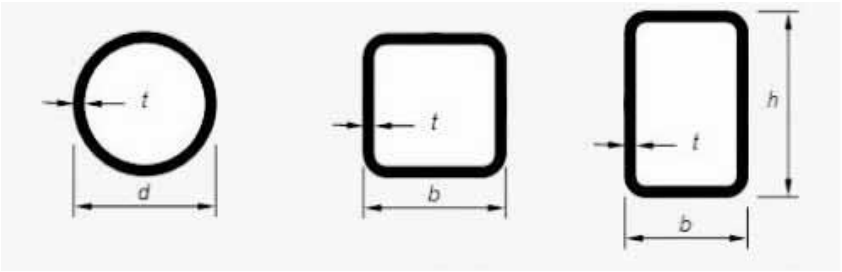
Rolled steel Bars

These are solid sections of square and round shape.



Rolled steel Tubes

These sections are designed by their nominal bore size. In each size classes of light, medium and heavy sections are there.



Rolled steel Plates

These are available in different sizes designated in terms of length, width and thickness. The thicknesses of stainless steel plates are commonly equal to or larger than 5 mm with widths larger than 250

Rolled steel Flats

When the thickness exceeds 5mm it is called flat sections. But the width in case of flat sections are limited Rolled steel sheets and strips

A stainless steel sheet has a thickness under 5 mm while its width is equal to or larger than 600 mm. The flat piece with thickness under 5 mm while its width is under 600 mm is considered as stainless steel strip.

1.3.2: Special considerations in steel designs

I. Minimum thickness: For all the structural steel members a minimum value of thickness is specified because in case of thinner sections very small amount of corrosion may result in reduction of a large area.
II. Shape and size: The rolled steel sections are available in various shape and sizes. Hence depending on the site requirement, loading conditions and shape and size of other members the sections are to designed.
III. Connection design: During fabrication different type of connector like bolts, welds, rivet and pins are used based the requirement.
IV. Buckling: As permissible load per unit area is very high in case of steel compared to other construction material, hence it results in smaller cross section and leads to a slender member which are highly susceptible to buckling. Hence to account for buckling effect, codes specify that parts of the section be taken as ineffective.

1.4: Loads and Load Combinations

Load is nothing, but the force acting on any structure. The is subjected to various types of load combinations in its life span. Hence to design any structure one should have the knowledge of different loads and their worst combinations a structure is subjected to.

Here are the various types of loads a structure is subjected to;

a) Dead load
b) Imposed load
c) Earthquake load
d) Wind load
e) Accidental load
f) Erection load
g) Secondary effect

Dead load: The loads who do not change their magnitude, direction, position with time are call ed dead load. Usually self weight of the structure is considered as dead load of the structure. It can be calculate easily from unit weight of the material. The details of dead load is describes in IS 875(part I).

Imposed load: The loads which are not permanently attached to the structure are called imposed loads. These loads are imposed to the structures temporarily. Loads such as Live load, crane load, snow load, dust load, rain load etc. are called imposed loads

Wind load: Force exerted on a structure due to horizontal and vertical component of wind is called wind load. The effect of wind load is given importance in case of high raise buildings, towers, water tanks etc. IS 875 (part III) gives details of calculations of wind load.

Earthquake loads: Earthquake loads are the horizontal loads imposed on a structure due to the horizontal and vertical component of acceleration imparted to the structure.

Accidental loads: The load due to any kind of accident like fire hazards, explosion etc. are called accidental loads. IS 875(part 5) describes about codal requirement of this load.

Erection load: During the transportation and placing of precast members they are subjected to different kind of loads called erection loads.

Secondary effect: Loads due to contraction or expansion, differential settlement, eccentric connections are called loads due to secondary effect.

Load combinations:

Load combinations for design purpose shall be those that produce forces and effects and consequently maximum stresses and deformations. The following load combinations with appropriate partial safety factors may be considered

a. Dead load + imposed
b. Dead load + imposed load + wind load
c. Dead load +wind or earthquake loads

1.5 Structural analysis and design philosophy (cl 4.1, 4.2, 4.3 of IS 800 : 2007)

For the purpose of complying with limit state of stability, strength and serviceability, effect of design actions on a structure and its members and connections, shall be determined by structural analysis by following method of analysis:

a) Elastic analysis
b) Plastic analysis
c) Advance analysis
d) Dynamic analysis

1.6: principles of limit state design

Design philosophies of steel structure is for achieving the design objectives, the design shall support characteristic values for material strengths and applied loads, that take into consideration the probability of variations in the material strengths and in the loads to be supported. The following design philosophies are used in limit state method of design to satisfy the requirement of strength, stability, serviceability, fatigue, durability, economy etc.

a) **Working stress method:** This theory is defined up to yield point of mild steel tensile curve. This theory is also called yield theory r elastic theory. The permissible stress is obtained from the yield stress by dividing with a factor called factor of safety. This theory underestimates the strength of the section and the designs produced with the help of this theory are highly uneconomical.
b) **Ultimate load method:** This method was developed to overcome the limitations of working stress method by accessing the actual load carrying capacity. It takes into account the reserve strength of the material beyond elastic range. This theory provides lighter economical designs but this theory does not satisfies serviceability criteria.
c) **Limit state method:** This method covers the deficiencies of both working stress method and unit load method.

Important Questions

Objective type Questions

1. Why is steel considered superior for structural applications compared to other materials?
2. How does the carbon content affect the properties of steel?
3. What are the type of structural steel?
4. What is the ductility of steel? why is it important?
5. Under what circumstances brittle failure of steel takes place?
6. What is the unit weight and modulus of elasticity of structural steel?
7. What do you mean by rolled steel sections?

Short type Questions

1. Write down the advantages and disadvantages of steel as a structural material.
2. What are the different types of rolled steel sections used in practice?
3. Explain briefly the various types of loads to be considered in the design of steel structure?