Course Content

- Design philosophies
- Introduction to Steel Structures
- Design of Welded connections
- Design of Bolted connections
- Design of Tension Members
- Design of Compression Members

Course Content

- Design of Column Bases
- Design of Beams
- Design of Composite Beams
- Design of Plate Girders

What is Steel?

- *Steel is an **alloy** in which iron is mixed with carbon and other elements.*
- An Alloy is a homogeneous mixture of two or more elements, at least one of which is a metal, and where the resulting material has metallic properties.
- An Alloy usually has different properties (sometimes significantly different) from those of its components.

Mention of Iron in Holy Quran

- Iron is mentioned in the Holy Quran 6 times:

1. Surah Bani Israil (17:50)
2. Surah Al Kahf (18: 96)
3. Surah Al Anbiya.. (21:22)
4. Surah Saba (34:10)
5. Surah Qaf (50:22)
6. Surah Al-Hadid (57:25)

Mention of Iron in Holy Quran

Al-Hadeed (Sura 57:25)

لَقَدْ أَرْسَلْنَا رُسُلَنَا بِالْبَيِّنَاتِ وَأَنزَلْنَا مَعَهُمُ الْكِتَابَ وَالْمِيزَانَ
لِيَقُومَ النَّاسُ بِالْقِسْطِ وَأَنزَلْنَا الْحَدِيدَ فِيهِ بَأْسٌ شَدِيدٌ وَمَنَافِعُ لِلنَّاسِ
وَلِيَعْلَمَ اللَّهُ مَن يَنصُرُهُ وَرُسُلَهُ بِالْغَيْبِ إِنَّ اللَّهَ قَوِيٌّ عَزِيزٌ ٢٥

We have indeed sent Our messengers with clear proofs, and sent down with them the book and the balance, so that people may uphold equity. And we *sent down iron* in which there is strong power, and benefits for the people; and (We did it) so that ALLAH knows who helps Him and his messengers without seeing (Him). Surely ALLAH is Strong, Mighty.

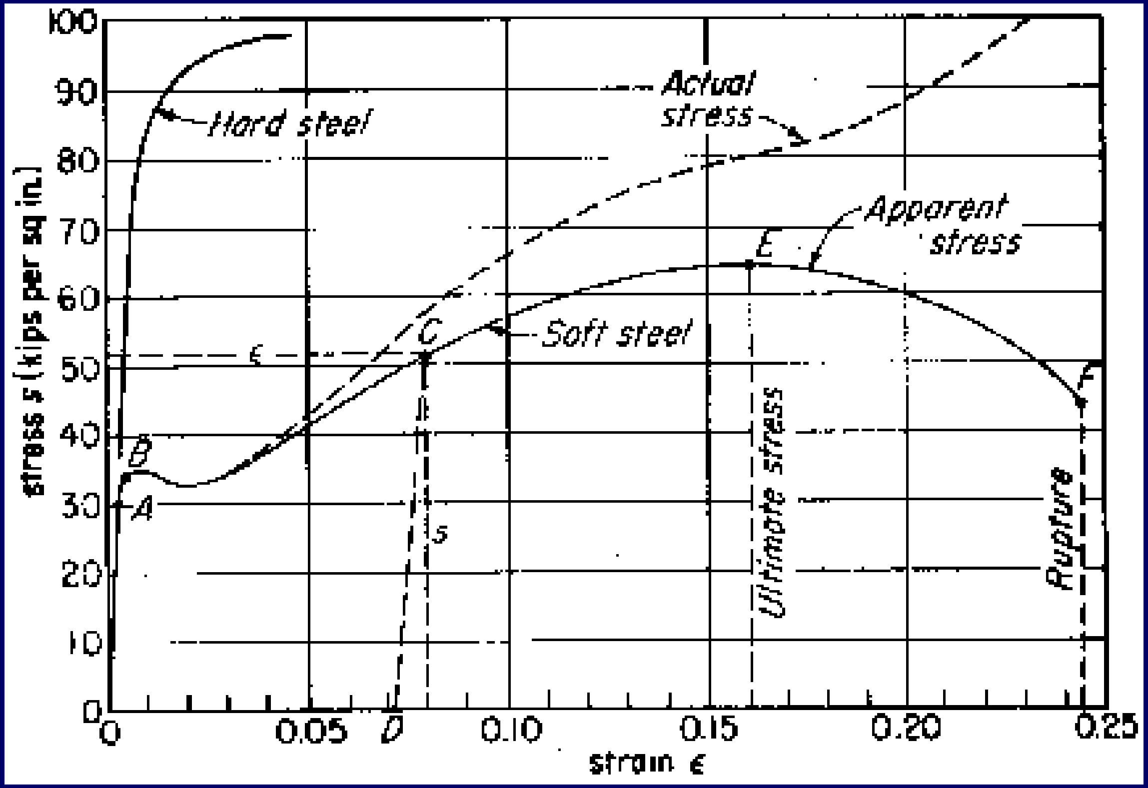
Effect of Carbon percentage on Steel Properties

Type of Steel	%age of Carbon
Mild Steel	Up to 0.25%
Medium Carbon Steel	0.25% to 0.45%
High Carbon Steel	0.45% to 1.50%

- Adding metals such as nickel, chromium, and tungsten to iron produces a wide range of **alloy steels**, including ***stainless steel*** and ***high speed steels***.

Effect of Carbon percentage on Steel Properties

- Carbon has a major effect on steel properties. Carbon is the primary hardening element in steel. Hardness and tensile strength increases as carbon content increases up to about 0.85%.



Mechanical Properties of Structural Steels

- Most widely used standards for structural materials are American Society for Testing & Materials (ASTM) Standards.
- ASTM specifications for structural steels generally identify the Process by which steel is to be made, chemical composition, and tensile requirements.

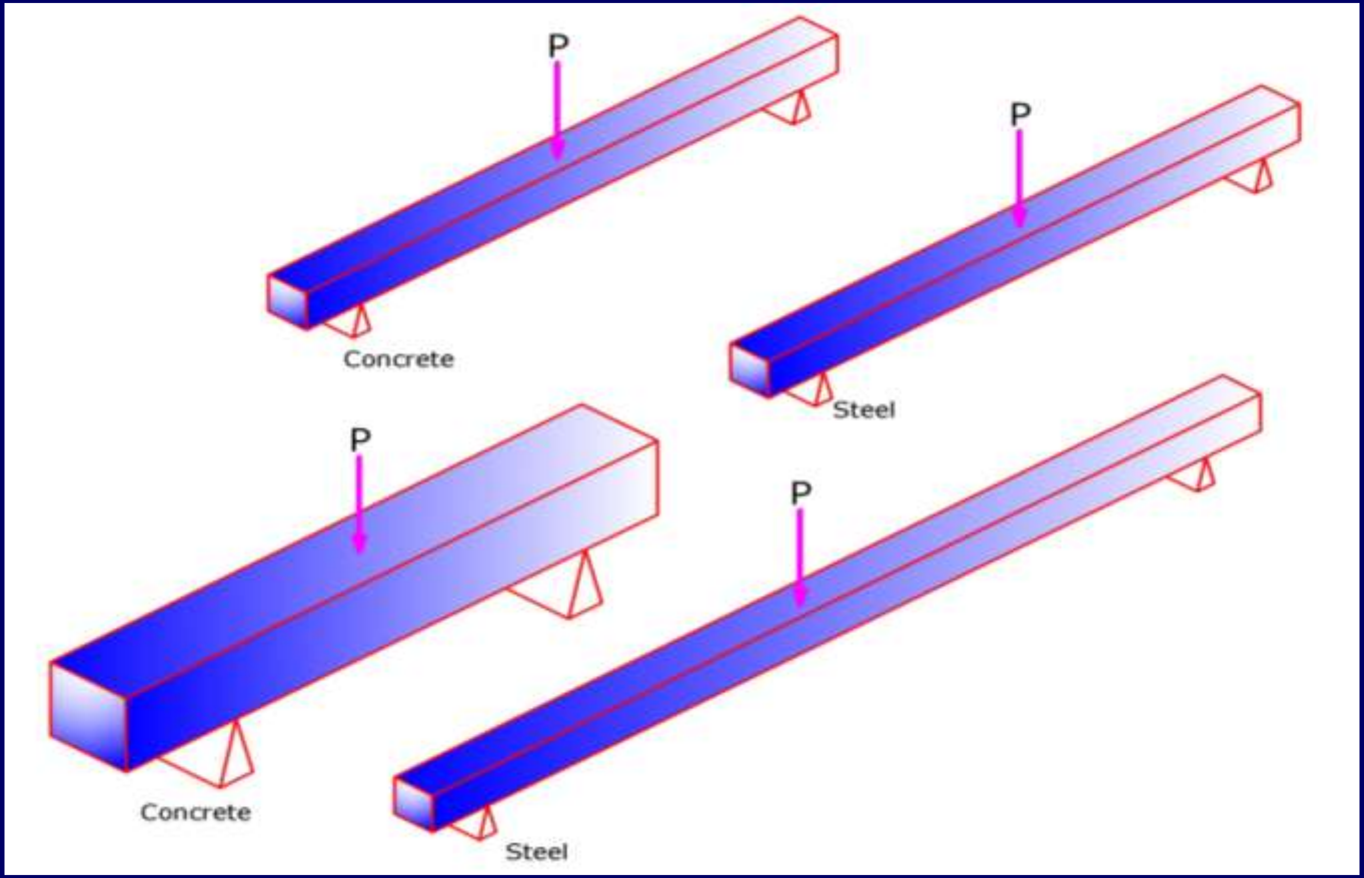
Mechanical properties of structural steel

Stiffness: The resistance of structural component to deformation.

- Material
- Length
- X-Section

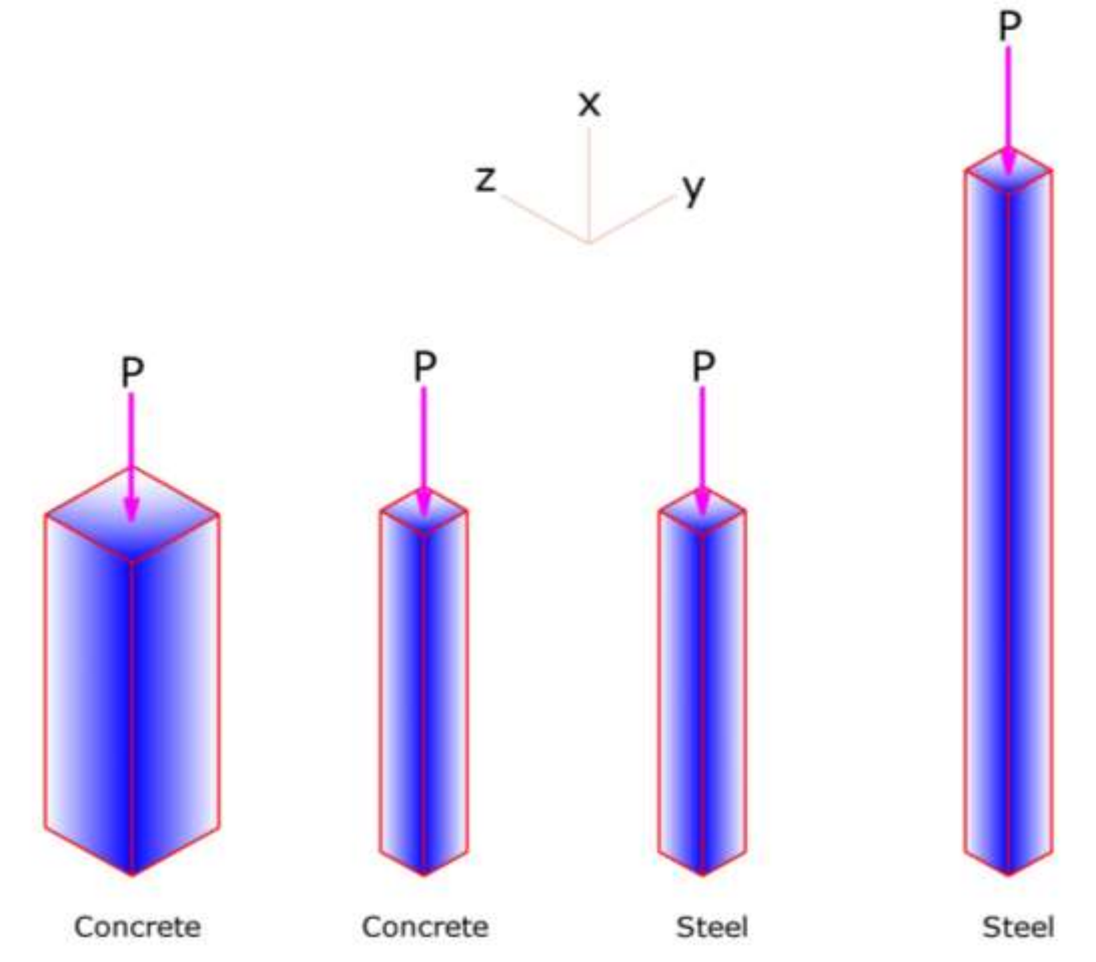
Mechanical properties of structural steel

Stiffness: Variation with Geometry and Material.



Mechanical properties of structural steel

Stiffness: Variation with Geometry and Material.



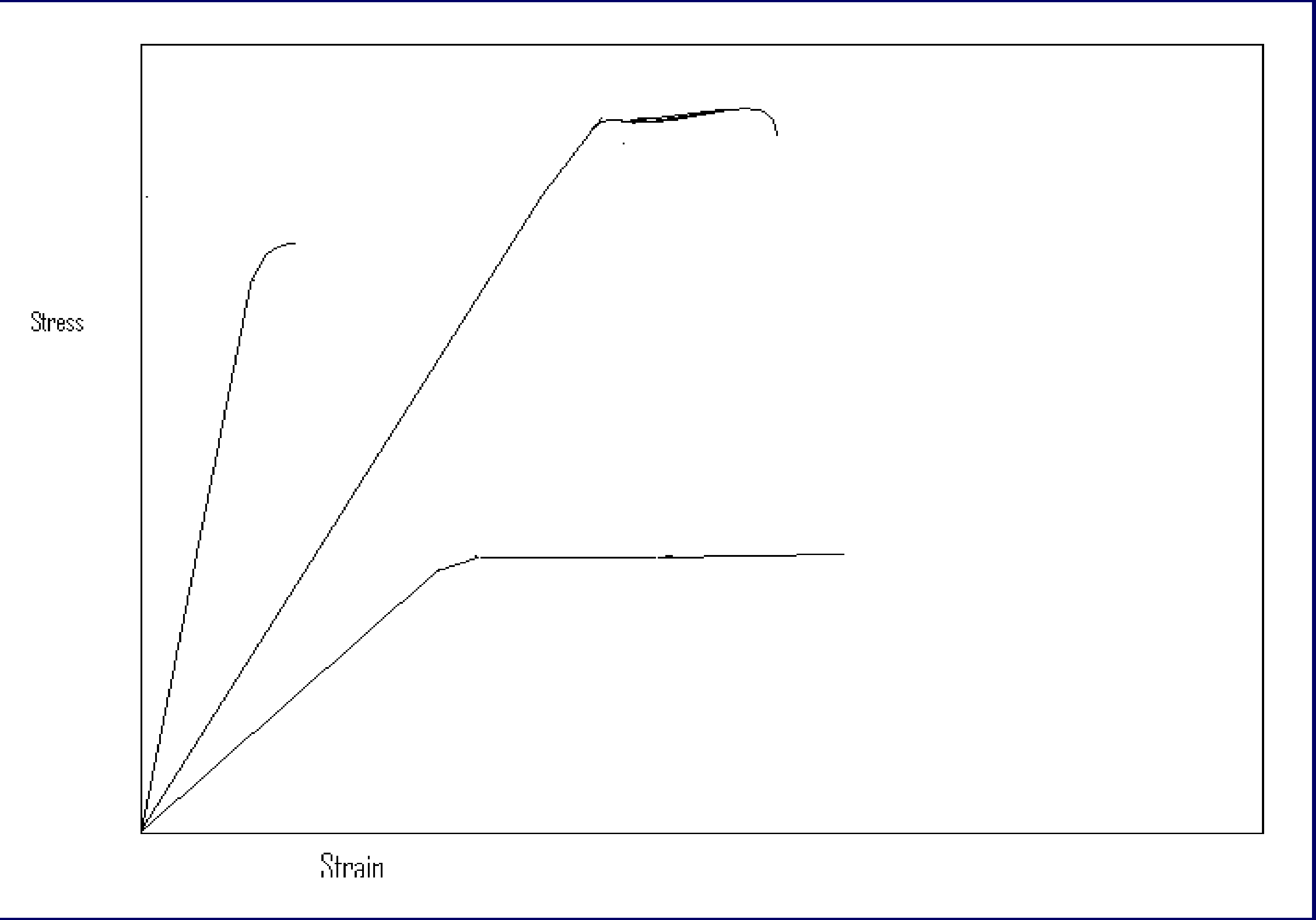
Mechanical properties of structural steel

Strength: The max load which a structure or structural component can resist.

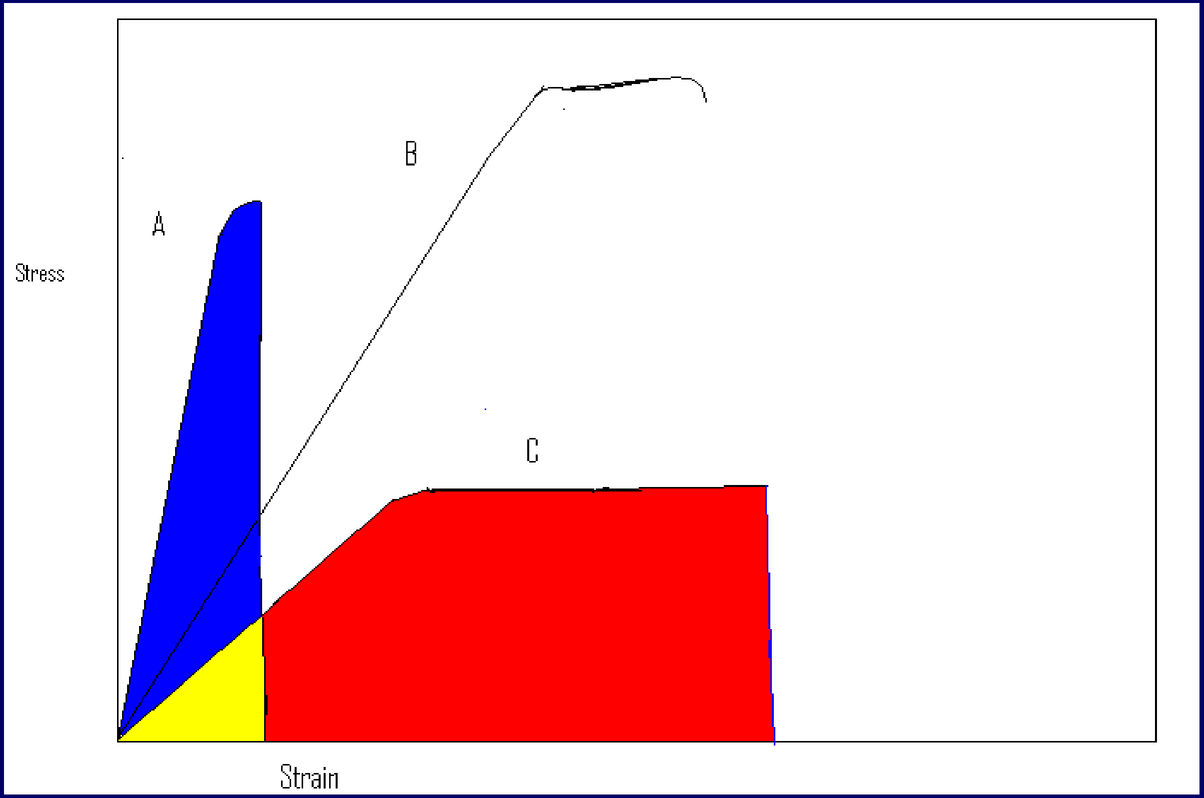
Toughness: The ability of a structure or structural component to absorb energy.

Fatigue is the weakening of a material caused by repeatedly applied loads.

Mechanical properties of structural steel



Mechanical properties of structural steel

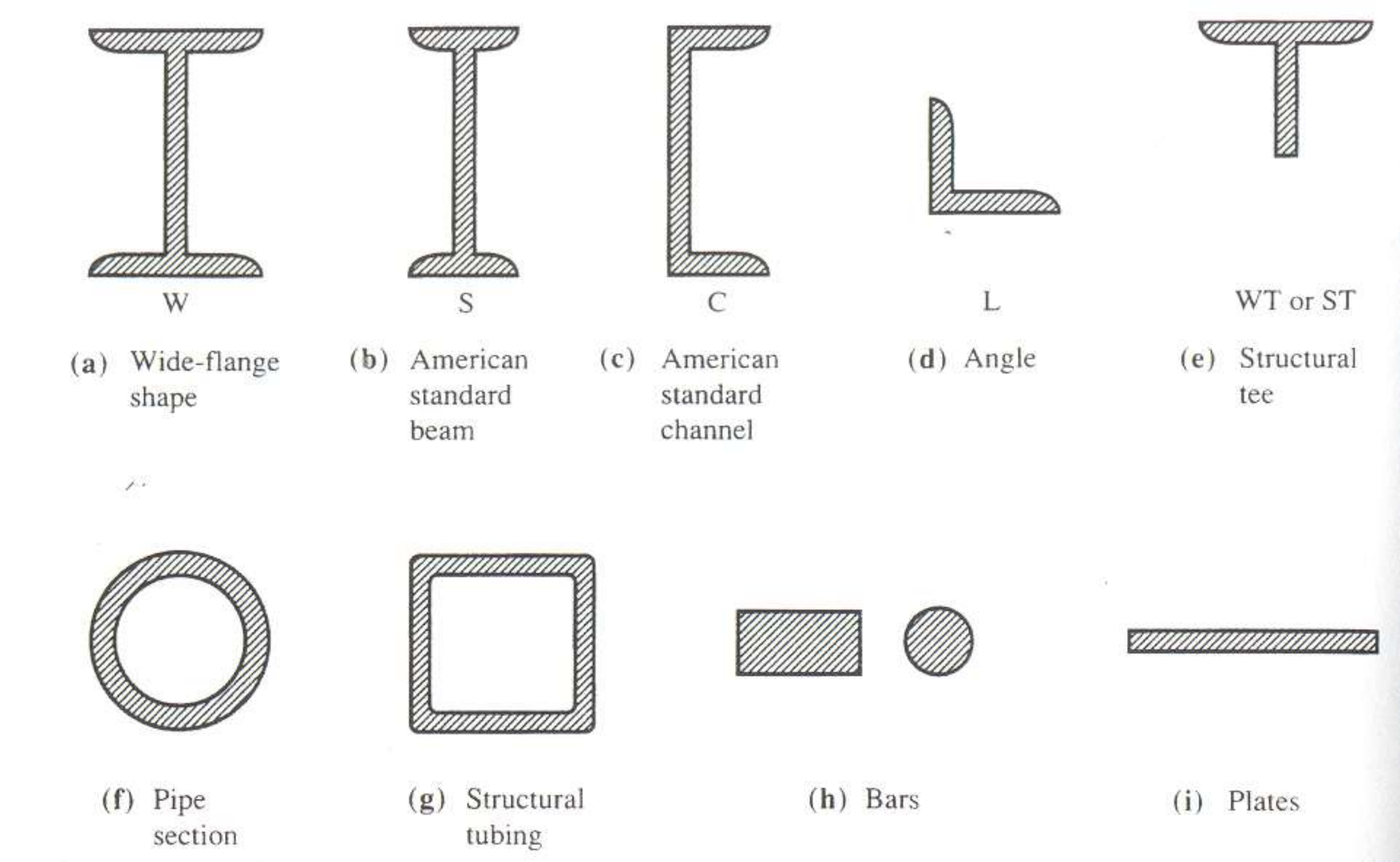


Material A is more Stiffer but less Tougher than Material C

Material A has more strength than Material C

Types of Steel Shapes

Standard Rolled Shapes



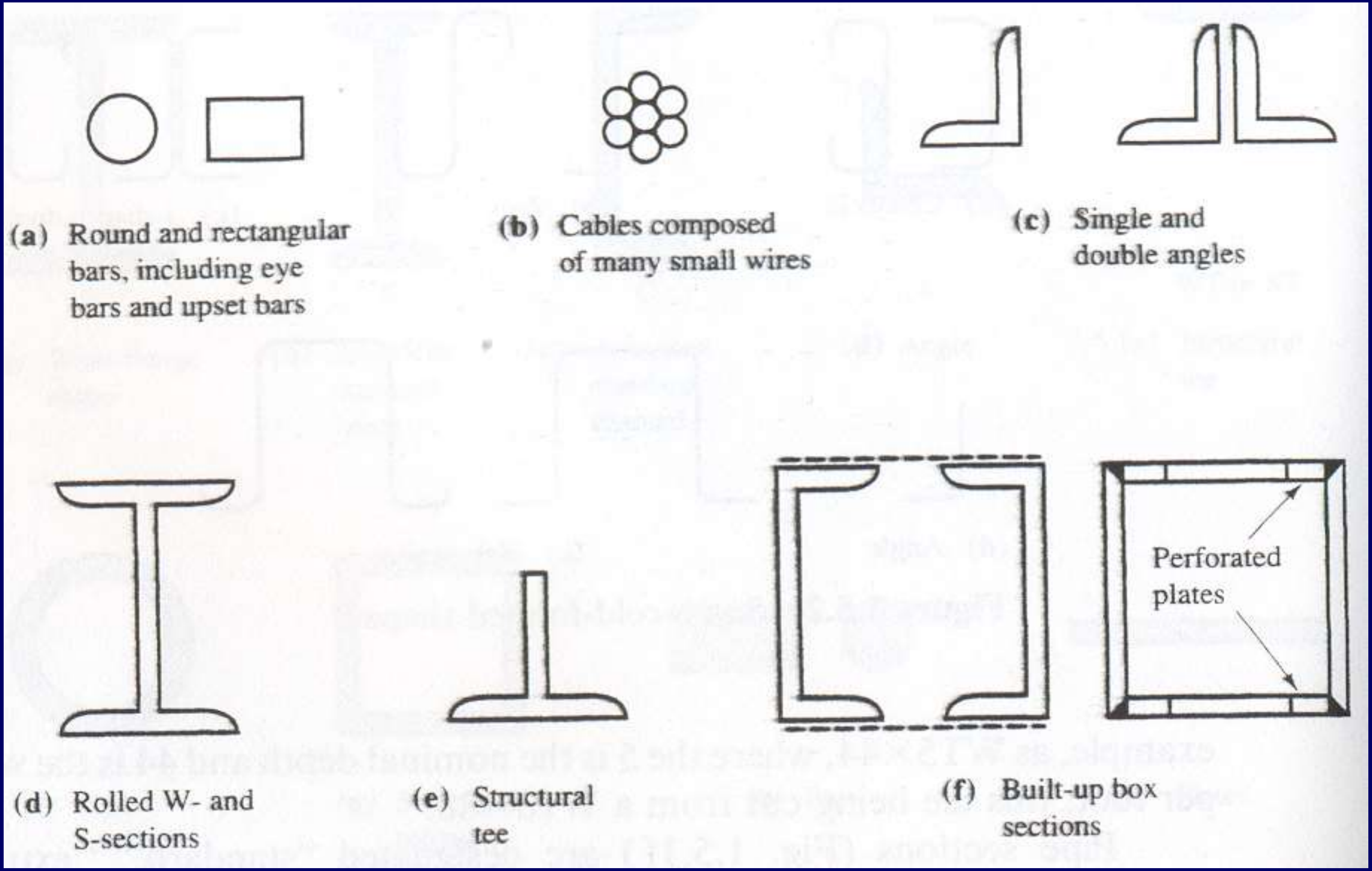
Types of steel structures

Tension Members

- Primarily occur as:
  - Chord Members in trusses:
  - In diagonal bracing in bracing systems;
  - Cable elements in suspension roofs, main cables of suspension bridges .

Types of Steel Shapes

Typical Tension Members



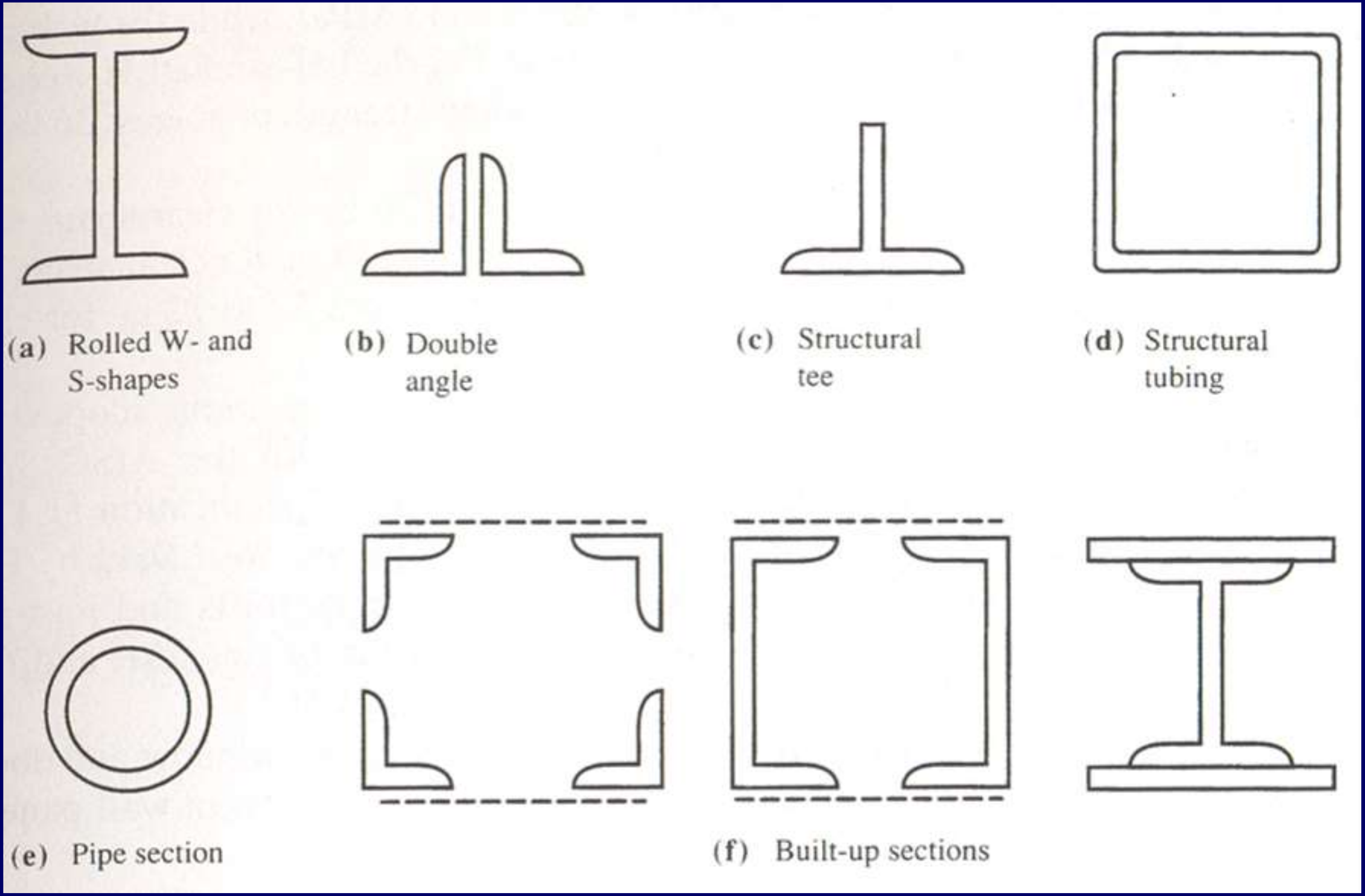
Types of steel structures

Compression Members

- Primarily occur as:
  - Columns in buildings;
  - Chord Members in trusses and diagonal members in end panels of trusses
  - Stability is an important consideration in design and behavior of compression members

Types of Steel Shapes

Typical Compression Members



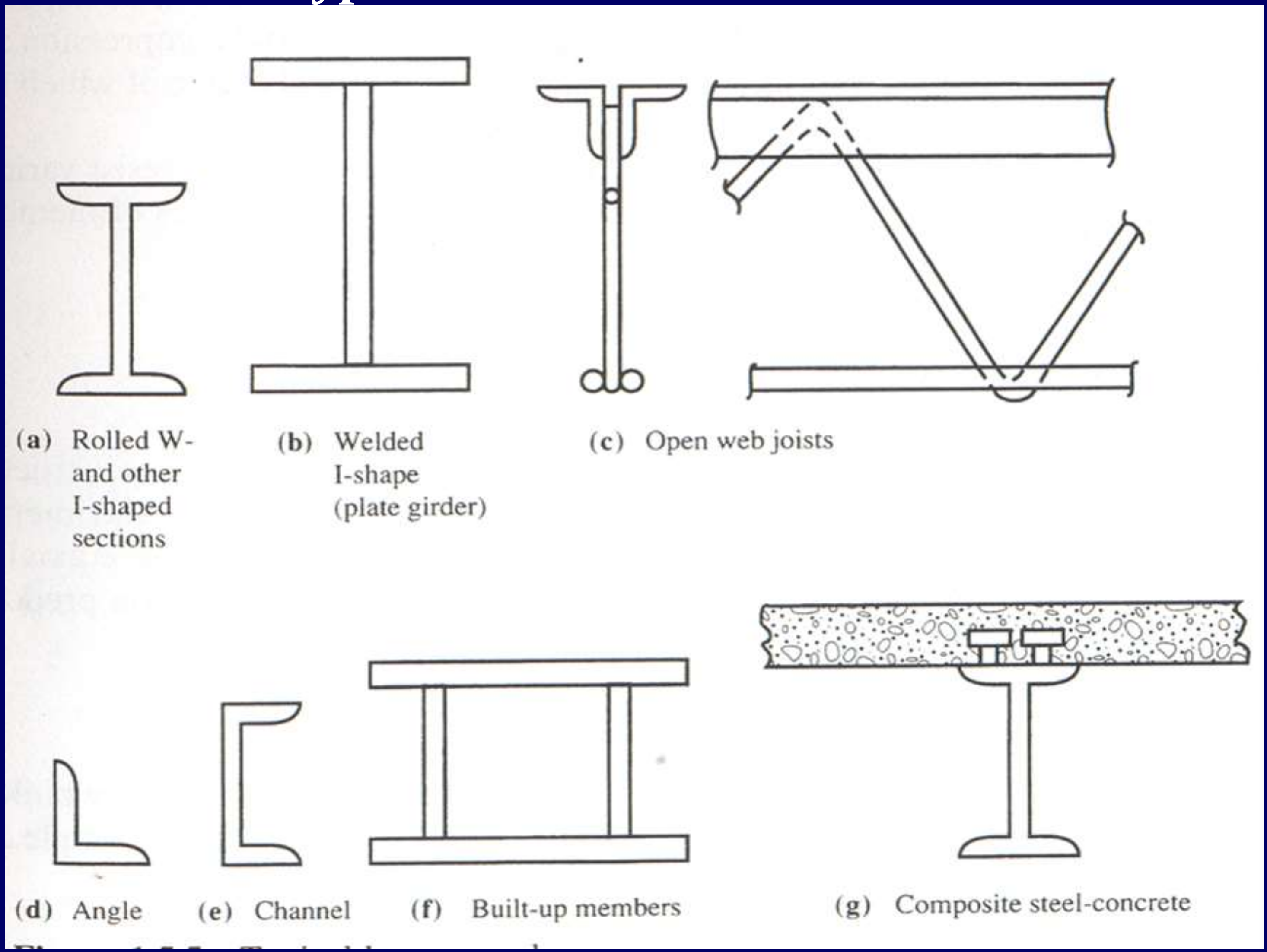
Types of steel structures

Beam Members

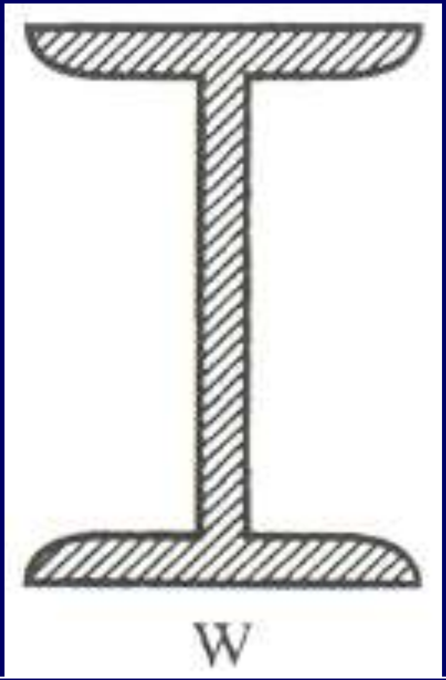
- Primarily loaded transverse to the longitudinal axis and resist loading by flexure.
- Commonly W shapes are used in most cases
- For deeper beams **I**-shaped sections made by welding plates are commonly used.
- Instability due to lateral Torsional Buckling is an important consideration

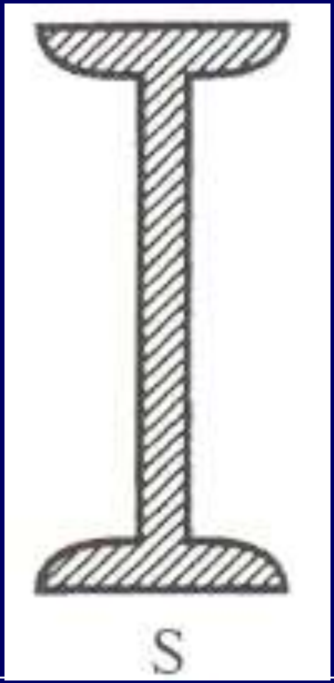
Types of Steel Shapes

Typical Beam Members



Difference between W and S shapes





W shape: Have wide flanges, efficient in resisting moments so used primarily as beams
S shape: Have wide webs, efficient in resisting shear (used in the past as railway tracks)

Symbolic Representation of Various shapes

- W30x90:
  - W represents shape of the section, I section in this case
  - 30 is the depth of the section in inches
  - 90 is the nominal weight in lb per ft
- L3x2x1/2
  - L represents shape of the section, angle
  - 3 is the length of one leg, inches
  - 2 is the length of the other leg, inches
  - ½ is the thickness of the angle, inches

Types of steel structures

- Classical Skeleton framing
- Steel truss
- Rigid frames
- Arches
- Domes
- Cable supported Roofs

Types of steel structures

Classical skeleton framing

- Classical system supported by beams, girders and columns.
- Beams: W or S shapes, Channel shapes for roof purlins.
- Columns: generally W shapes

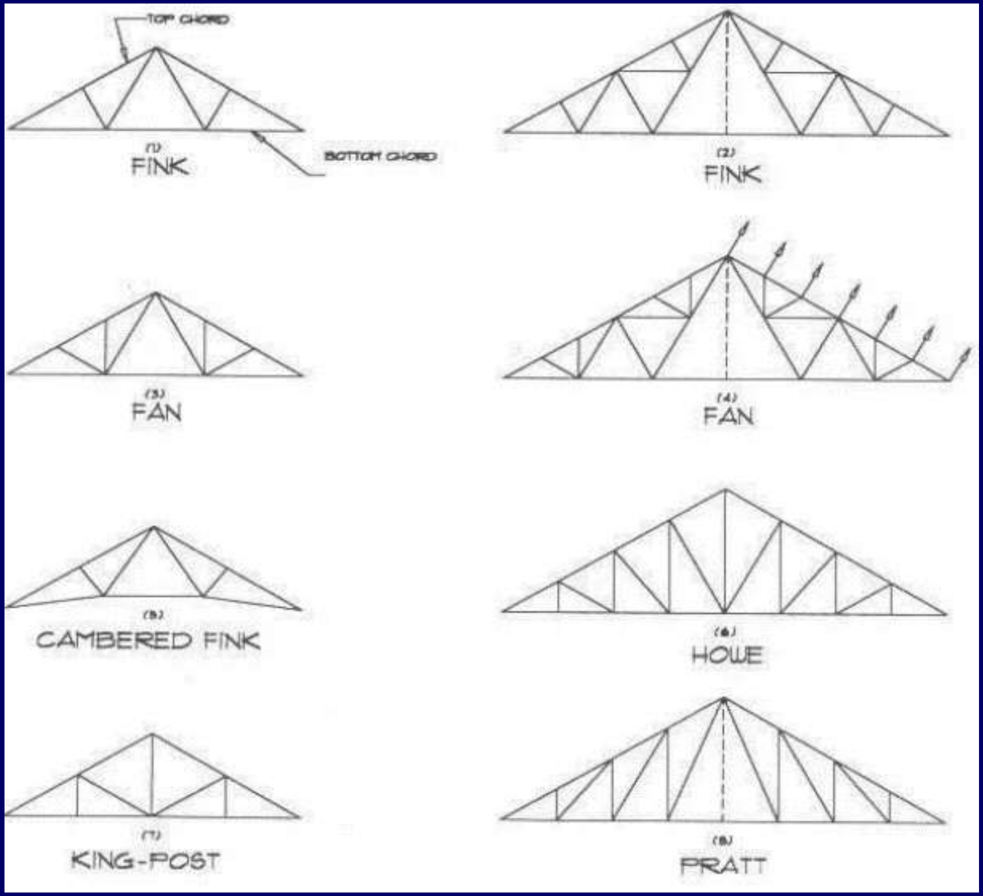
Types of steel structures

Classical skeleton framing

Types of steel structures

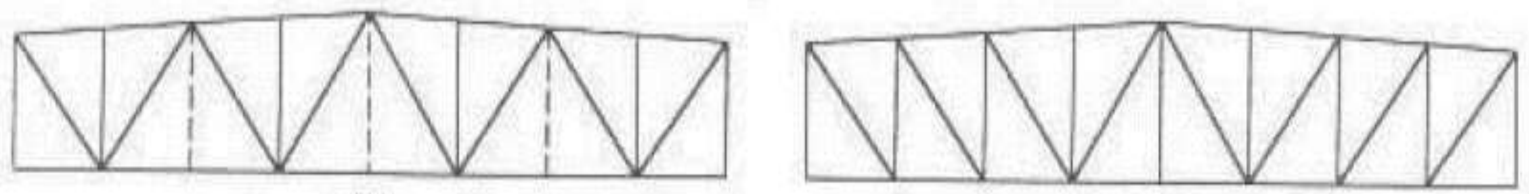
Steel trusses

- Triangular rigid structure
- Most common double pitched roof trusses:
- Fink & Pratt.
- Most common flat trusses: Pratt &Warren



Types of steel structures

Steel trusses



FLAT WARREN

FLAT PRATT

FIG. 2.4 TYPES OF ROOF TRUSSES

Types of steel structures

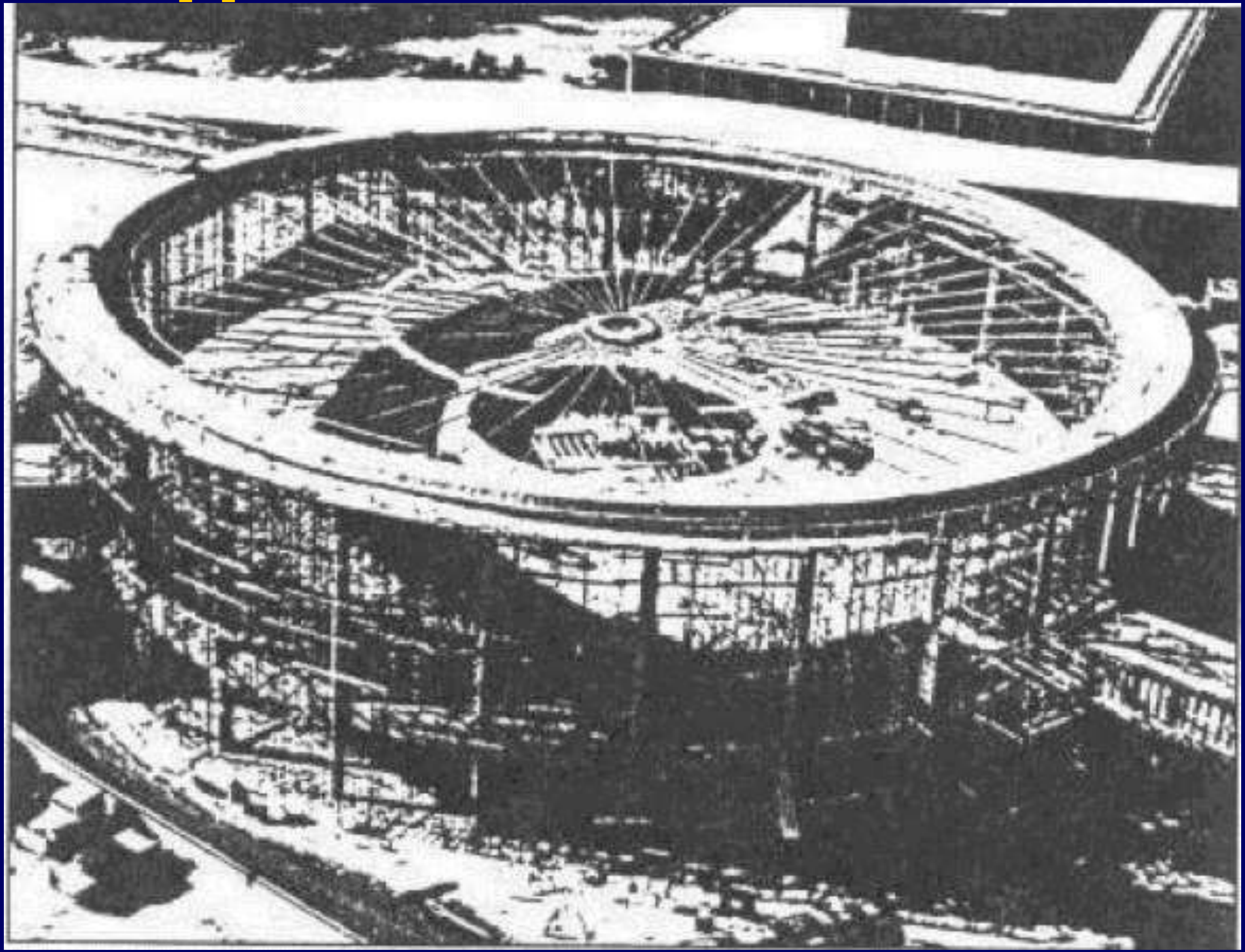
Steel trusses: **Example of steel truss with built up members**

Truss Bridge

Built-up Members

Types of steel structures

Cable supported roof



Examples of Famous steel structures

Eiffel Tower, Paris

- 990ft

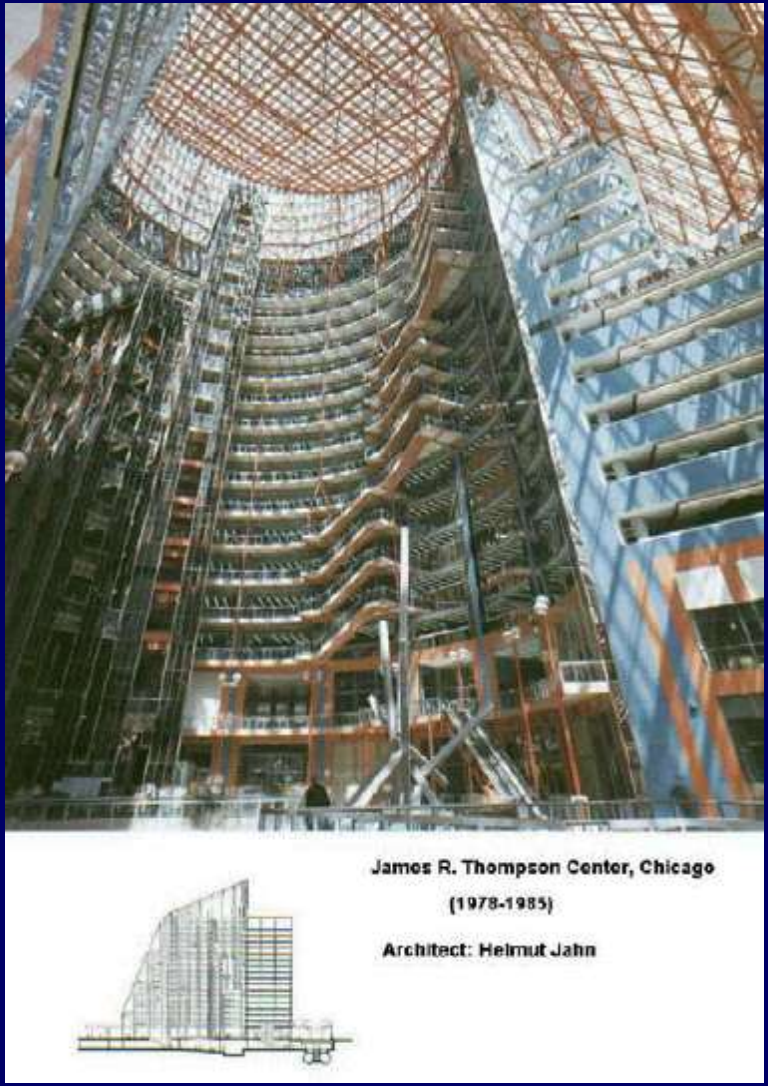
Eiffel Tower, Paris

Engineer: Gustave Eiffel (1887- 1889)

Examples of Famous steel structures

James R. Thompson Center, Chicago

- The building is enclosed by 17 story curtain walls.
- The diameter of rotunda is 160ft



Examples of Famous steel structures

Indoor Football Facility, University of Illinois, Urbana

- The roof structure is semi-parabolic dome

Indoor Football Facility- University of Illinois / Urbana, Champaign

Examples of Famous steel structures

- 110 Stories Tall
- Total Height = 1725 ft
- Based on revolutionary Bundled Tube Design
- Rigid outer walls act as walls of hollow tube
- There are 9 tubes in all
- The number of tubes reduces with height
- Designed by late Fazl-ur-Rehman from Bangladesh
- Supported by 114 piles

Design Philosophies

- A general statement assuming safety in engineering design is:
- **Resistance ≥ Effect of applied loads ---(1)**
- In eq(1) it is essential that both sides are evaluated for same conditions and units e.g. compressive stress on soil should be compared with bearing capacity of soil

Design Philosophies

- Resistance of structures is composed of its members which comes from **materials & X-section**

- Terms like Demand, Stresses, and Loads are used to express Effect of applied loads.

Limit States

- When particular loading reaches its limit, failure is the assumed result, i.e. the loading condition become failure modes, such a condition is referred to as limit state and it can be defined as
- "A limit state is a condition beyond which a structural system or a structural component ceases to fulfill the function for which it is designed."

Limit States

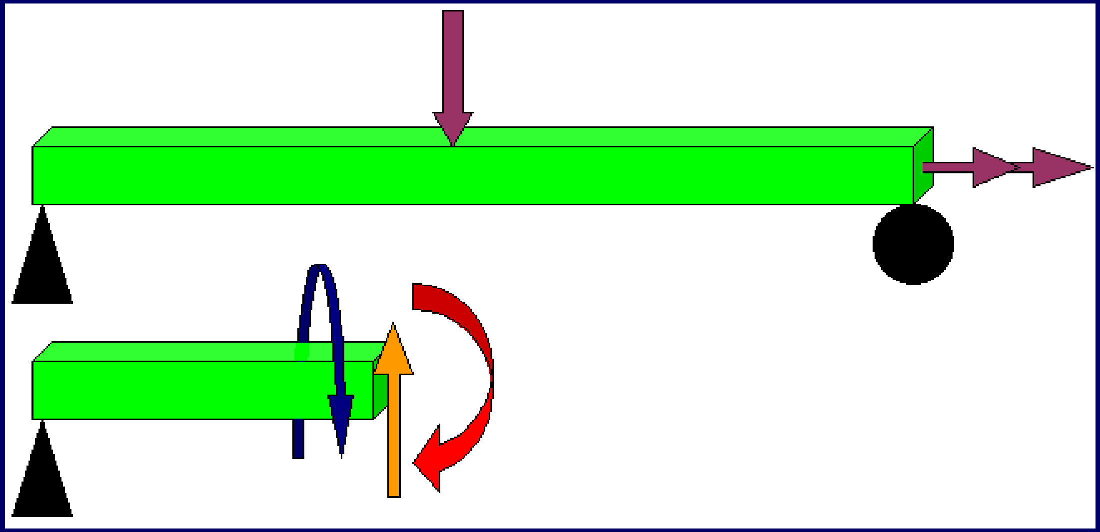
- There are three broad classification of limit states:

1. Strength limit states
2. Serviceability limit states
3. Special limit states

Limit States

Strength Limit States:

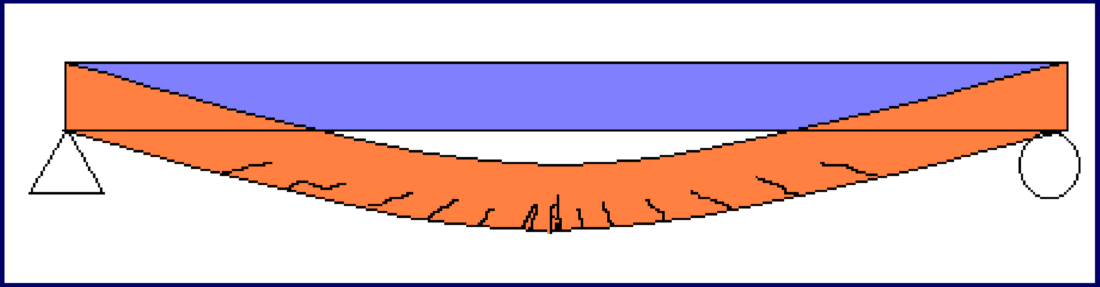
- Flexure
- Torsion
- Shear
- Fatigue
- Settlement
- Bearing



Limit States

Serviceability Limit States:

- Cracking
- Excessive Deflection
- Buckling
- Stability



Limit States

Special Limit States:

- Damage or collapse in extreme earthquakes.
- Structural effects of fire, explosions, or vehicular collisions.

Design Considerations

- Structure and Structural Members should have adequate strength, stiffness and toughness to ensure proper functioning during service life
- Reserve Strength should be available to cater for:
  - Occasional overloads and underestimation of loads
  - Variability of strength of materials from those specified
  - Variation in strength arising from quality of workmanship and construction practices

Design Considerations

- Structural Design must provide adequate margin of safety irrespective of Design Method

- Design Approach should take into account the probability of occurrence of failure in the design process

Design Considerations

- An important goal in design is to prevent limit state from being reached.

- It is not economical to design a structure so that none of its members or components could ever fail. Thus, it is necessary to establish an acceptable level of risk or probability of failure.

Design Considerations

- Brittle behavior is to be avoided as it will imply a sudden loss of load carrying capacity when elastic limit is exceeded.
- Reinforced concrete can be made ductile by limiting the steel reinforcement.

Design Considerations

- To determine the acceptable margin of safety, opinion should be sought from experience and qualified group of engineers.
- In steel design AISC manuals for ASD & LRFD guidelines can be accepted as reflection of such opinions.

Design Considerations

- Any design procedure require the confidence of Engineer on the analysis of load effects and strength of the materials.

- The two distinct procedures employed by designers are **Allowable Stress Design (ASD) & Load & Resistance Factor Design (LRFD).**

Allowable Stress Design (ASD)

- Safety in the design is obtained by specifying, that the effect of the loads should produce stresses that is a fraction of the yield stress f_y, say one half.

Allowable Stress Design (ASD)

- Since the specifications set limit on the stresses, it became allowable stress design (ASD).

- It is mostly reasonable where stresses are uniformly distributed over X-section (such on determinate trusses, arches, cables etc.)

ASD Drawbacks

- Implied in the ASD method is the assumption that the stress in the member is zero before any loads are applied, i.e., no residual stresses exist from forming the members.

ASD Drawbacks

- ASD does not give reasonable measure of strength, which is more fundamental measure of resistance than is allowable stress.
- Another drawback in ASD is that safety is applied only to stress level. Loads are considered to be deterministic (without variation).

Load and Resistance Factor Design (LRFD)

- To overcome the deficiencies of ASD, the LRFD method is based on:

Strength of Materials

- It consider the variability not only in resistance but also in the effects of load.
- It provides measure of safety related to probability of failure.

Thanks