Chapter 1. Types of Structures and Loads

1.1 INTRODUCTION

- Structure: refers to a system of connected parts that can support loads while performing its primary functions.
- Structures can be classified according to their uses:
    - *Civil Structures* - Building, bridges, towers etc. are used by civilians or general public.
    - *Military Structures* – ships, aircraft frames, tanks etc. used by the military etc.
- Normally all static / stationary structures used by the common public are designed by CIVIL Engineers.
- Engineers must design the structure for:
    - *Safety*
    - *Serviceability*
    - *Aesthetics*
    - *Economy*
    - *Environmental conditions*
- Engineers must consider several possibilities for a structure before selecting a final design based on several performance criteria.
- DESIGN PROCESS – creative and technical
    - Requires a *fundamental* knowledge of material properties and mechanics
    - Requires knowledge of various types of structural forms and configurations
    - Calculation of loads and load effects acting on the structure
    - Knowledge of structural analysis to calculated design forces
    - Requires knowledge of designing structural members and connections
    - Ability to evaluate designs and consider other options
- In this course we will study the basic analysis and design process

1.2 CLASSIFICATION OF STRUCTURES

- As an engineer, you must be able to classify structures according to their form and function and you must also be able to recognize various types of elements composing a structure.
- STRUCTURAL SYSTEM – composed of structural members joined together by structural connections. Each structural system may be composed of one or more of the **four basic types of structures.**
- The four basic types of structures are:
  - *Trusses*
  - *Cables and Arches*
  - *Frames*
  - *Surface Structures*

1.2.1 TRUSSES

- Trusses consist of slender members, arranged in a triangular pattern.
- Planar trusses are composed of members that lie in the same plane. They are frequently used to support *bridges* and *roofs*.
- Space trusses have members extending in three dimensions and are suitable for transmission line towers etc.
- All members are connected together by *PINS*, which are free to rotate (literally?).
- Loads that cause the entire truss to bend are converted into axial tensile and compressive forces in the members.
- Truss members are usually subjected to axial forces only.
- Truss members use less material to support a given load. But, they require a lot of fabrication.
- Trusses can be used in the 30 – 400 ft. range. Trusses spanning greater than 400 ft. have also been designed.
- **Select a truss** for the design when the span of the structure is large and there is no restriction on depth in the design process.

1.2.2 CABLES AND ARCHES

- Cables and arch type structures are used to span long distances
- Cables are usually **flexible** and carry their loads in **tension**
- The external load is usually applied vertically (not along the axis of the cable). As a result, the cable deforms with a *SAG*.
- Cables are commonly used to support *bridges* and building *roofs.*
- Cables have an advantage over beams and trusses, especially for spans greater than 150 ft.
- Past and future uses – Rope bridges and Composite Cables
- Cables are limited by their SAG and methods of **anchorage.**
- ***MACKINAC BRIDGE, GOLDEN GATE BRIDGE***

Arches

- An arch has the reverse curvature of a cable and it achieves its strength in compression
- The arch must be **rigid** in order to maintain its shape.
- It is primarily subjected to compression (but also some shear and moment).
- Arches are used in bridge structures, dome roofs, and openings in masonry walls.

1.2.3 FRAMES

- Frames are commonly used in building structures.
- Frames are composed of beams and columns that are connected together.
- Planar (2D) frame with all members in one plane
- Space (3D) frame with all members in more than one plane.
- Steel Frames – Concrete Frames. Most commonly used buildings
- There are different types of frames depending on the connections between beams and columns
    - Braced frames – All connections between beams and columns are pinned and there are diagonal bracing members
    - Moment resisting frames – Connections between beams and columns are rigid and there is no need for diagonal bracing members.

1.2.4 SURFACE STRUCTURES

- Membrane, plate, or shell type structures with much less thickness as compared to its other dimensions.
- The structure is subjected to in-plane (tension or compression forces mainly).
- Surface structures may be made of rigid material such as reinforced concrete.
- The structures may be shaped as folded plates, cylinders, etc.
- They are referred to as thin plates or shells.

1.3 CLASSIFICATION OF STRUCTURAL MEMBERS

- There are five basic types of structural members. These are as follows:
  - *Tension Members* or Tie Rods
  - *Compression Members* or Columns or Struts
  - *Flexural Members* or Beams
  - *Members subjected to combined loading* or Beam-Columns.

1.3.1 Tension Members

- Structural members subjected to tensile forces are often referred to as *tie rods*.
- These members are usually slender and often chosen from rods, bars, angles, or channels.
- They occur most commonly in **truss structures** and in **braced frames**.

1.3.2 COLUMNS AND STRUTS

- Column members are generally vertical and resist axial compressive loads.
- Tubes and I-sections are often used for metal columns.
- Circular and square cross-sections with reinforcing bars are used for concrete compression members.
- Compression members that occur in trusses are usually called struts. They may be vertical or inclined depending on the layout of the truss.

1.3.3 BEAMS or Flexural Members

- Beams are usually straight horizontal members that are used primarily to carry vertical loads.
- Beams are usually classified according to their support conditions.
- When the beam cross-section varies along the length it is called as a tapered or haunched beam.
- When the beam is curved along the longitudinal axis, it is called as a curved beam.
- Beams are primarily designed to resist bending moment and shear force ?
- The cross-section for beams made from metals (steel or aluminum) have been optimized to use the least amount of material.
- The optimized cross-section looks like an I-shape. The horizontal plates are called flanges and the vertical plate is called 'web'.
- In this shape, the flanges primarily resist the moments and the web resists the shear. The optimum beam section has wide flanges and is called a wide-flange (W) section.
- The forces in the top and bottom flanges of the beam form the necessary couple to resist the applied moment **M**.
- Steel mills produce beams in a single unit by hot rolling them. You can order steel beams with depths up to 40 in. that are capable of spanning up to 75 ft. If longer lengths are required, they can be spliced in the field.
- If greater depths are needed, plate girders can be used. Plate girders are made by welding together three plates (the web and the two flanges).

- Concrete beams are generally rectangular in cross-section, since it is easy to construct this form directly in the field.
- Concrete as a material is weak in resisting tension. Therefore, steel 'reinforcing rods' are cast into the beam within regions of the cross-section subjected to tension.
- Precast concrete girders are fabricated at a shop and then transported to the job site.
- Prestressed concrete beams or girders are also used nowadays for bridges.

1.3.4 Beam-Column Members

- Columns that are subjected to flexural forces (bending moment) in addition to axial forces are called beam-columns.
- Steel beam-columns are also usually designed with I shaped sections.
- Concrete beam-columns are similar to concrete columns, but reinforcing steel is added to resist the additional bending moment.