CHAPTER

8a

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Structural Steel Design
LRFD Method

Third Edition

INTRODUCTION TO BEAMS

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Part II – Structural Steel Design and Analysis

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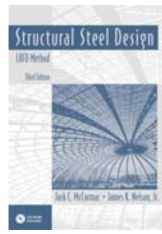

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ENCE 355 - Introduction to Structural Design

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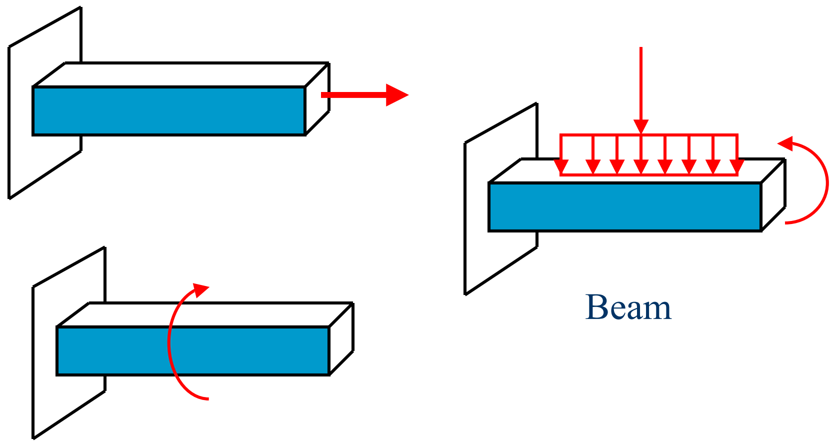
Types of Beams

- A beam is generally considered to be any member subjected to principally to transverse gravity or vertical loading.
- The term transverse loading is taken to include end moments.
- There are many types of beams that are classified according to their size, manner in which they are supported, and their location in any given structural system.

Types of Beams

Figure 1. Loading on Beams

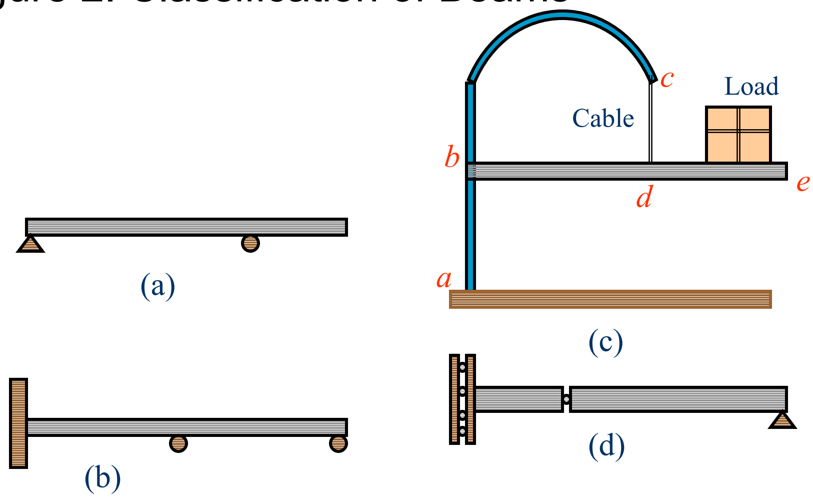


Types of Beams

- Beams can be
  - Straight as shown in Figure 2c.
    - For example the straight member bde.
  - Curved as shown in Figure 2c.
    - For example the curved member abc.
- Beams are generally classified according to their geometry and the manner in which they are supported.

Types of Beams

Figure 2. Classification of Beams



Types of Beams

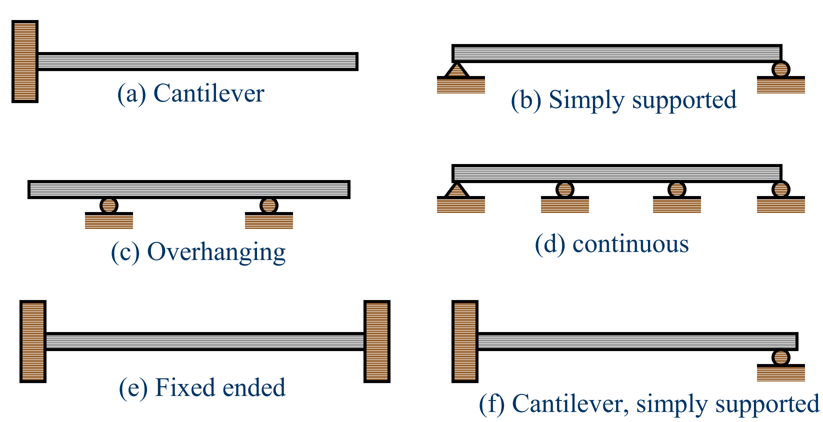
- Geometrical classification includes such features as the shape of the cross section, whether the beam is
  – Straight or
  – Curved
- Or whether the beam is
  – Tapered, or
  – Has a constant cross section.

Types of Beams

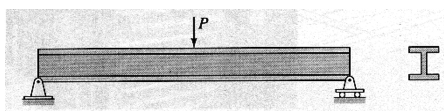
- Beams can also be classified according to the manner in which they are supported. Some types that occur in ordinary practice are shown in Figure 3, the names of some of these being fairly obvious from direct observation.
- Note that the beams in (d), (e), and (f) are statically indeterminate.

Types of Beams

- Figure 3. Types of Beams Based on the Manner in Which They are Supported.



Types of Beams



Types of Beams

Types of Beams

- Beams used in Buildings and Bridges
  - Girders
    - Usually the most important beams, which are frequently at wide spacing.
  - Joists
    - Usually less important beams, which are closely spaced, frequently with truss-type webs.
  - Stringers
    - Longitudinal bridge beams spanning between floor beams.

Types of Beams

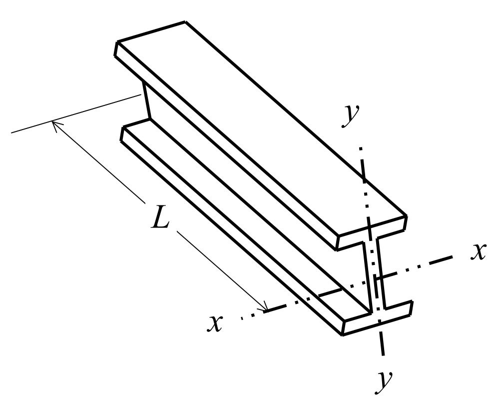
- Beams used in Buildings and Bridges (cont'd)
  - Purlins
    - Roof beams spanning between trusses.
  - Girts
    - Horizontal wall beams serving principally to resist bending due to wind on the side of an industrial building.
  - Lintels
    - Members supporting a wall over window or door openings.

Sections Used As Beams

- Among the steel shapes that are used as beam include
  - **W** shapes, which normally prove to be the most economical beam sections, and they have largely replaced channels and **S** sections for beam usage.
  - Channels are sometimes used for beams subjected to light loads, such as purlins, and in places where clearances available require narrow flanges.

Sections Used As Beams

- Figure 4. W Section as a Beam



Sections Used As Beams

- Another common type of beam section is the open web joist or bar joist.
- This type of section, which commonly used to support floor and roof slabs, is actually a light shop-fabricated parallel chord truss.
- It is particularly economical for long spans and light loads.

Bending Stresses

- Bending moment produces bending strains on a beam, and consequently compressive and tensile stresses.
- Under positive moment (as normally the case), compressive stresses are produced in the top of the beam and tensile stresses are produced in the bottom.
- Bending members must resist both compressive and tensile stresses.

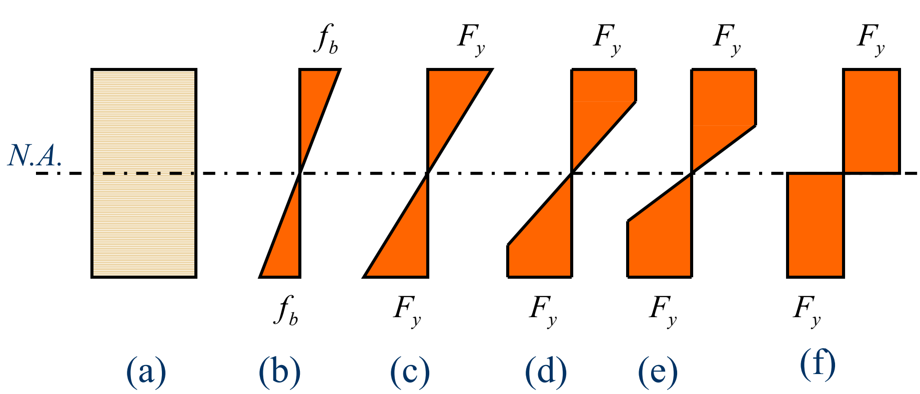
Bending Stresses

- Stresses in Beams
  - For introduction to bending stress the rectangular beam and stress diagrams of Fig. 5 are considered.
  - If the beam is subjected to some bending moment that stress at any point may be computed with the usual flexure formula:

$$f_b = \frac{Mc}{I} \qquad (1)$$

Bending Stresses

- Figure 5. Variation in Bending Stresses



Bending Stresses

- Stresses in Beams
  - It is important to remember that the expression given by Eq. 1 is *only* applicable when the maximum computed stress in the beam is below the *elastic limit*.
  - The formula of Eq. 1 is based on the assumption that the stress is proportional to the strain, and a plane section before bending remains plane after bending.

Bending Stresses

- Stresses in Beams
  - The value of I/c is a constant for a particular section and is known as the *section modulus* S.
  - The flexure formula may then be written as follows:

$$\sigma = \frac{M}{S} \qquad (2)$$

Bending Stresses

- Plastic Moment
  - In reference to Fig. 5:
    - Stress varies linearly from the neutral axis to extreme fibers, as shown in Fig. 5b.
    - When the moment increases, there will also be a linear relationship between the moment and the stress until the stress reaches the yield stress F_Y, as shown in Fig. 5c.
    - In Fig. 5d, when the moment increases beyond the yield moment, the outermost fibers that had previously stressed to their yield point will continue to have the same but will yield.

Bending Stresses

- Plastic Moment
  - In reference to Fig. 5 (cont'd):
    - The process will continue with more and more parts of the beam cross section stressed to the yield point as shown by the stress diagrams of parts (d) and (e) of Fig. 5., until finally a full plastic distribution is approached as shown in Fig. 5f.

Bending Stresses

- Plastic Moment
  - Definition

    "*The plastic moment can be defined as the moment that will produce full plasticity in a member cross section and create a plastic hinge*".

Bending Stresses

- Shape Factor
  - Definition

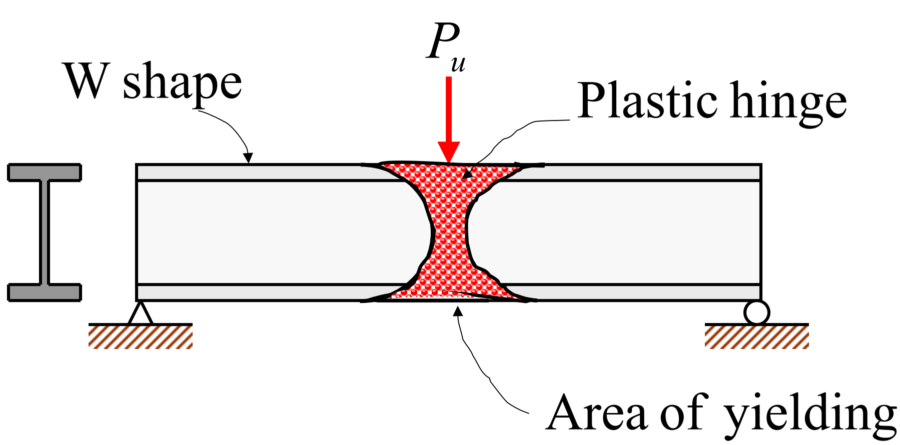
    "The shape factor of a member cross section can be defined as the ratio of the plastic moment M_p to yield moment M_y".
  - The shape factor equals 1.50 for rectangular cross sections and varies from about 1.10 to 1.20 for standard rolled-beam sections

Plastic Hinges

- The Concept of Plastic Hinge
  - The plastic hinge concept is illustrated as shown in the simple beam of Fig. 6.
  - The load shown in the figure is applied to the beam and increased in magnitude until the yield moment is reached and the outermost fiber is stressed to the yield stress.
  - The magnitude of the load is further increased with the result that the outer fibers begin to yield.

Bending Stresses

Figure 6. Plastic Hinge



Plastic Hinges

- The Concept of Plastic Hinge (cont'd)
  - The yielding spreads out to other fibers away from the section of maximum moment as indicated in Fig. 6.
  - The length in which this yielding occurs away from the section in question is dependent on the loading conditions and the member cross section.
  - For a concentrated load P_u applied at the center line of a simply-supported beam with a rectangular cross section, yielding in

Plastic Hinges

- The Concept of Plastic Hinge (cont'd)

  extreme fibers at the time the plastic hinge is formed will extend for one-third of the span.
  - For a W section in similar circumstances, yielding will extend for approximately one-eighth of the span.
  - During the same period, the interior fibers at the section of maximum moment yield gradually until nearly all of them have yielded and a plastic hinge is formed.

Plastic Hinges

- The Concept of Plastic Hinge (cont'd)
  – The effect of the plastic hinge is assumed to be concentrated at one section for analysis purposes.
  – However, it should be noted that this effect may extend for some distance along the beam.
  – For the calculation of deflection and for the design of bracing, the length over which yielding extends is very important