CHAPTER 5
Approximate Analysis of Indeterminate Structures

Objectives
- Portal method
- Cantilever method

Use of approximate method

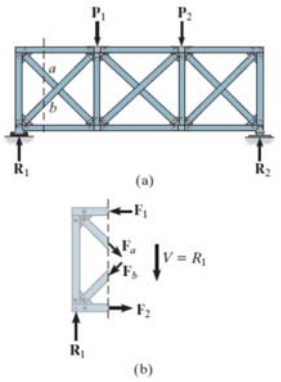
- The analysis when using a model must satisfy both the conditions of:
  - Equilibrium
  - Compatibility of displacements at joints
- For an initial design, member sizes are not known & statically indeterminate analysis cannot be done
- A simpler model must be developed,i.e., a statically determinate analysis

Use of approximate method

- The analysis of this model is known as an approximate analysis
- The preliminary design of the members can be made
- After which, the more exact indeterminate analysis can be performed & the design refined

Trusses

- The truss used for lateral bracing of a building is not considered a primary element
- It will therefore be analysed using approximate methods
- Hence, the truss is indeterminate to the third degree



Trusses

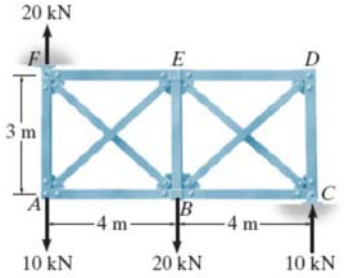
- 3 assumptions must be made in order to reduce the truss to one that is statically determinate
- Assumptions may be made in regards with the following:
  - When 1 diagonal in the panel is in tension, the corresponding cross diagonal will be in compression\
- Two methods of analysis are generally acceptable:
- Method 1
  - If the diagonals are intentionally designed to be long & slender, it is reasonable to assume they cannot support compression force
  - Otherwise, they may easily buckle
  - Hence, the compressive diagonal is assumed to be zero-force member

Trusses

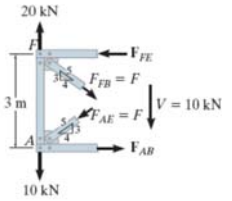
- Method 2
  - If the diagonals are intended to be constructed from large rolled sections such as angles or channels, they may be equally capable of supporting a tensile & compressive force
  - We will assume that tension & compression diagonals each carry half the panel shear

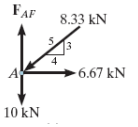
Example 1

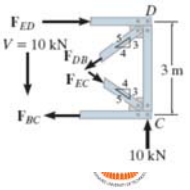
Determine (approximately) the forces in the members of the truss.



Example 1 cont'd







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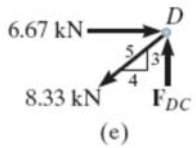
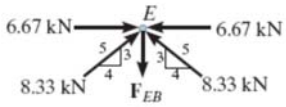


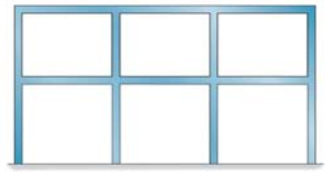
(e)



(f)

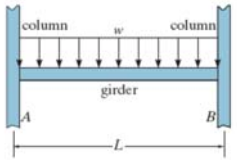
Vertical loads on building frames

- Building frames often consist of girders that are rigidly connected to columns
- This is to allow the structure to better able to resist the effects of lateral forces
- One technique would be to consider only the members within a localised region of the structure
- This is possible if the deflections of the members within the region caused little disturbance to the members outside the structure
- The approximate location of the points of inflection can be specified
- These points are zero moments


typical building frame

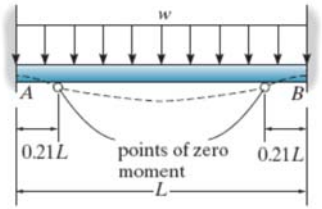
Vertical loads on building frames

- Assumptions for approximate analysis
  - The column supports at A & B will each exert 3 reactions on the girder
  - The girder will be statically indeterminate to the third degree
  - 3 assumptions would be needed to perform an approximate analysis

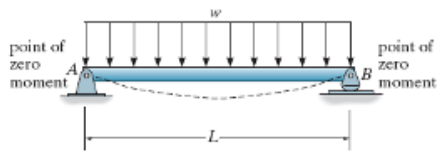


Vertical loads on building frames

- Assumptions for approximate analysis
  - If the columns are stiff, no rotation at A & B will occur
  - However, if the column connections at A & B are very flexible, then zero moments will occur at the supports
  - In reality, the columns will provide some flexibility at the supports



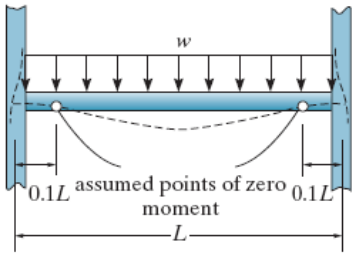
fixed supported
(b)



simply supported
(c)

Vertical loads on building frames

- Assumptions for approximate analysis
  - Therefore, point of zero moment occurs at the average point between the two extremes (0.21L+0) / 2 ~ 0.1L from each support



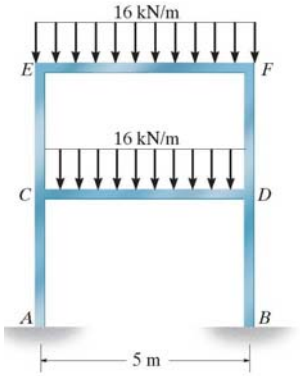
approximate case
(d)

Vertical loads on building frames

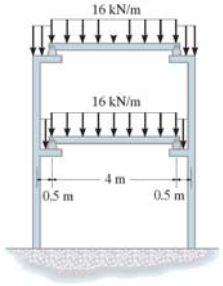
- Assumptions for approximate analysis
  - The 3 assumptions are:
  - There is zero moment in the girder, 0.1L from the left support
  - There is zero moment in the girder, 0.1L from the right support
  - The girder does not support an axial force

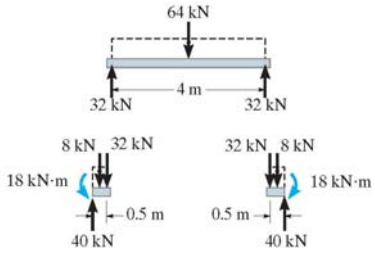
Example 2

- Determine (approximately) the moment at the joints *E* and *C* caused by members *EF* and *CD* of the building bent.



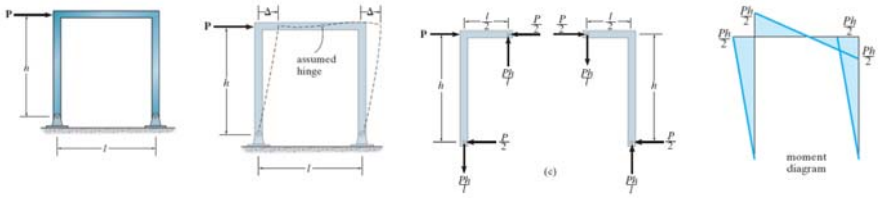
Example 2 cont'd





Portal Frames & Trusses

- Portal frames are used to transfer horizontal forces applied at the top of frame to the foundation
- Portals can be pin supported, fixed supported or supported by partial fixity

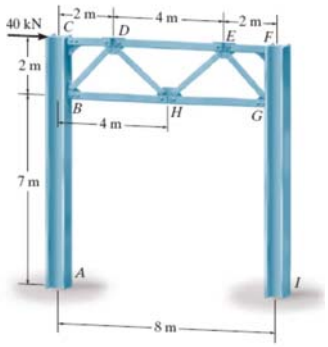


Portal Frames & Trusses

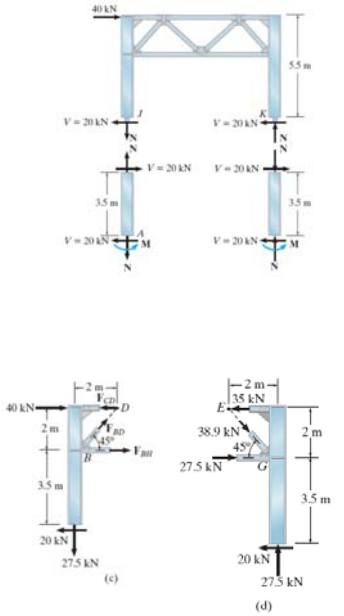
- We analyse the trussed portals using the same assumptions as those for simple portal frames
- For pin-supported column, assume horizontal shear are equal
- For fixed-supported column, assume horizontal reactions are equal and an point of inflection occurs on each column, midway between base of column & the lowest point of truss member connection to column

Example 3

Determine by approximate methods the forces acting in the members of the Warren portal.

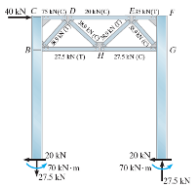


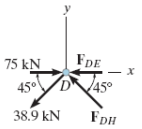
Example 3 cont'd

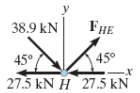


Example 3 cont'd

Example 3 cont'd

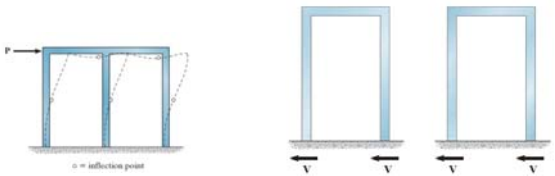






Lateral loads on building frames: Portal method

- A building bent deflects in the same way as portal frame
- Each bent of the frame can be considered as a series of portals
- The interior columns would represent the effect of 2 portal columns & would carry 2x the shear V as the exterior columns

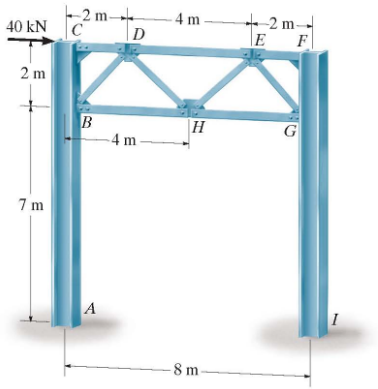


Lateral loads on building frames: Portal method

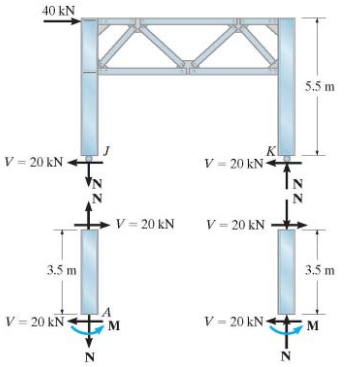
- The portal method for analyzing fixed supported building frames requires the following assumptions:
  - A hinge is placed at the center of each girder
  - A hinge is placed at the center of each column
  - At a given floor level, the shear at the int column hinges is 2x that at the ext column hinges
- These assumptions provide an adequate reduction of the frame to one that is statically determinate and yet stable under loading
- This method is more suitable for buildings having low elevation and uniform framing

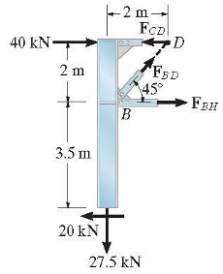
Example 4

Determine (approximately) the reactions at the base of the columns of the frame. Use the portal method of analysis.

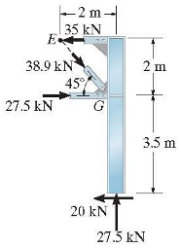


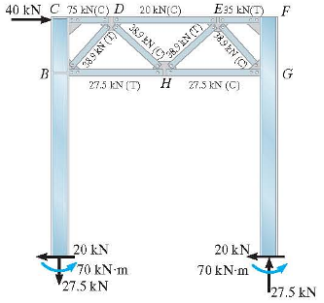
Example 4 cont'd

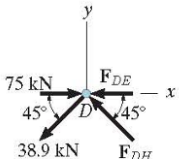


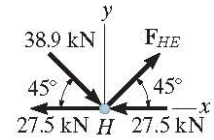


Example 4 cont'd







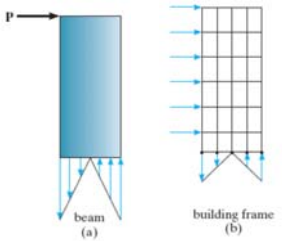


Lateral loads on building frames: Cantilever method

- This method is based on the same action as a long cantilevered beam subjected to a transverse load
- This causes a bending stress that varies linearly from the beam's neutral axis
- In a similar manner, the lateral loads on a frame tends to tip the frame over or cause a rotation about a neutral axis lying in the horizontal plane that passes through the columns at each floor level

Lateral loads on building frames: Cantilever method

- To counter this, the axial forces in the columns will be tensile on one side of the neutral axis & compressive on the other side
- It is reasonable to assume this axial stress has a linear variation from the centroid of the neutral axis
- This method is appropriate if the frame is tall & slender or has columns with different x-sectional areas

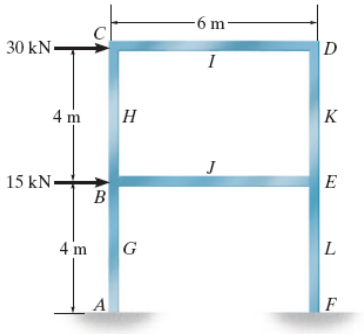


Lateral loads on building frames: Cantilever method

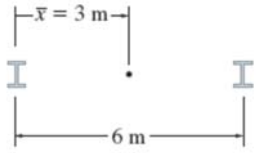
- The following assumptions apply for a fixed support frame
  - A hinge is placed at the center of each girder
  - A hinge is placed at the center of each column
  - The axial stress in a column is proportional to its distance from the centroid of the cross-sectional areas of the columns at a given floor level
  - Since stress = force per area, then in the case of equal cross-sectional areas, the force in a column is proportional to its distance from the centroid
- These assumptions reduce the frame to one that is both stable & statically determinate

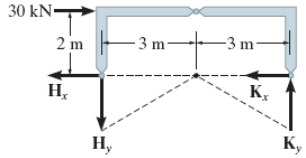
Example 5

Determine (approximately) the reactions at the base of the columns of the frame. Use the cantilever method of analysis.

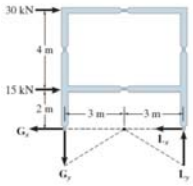


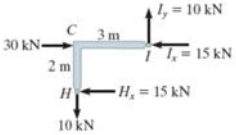
Example 5 cont'd

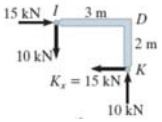




Example 5 cont'd







Example 5 cont'd