Rigid Frames

- composed of linear elements
- member geometry fixed at joints
  - no relative rotation
- statically indeterminate
- see
  - shear
  - axial forces
  - bending moments

Rigid Frames

- rigidity
- end constraints
- smaller horizontal members
- larger vertical members
Rigid Frames

- moments get redistributed
- deflections are smaller
- effective column lengths are shorter

Rigid Frames Analysis

- members see
  - shear
  - axial force
  - bending
- V & M diagrams
  - plot on “outside”

Rigid Frames

- resists lateral loadings
- shape depends on stiffness of beams and columns
- 90° maintained

Rigid Frame Analysis

- need support reactions
- free body diagram each member
- end reactions are equal and opposite on next member
- “turn” member like beam
- draw V & M
Rigid Frame Analysis

- FBD & M
  - opposite end reactions at joints

Analysis Methods

- computer-based
  - matrix analysis or finite element analysis
  - equilibrium
  - support conditions
  - joint locations
  - relative stiffness of members
  - output
    - deflections
    - member forces

Analysis Methods

- approximate methods
  - presume where inflection points occur in deformed shape
  - these points have zero moment
  - “portal method”
    - hinge is placed at the center of each girder
    - hinge is placed at the center of each column
    - shear at interior columns is twice that of exterior columns
**Rigid Frames**
- member sizes do affect behavior
- location of inflection points critical

**Sidesway**
- translation with vertical load

![Frame structures with different relative column and beam stiffnesses](image1)

![Support Settlements](image2)

**Support Settlements**
- moments induced

**Multistory Frame Analysis**
- cantilever method (approximate)
  - point of inflection at midspan of each beam
  - point of inflection at midheight of each column
  - axial force in each column proportional to the horizontal distance of that column from the centroid of all columns in the story
  - centroids are “average” locations

![Original location vs. Location after settlement](image3)

![Single-bay frame](image4)

![Multistory frame](image5)
Multistory Frame Analysis

• cantilever method (approximate)

Rigid Frame Design - Types

Uniform loading conditions
Diagrams plotted on compression faces (U.S. convention)
Diagrams plotted on tension faces
Galerie des Machines (see Figures 5-15, 5-16)

Three-hinged frame
Bending moments
Bending moments
Shape of structure

Two-hinged frame
Bending moments
Bending moments
Shape of structure

Two-hinged frame with cantilevers
Bending moments
Bending moments
Shape of structure

Rigid Frame Design

• materials
  – steel
  – monolithic concrete
  – laminated wood

• forms
  – small
  – large

Rigid Frame Design

Riola Parish Church, Alto Alvar
http://nisee.berkeley.edu/godden
Rigid Frame Design

• staggered truss
  – rigidity
  – clear stories

Rigid Frame Design

• connections
  – steel
  – concrete

Rigid Frame Design

• considerations
  – need frame?
  – minimize moment (affects member size)
  – increasing stiffness
    • redistributes moments
    • limits deflections
  – joint rigidity
  – support types

Rigid Frame Design

• load combinations
  – worst case for largest moments...
  – wind direction can increase moments

http://nisee.berkeley.edu/godden
Combined Stresses

- beam-columns have moments at end
- often due to eccentric load

Combined Stresses & Design

- axial + bending
  \[ f_{\text{max}} = \frac{P}{A} + \frac{Mc}{I} \]
  \[ M = P \cdot e \]
- design
  \[ f_{\text{max}} \leq F_{cr} = \frac{f_{cr}}{F.S.} \]

Eccentric Loading

- find \( e \) such that the minimum stress = 0
  \[ f_{\text{min}} = \frac{P}{A} - \frac{(Pe)c}{I} = 0 \]
- area defined by \( e \) from centroid is the kern

Biaxial Bending

- when there is moment in two directions
  \[ M_1 = P \cdot e_1 \quad M_2 = P \cdot e_2 \]
  \[ f_{\text{max}} = \frac{P}{A} + \frac{M_1 y}{I} + \frac{M_2 z}{I} \]
- biaxial bending
Stress Limit Conditions
– ASD interaction formula
\[ \frac{f_a}{F_a} + \frac{f_b}{F_b} \leq 1.0 \]
– with biaxial bending
\[ \frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \leq 1.0 \]

Stress Limit Conditions
– in reality, as the column flexes, the moment increases
\[ \frac{f_a}{F_a} + \frac{f_b \times (\text{Magnification factor})}{F_{bx}} \leq 1.0 \]

Design for Combined Stress
• satisfy
  – strength
  – stability
• pick
  – section

Tools – Multiframe4D
• in computer lab
**Tools – Multiframe4D**

- frame window
  - define frame members
    - or pre-defined frame
  - select points, assign supports
  - select members, assign section
  - load window
  - select point or member, add point or distributed loads

**Tools – Multiframe4D**

- to run analysis choose
  - Analyze menu
    - Linear
- plot
  - choose options
- results
  - choose options