Rigid Frames

• rigid frames have no pins
• frame is all one body
• joints transfer moments and shear
• typically statically indeterminate
• types
  – portal
  – gable

Rigid Frames

– moments get redistributed
– deflections are smaller
– effective column lengths are shorter
– very sensitive to settling
Rigid Frames

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

Braced Frames

- pin connections
- bracing to prevent lateral movements

Rigid Frames

- staggered truss
  - rigidity
  - clear stories

Rigid Frames

- connections
  - steel
  - concrete
Braced Frames

- types of bracing
  - knee-bracing
  - diagonal
  - X
  - K or chevron
  - shear walls

Shear Walls

- resist lateral load in plane with wall

Compression Members

- designed for strength & stresses
- designed for serviceability & deflection
- need to design for stability
  - ability to support a specified load without sudden or unacceptable deformations

Column Buckling

- axially loaded columns
- long & slender
  - unstable equilibrium = buckling
  - sudden and not good
**Modeling**

- can be modeled with a spring at mid-height
- when moment from deflection exceeds the spring capacity ... “boing”
- critical load $P$

**Effect of Length**

- long & slender
- short & stubby

**Buckling Load**

- related to deflected shape ($P\Delta$)
- shape of sine wave
- Euler’s Formula
- smallest $I$ governs

$$P_{\text{critical}} = \frac{\pi^2 EI}{(L)^2}$$

**Critical Stress**

- short columns
  $$f_{\text{critical}} = \frac{P_{\text{actual}}}{A} < F_a$$
- slenderness ratio $= \frac{L_e}{r}$ ($L/d$)
- radius of gyration $= r = \sqrt{\frac{I}{A}}$

$$f_{\text{critical}} = \frac{P_{\text{critical}}}{A} = \frac{\pi^2 EA r^2}{A(L_e)^2} = \frac{\pi^2 E}{(L_e/r)^2} \quad P_{\text{critical}} = \frac{\pi^2 EA}{(L_e/r)^2}$$
**Critical Stresses**

- when a column gets stubby, $F_y$ will limit the load for steel
- real world has loads with eccentricity

**Effective Length**

- end conditions affect shape
- effective length factor, $K$  
  $$L_e = K \cdot L$$

**Bracing**

- bracing affects shape of buckle in one direction
- both should be checked!

**Centric & Eccentric Loading**

- centric
  - allowable stress from strength or buckling
- eccentric
  - combined stresses
Combined Stresses

- axial + bending

\[ f_{\text{max}} = \frac{P}{A} + \frac{Mc}{I} \]

\[ M = P \cdot e \]

- design

\[ f_{\text{max}} \leq \frac{f_{cr}}{F.S.} \]

Stress Limit Conditions

- ASD interaction formula

\[ \frac{f_a}{F_a} + \frac{f_b}{F_b} \leq 1.0 \]

- with biaxial bending

\[ \frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \leq 1.0 \]

interaction diagram

Stress Limit Conditions

- in reality, as the column flexes, the moment increases

- \( P-\Delta \) effect

\[ \frac{f_a}{F_a} + \frac{f_b \times (\text{Magnification factor})}{F_{bx}} \leq 1.0 \]

Rigid Frame Analysis

- members see
  - shear
  - axial force
  - bending

- V & M diagrams
  - plot on “outside”
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

Rigid Frame Design

- columns in frames
  - ends can be “flexible”
  - stiffness affected by beams and column = \( \frac{EI}{L} \)
  - \( G = \Psi = \frac{\sum EI}{l_c} \)
  - for the joint
    - \( l_c \) is the column length of each column
    - \( l_b \) is the beam length of each beam
    - measured center to center
**Tools – Multiframe**

- **in classrooms and OAL**

**Tools – Multiframe**

- 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 – Multiframe**

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