Design of Beam-Columns

Beam-Column - Outline

- Beam-Columns
- Moment Amplification Analysis
- Second Order Analysis
- Compact Sections for Beam-Columns
- Braced and Unbraced Frames
- Analysis/Design of Braced Frames
- Analysis/Design of Unbraced Frames
- Design of Bracing Elements

Design for Flexure – LRFD Spec.

- Commonly Used Sections:
  - I – shaped members (singly- and doubly-symmetric)
  - Square and Rectangular or round HSS

Beam-Columns

INTRODUCTION

Members subject to P & M & V

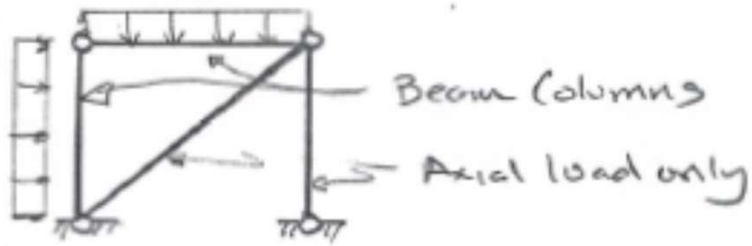
axial tension + bending (simple – no need for 2nd order analysis)

axial compression + bending = "BEAM COLUMN" (more difficult due to need for 2nd order analysis)

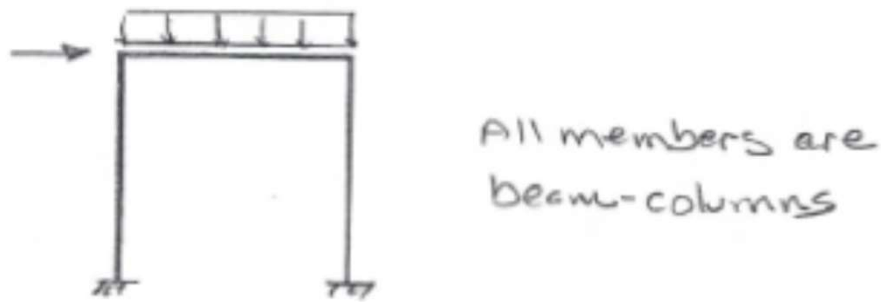
Beam-Columns

EXAMPLES OF BEAM COLUMNS

- Braced Frame



- Unbraced Frame



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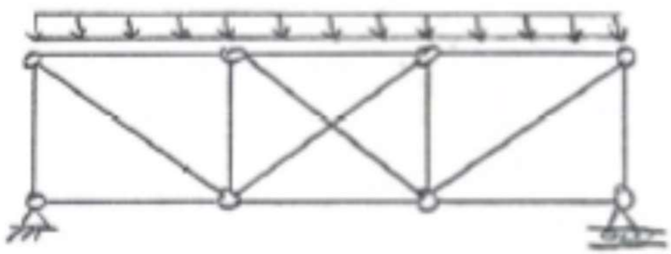
- Truss with loads applied between panel points



Top chord members are beam-columns

Beam-Column Issues

I. ANALYSIS - DETERMINE P & M IN MEMBER

II. STRENGTH - WHAT IS P & M AT FAILURE ?

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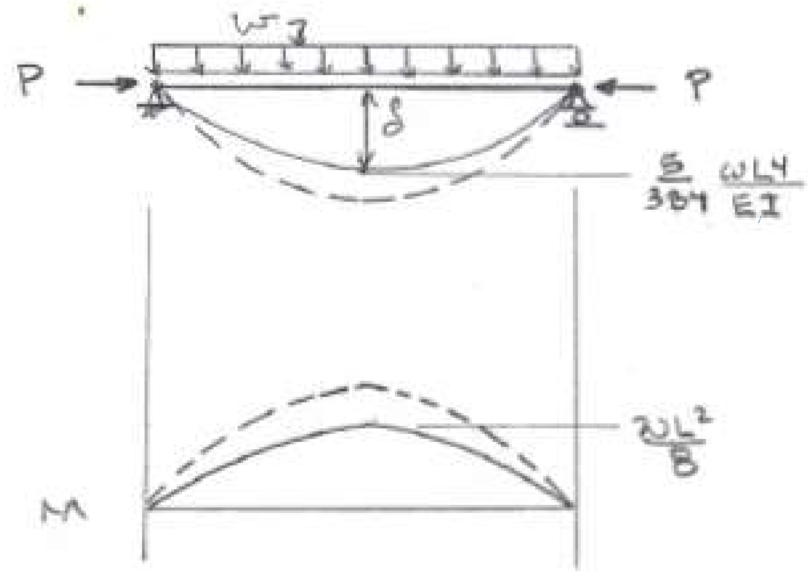
ANALYSIS ISSUES

2nd order effects must be considered in the analysis



——— = first order response

- - - - - - - = 2nd order response

The load P acting through the deflection δ produces additional deflection & additional moment.

i.e. "P-δ" effects amplify the first order response

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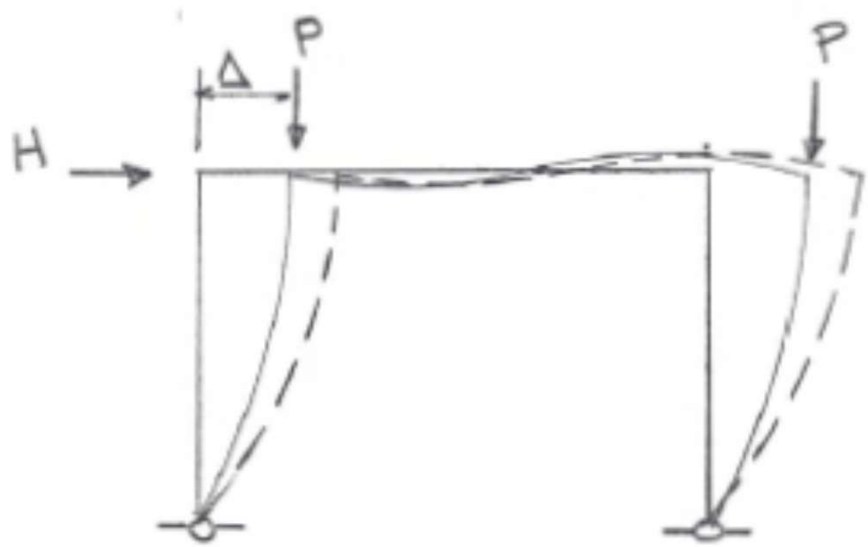

The load P acting through the deflection Δ (i.e. "P-Δ" effects) amplify the first order deflections & moments.

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STRENGTH OF BEAM-COLUMNS

Limit states for beam-columns:

- Fully yielded cross-section
- Instability
  - (a) local buckling (check b/t limits)
  - (b) overall member buckling
    - in-plane buckling (instability involves only bending of member – no twist)
    - lateral-torsional buckling (instability involves bending & twist)

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Likely failure modes due to combined bending and axial forces:

- Bending and Tension: usually fail by yielding
- Bending (uniaxial) and compression: Failure by buckling in the plane of bending, without torsion
- Bending (strong axis) and compression: Failure by LTB
- Bending (biaxial) and compression (torsionally stiff section): Failure by buckling in one of the principal directions.
- Bending (biaxial) and compression (thin-walled section): failure by combined twisting and bending
- Bending (biaxial) + torsion + compression: failure by combined twisting and bending

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- Structural elements subjected to combined flexural moments and axial loads are called *beam-columns*
- The case of beam-columns usually appears in structural frames
- The code requires that the sum of the load effects be smaller than the resistance of the elements

$$\frac{\sum \gamma_i Q_i}{\phi R_n} \leq 1.0$$

- Thus: a column beam interaction can be written as

$$\frac{P_u}{\phi_c P_n} + \left[\frac{M_{ux}}{\phi_b M_{nx}} + \frac{M_{uy}}{\phi_b M_{ny}}\right] \leq 1.0$$

  - This means that a column subjected to axial load and moment will be able to carry less axial load than if no moment would exist.

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- AISC code makes a distinct difference between lightly and heavily axial loaded columns

$$for\ \frac{P_u}{\phi_c P_n} \geq 0.2$$

$$\frac{P_u}{\phi_c P_n} + \frac{8}{9}\left[\frac{M_{ux}}{\phi_b M_{nx}} + \frac{M_{uy}}{\phi_b M_{ny}}\right] \leq 1.0$$

AISC Equation

$$for\ \frac{P_u}{\phi_c P_n} \leq 0.2$$

$$\frac{P_u}{2\phi_c P_n} + \left[\frac{M_{ux}}{\phi_b M_{nx}} + \frac{M_{uy}}{\phi_b M_{ny}}\right] \leq 1.0$$

AISC Equation

Beam-Columns

- Definitions

P_u = *factored axial compression load*

P_n = *nominal compressive strength*

M_{ux} = *factored bending moment in the x-axis, including second-order effects*

M_{nx} = *nominal moment strength in the x-axis*

M_{uy} = *same as* M_{ux} *except for the y-axis*

M_{ny} = *same as* M_{nx} *except for the y-axis*

ϕ_c = *Strength reduction factor for compression members = 0.90*

ϕ_b = *Strength reduction factor for flexural members = 0.90*

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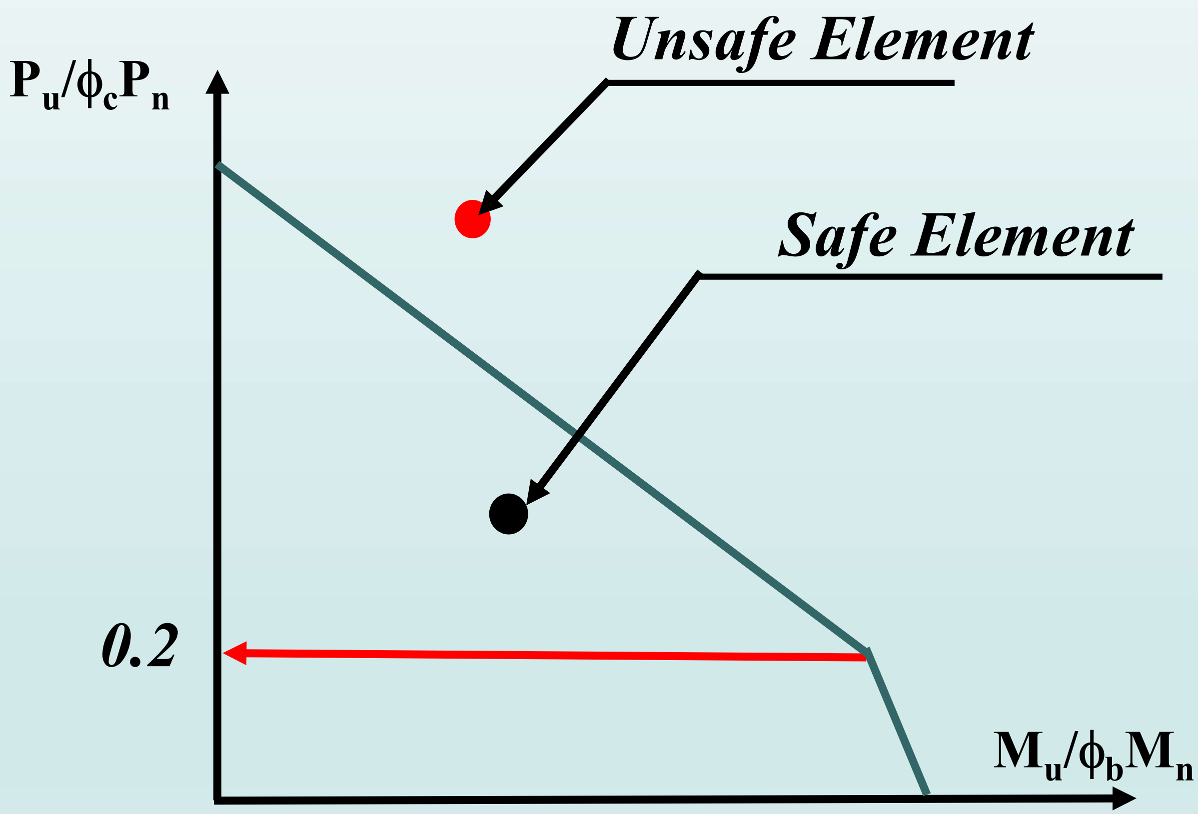
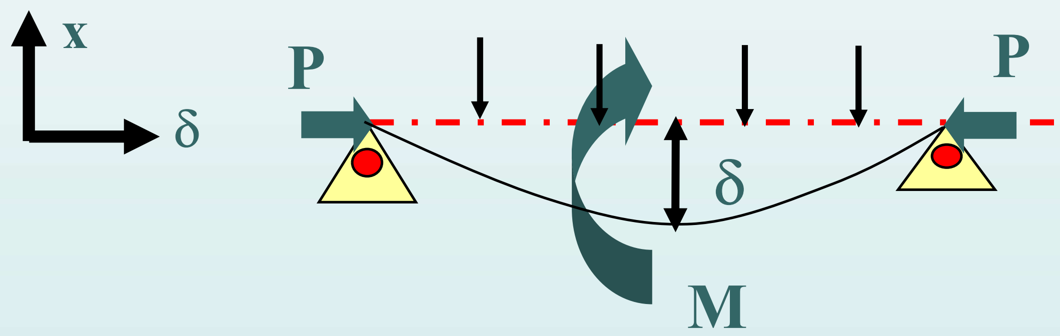
- **The increase in slope for lightly axial-loaded columns represents the less effect of axial load compared to the heavily axial-loaded columns**



These are design charts that are a bit conservative than behaviour envelopes

Moment Amplification

- When a large axial load exists, the axial load produces moments due to any element deformation.



- The final moment "M" is the sum of the original moment and the moment due to the axial load. The moment is therefore said to be amplified.

- As the moment depends on the load and the original moment, the problem is nonlinear and thus it is called second-order problem.