Metallic Structures – STR303

CHAPTER 5
BEAM COLUMN

I. INTRODUCTION

- Beam Columns are structural members subjected to:
  - Bending moment (Simple or Bi-Axial)
  - Shear Force (Usually associated with the bending moment)
  - Torsion
  - Axial Force
- Combined Behavior of Beams and Columns

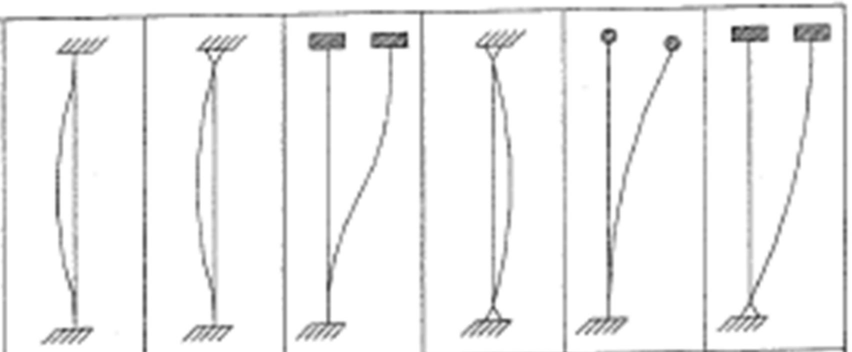
II. APPLICATIONS

- Columns of Frames
- Columns of Framed Truses
- Multi-Storey Buildings

III. Buckling Length of Columns

- Well Defined End Conditions

Table 2.4 Buckling Length Factor for Members with Well Defined End Conditions

BUCKLING MODE						
K	0.65	0.80	1.20	1.00	2.10	2.00
END CONDITIONS	ROTATION PREVENTED, TRANSLATION PREVENTED					
	ROTATION PERMITTED, TRANSLATION PREVENTED					
	ROTATION PREVENTED, TRANSLATION PERMITTED					
	ROTATION PERMITTED, TRANSLATION PERMITTED					

III. Buckling Length of Columns

- Columns in rigid frames

$$G = \frac{\sum \left(I/L \right)_{columns}}{\sum \left(I/L \right)_{girders}}$$

Column Base Condition	A, B (hinged base)	A, B (fixed base)
G_B	$G_B = 10.0$	$G_B = 1.0$

Sidesway prevented	$(I/L)_g$ X 1.5	$(I/L)_g$ X 2.0
Sidesway permitted	$(I/L)_g$ X 0.5	$(I/L)_g$ X 0.67

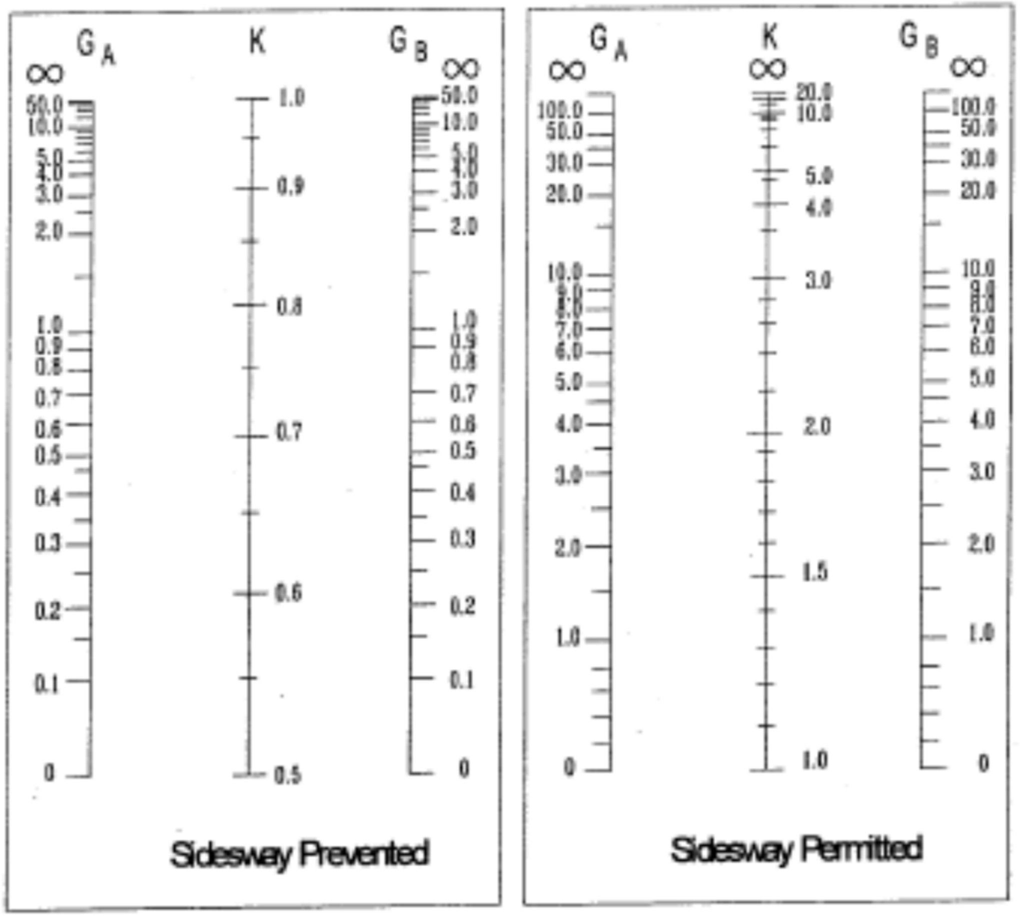
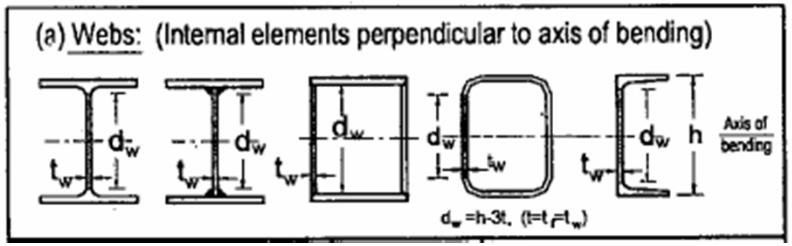


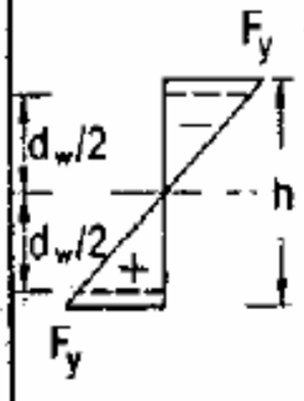
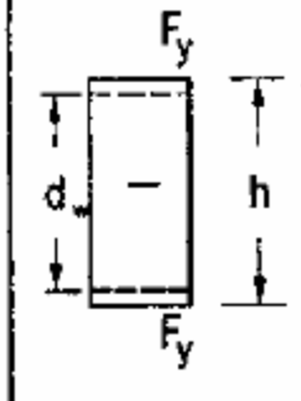
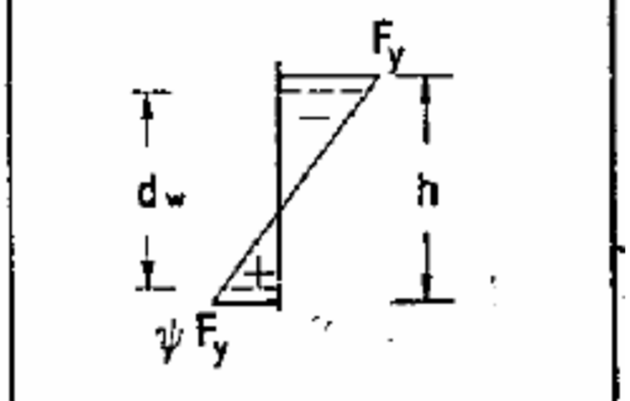
Figure 2.7 Alignment Charts for Buckling Length Factor (*K*) of Columns in Rigid Frames

IV. Section Classification

- Stiffened Web

Table (2.1a) Maximum Width to Thickness Ratios for Stiffened Compression Elements



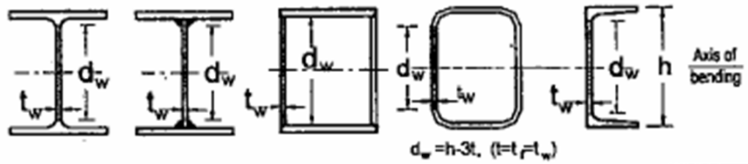
2.Non-Compact Stress distribution in element.			
	$\psi = -1$	$\psi = 1$	$\psi > -1$
	$\frac{d_w}{t_w} \leq \frac{190}{\sqrt{F_y}}$	$\frac{d_w}{t_w} \leq \frac{64}{\sqrt{F_y}}$	$\frac{d_w}{t_w} \leq \frac{190/\sqrt{F_y}}{2+\psi}$

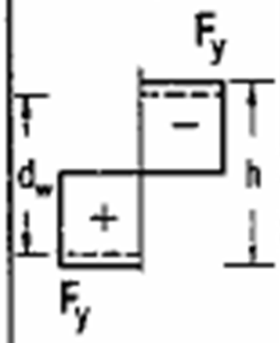
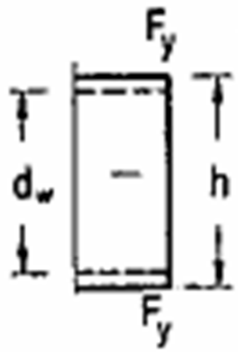
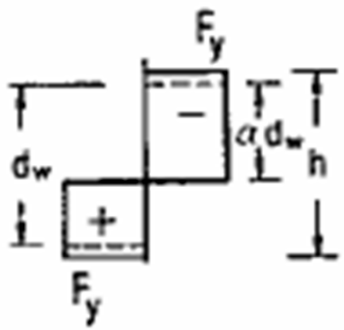
IV. Section Classification

- Stiffened Web

Table (2.1a) Maximum Width to Thickness Ratios for Stiffened Compression Elements

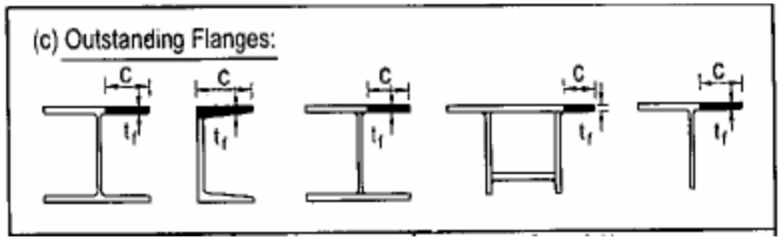
(a) Webs: (Internal elements perpendicular to axis of bending)

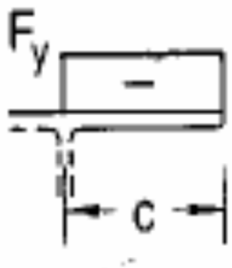


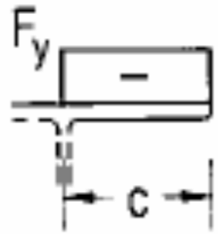
Class / Type	Web Subject to Bending	Web Subject to Compression	Web Subject to Bending and Compression	
1. Compact Stress distribution in element. (Not for single channel)				
	$\alpha = 0.5$	$\alpha = 1.0$	$\alpha > 0.5$	$\alpha \leq 0.5$
	$\frac{d_w}{t_w} \leq \frac{127}{\sqrt{F_y}}$	$\frac{d_w}{t_w} \leq \frac{58}{\sqrt{F_y}}$	$\frac{d_w}{t_w} \leq \frac{699/\sqrt{F_y}}{13\alpha - 1}$	$\frac{d_w}{t_w} \leq \frac{63.6/\alpha}{\sqrt{F_y}}$

IV. Section Classification

- Un-stiffened Flange
  - Subjected to uniform compression
  - Same limits as Beams and Columns

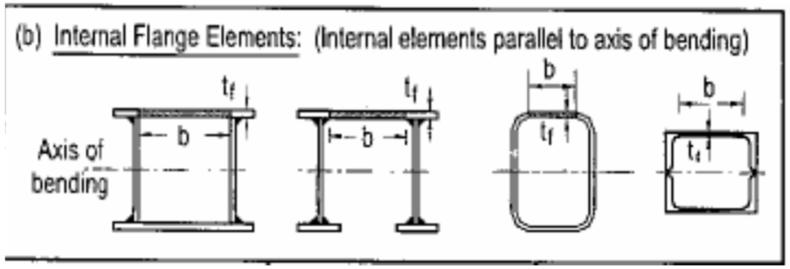


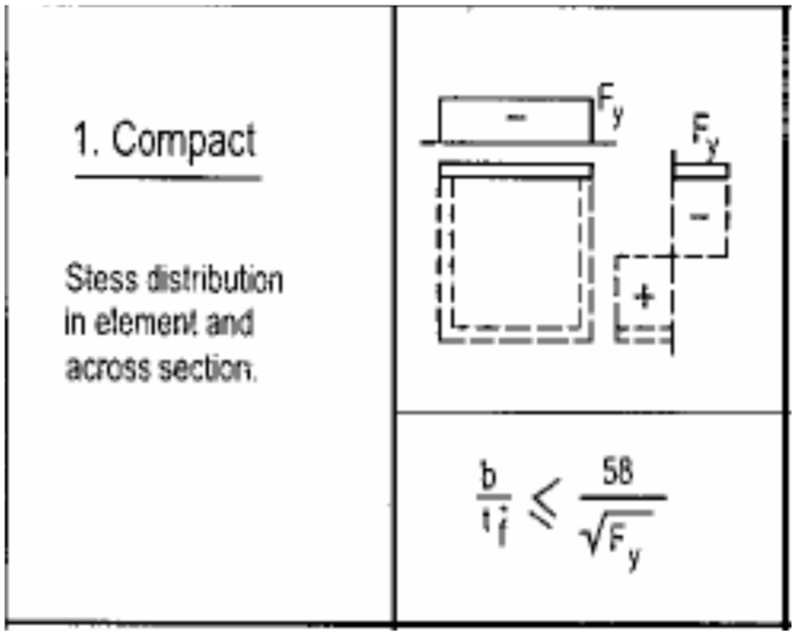
1. Compact	
Stress distribution in element.	
Rolled	$\frac{c}{t_f} \leq 16.9/\sqrt{F_y}$
Welded	$\frac{c}{t_f} \leq 15.3/\sqrt{F_y}$

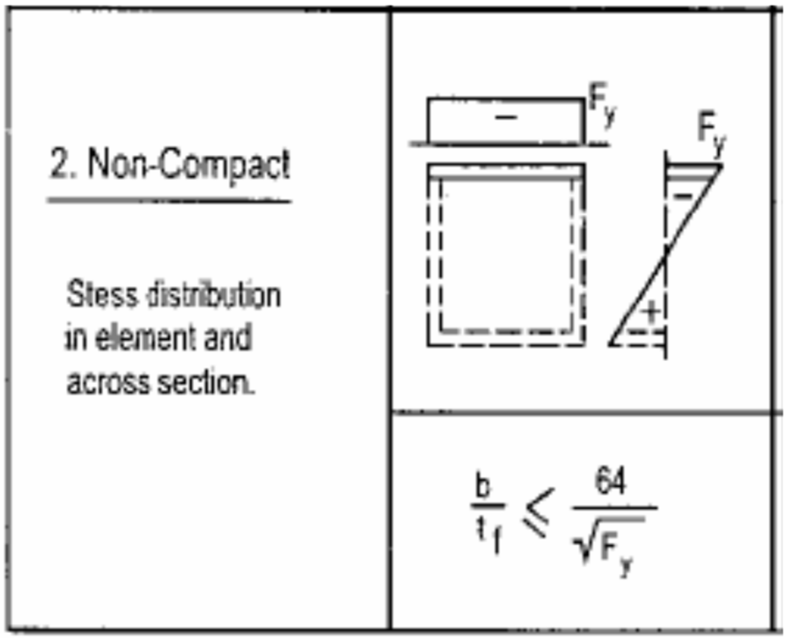
2. Non-Compact	
Stress distribution in element.	
Rolled	$\frac{c}{t_f} \leq 23/\sqrt{F_y}$
Welded	$\frac{c}{t_f} \leq 21/\sqrt{F_y}$

IV. Section Classification

- Stiffened Flange
  - Subjected to uniform compression
  - Same limits as Beams and Columns



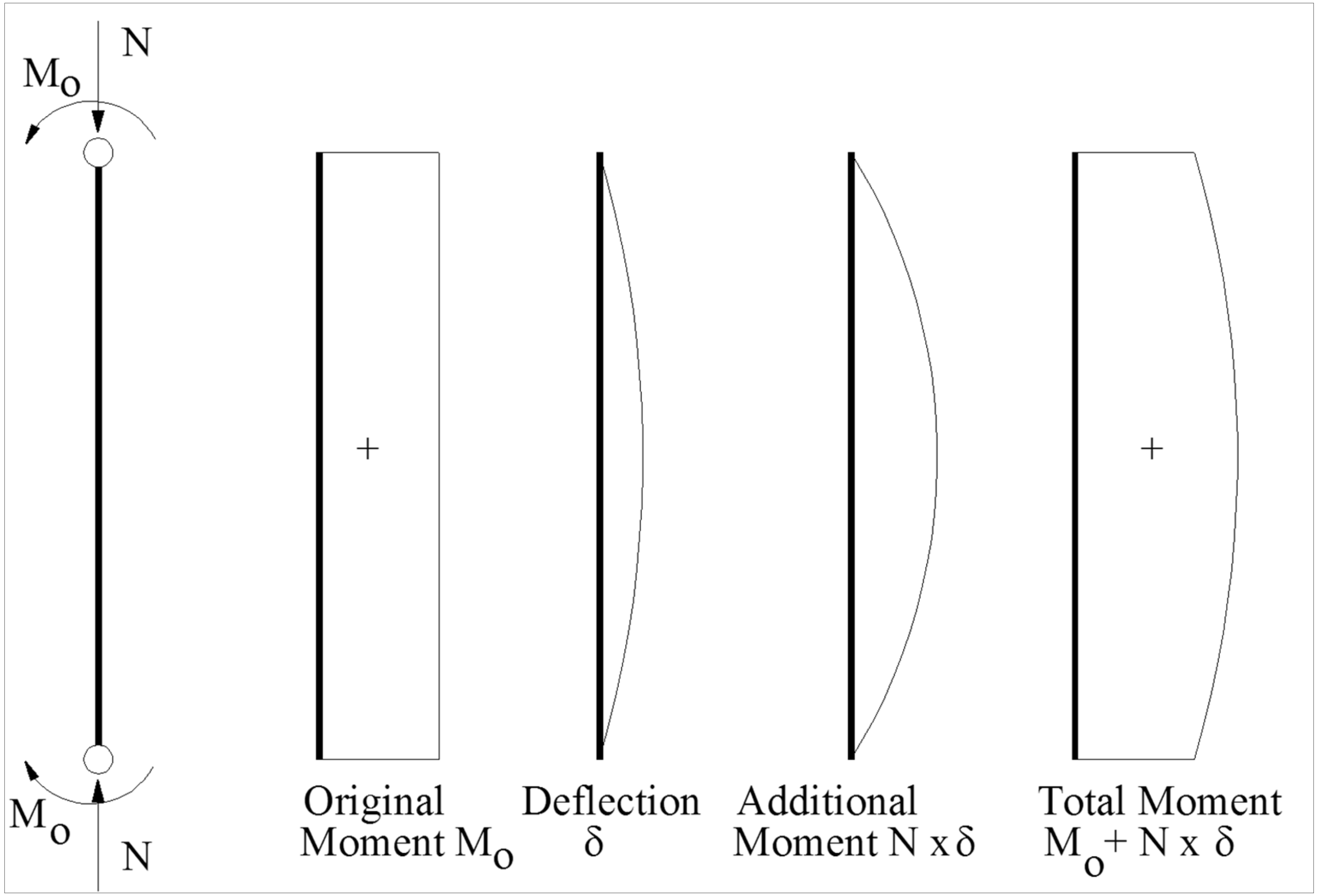




V. Behavior of Beam Columns

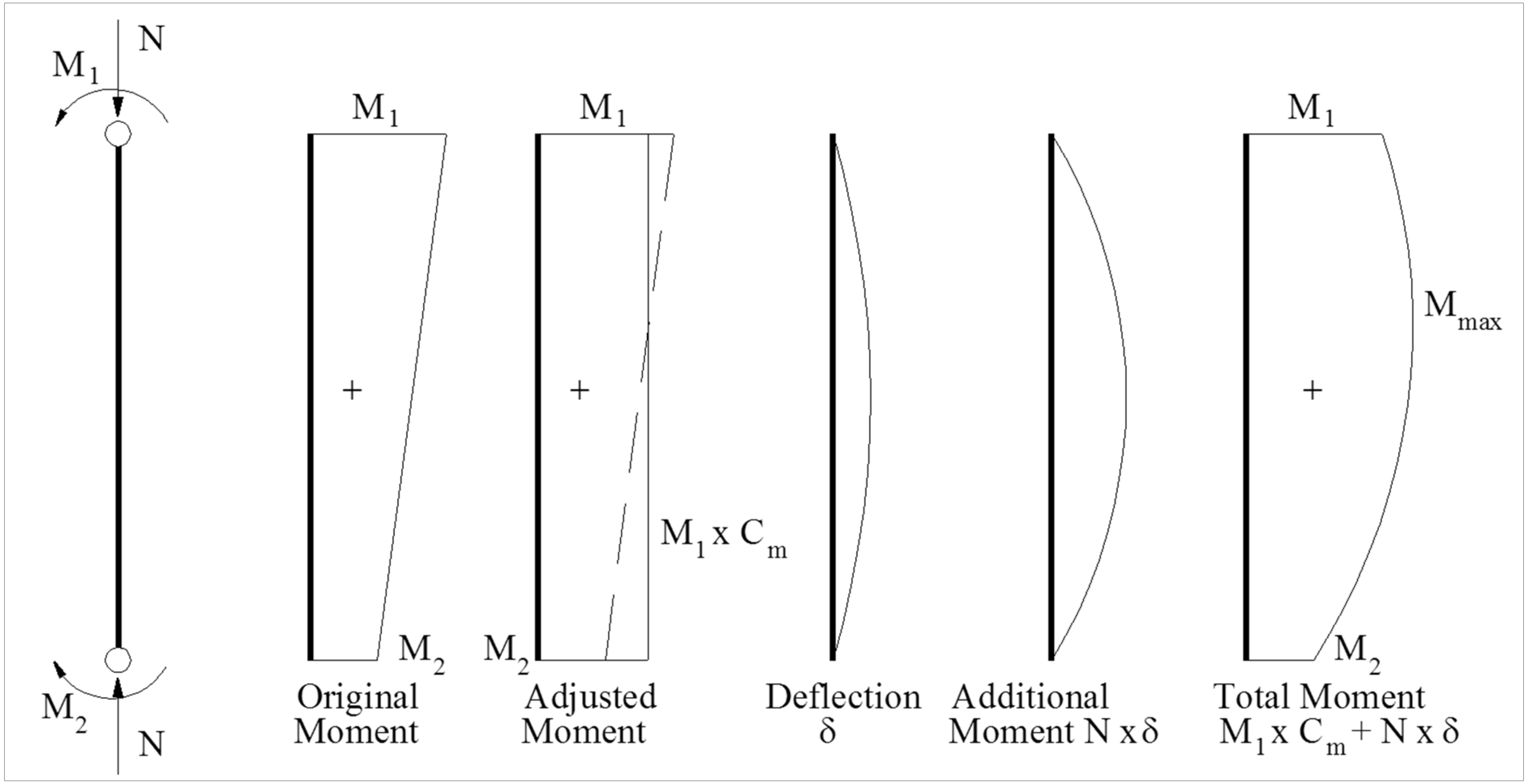
- *The applied Bending Moment Produces A deflected Shape*
- *The Normal Force Produces Additional Bending Moment due to the Deflected Shape that should be added to the Original Bending Moment (Second Order Effect)*

V. Behavior of Beam Columns



$$M_{Total} = M_o + N \times \delta = A \times M_o$$

V. Behavior of Beam Columns



$$M_{Total} = M_1 \times C_m + N \times \delta = C_m \times A \times M_1 = A_1 \times M_1$$

V. Behavior of Beam Columns

- A = Amplification Factor

$$A = \frac{1}{1 - \frac{P}{P_E}} = \frac{1}{1 - \frac{f_{ca}}{f_{EX}}}$$

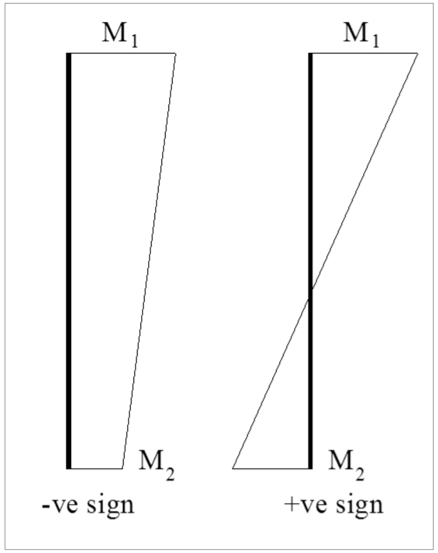
  - P = Actual Normal on Column
  - P_E = Euler Buckling Load of Column
  - f_{ca} = actual axial stress on Column
  - f_{EX} = Euler Stress

$$F_{EX} = \frac{7500}{\left(L_x / i_x \right)^2}$$

V. Behavior of Beam Columns

- C_m = Moment modification factor
  - Frames prevented from side sway without transverse loads

$$C_m = 0.6 - 0.4 \frac{M_2}{M_1} > 0.4 \quad (M_1 > M_2)$$



  - Frames prevented from side sway with transverse loads
    - Fixed at ends $C_m = 0.85$
    - Simply supported $C_m = 1.0$
  - Frames permitted to sway $C_m = 0.85$

VI. Check of Stresses

$$\frac{f_{ca}}{F_c} + \frac{A_1 \times f_{bx}}{f_{bcx}} + \frac{A_2 \times f_{by}}{f_{bcy}} \leq 1.0$$

- f_{ca} = Actual axial stress = (N / Area)
- F_c = Allowable axial stress (column equations)
- f_{bx} = Actual bending stress about X (M_x / Z_x)
- f_{by} = Actual bending stress about Y (M_y / Z_y)
- f_{bcx} = Allowable bending stress about X (Beam equation)
- f_{bcy} = Allowable bending stress about Y (Beam equation)

$$A_1 = \frac{C_{mx}}{1 - \frac{P}{P_{EX}}} = \frac{C_{mx}}{1 - \frac{f_{ca}}{f_{EX}}}$$

$$A_2 = \frac{C_{my}}{1 - \frac{P}{P_{EY}}} = \frac{C_{my}}{1 - \frac{f_{ca}}{f_{EY}}}$$

- If f_{ca} / F_c < 0.15 take A_1 and A_2 = 1.0

VII. Design Steps

- Determine Statical System:
  - Straining Actions (M, N, Q)
  - Determine Buckling Lengths (L_x, L_y, L_u)
  - Determine C_b and C_m
  - Deal with each braced segment as a separate beam column
- Selection of Section (Approximate Design)
  - Obtain approximate Z from applied bending. Note that the section is also subjected to Normal force (reduce the allowable stress)

$$Z_{req.} = \frac{M}{f_{all.}\ (1.0\ t/cm^2)}$$

  - Choose a section
  - Get properties (A, I_x, I_y, Z_x, Z_y, i_x, i_y, ...etc)

VII. Design Steps

- Determine section classification:
  - Compact
  - Non-compact
- Check Safety of Stresses
  - Determine actual stresses (f_{ca}, f_{bx}, f_{by})
  - Determine allowable stresses (f_c, f_{bcx}, and f_{bcy})
  - Calculate amplification factors (A_1, A_2)
  - Check safety of normal stresses
  - Check safety of shear stresses