Summary

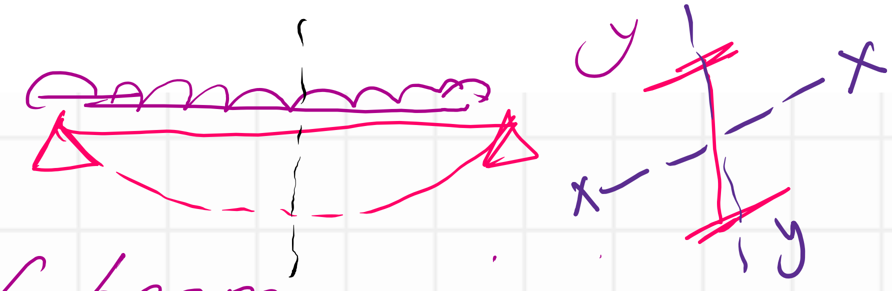
1. Difference between beam buckling and a Column buckling
2. What is the difference between Local and general buckling
3. Table For K Values based on Euler's Formula For different end Conditions Table A7.1 and Commentary CA7.1
4. Practice Problem For Column strength

Summary of the content of posts 2-2a

3.2 COLUMN BUCKLING

- Consider a long slender compression member. If an axial load P is applied and increased slowly, it will ultimately reach a value P_{cr} that will cause buckling of the column. <u>P_{cr} is called the critical buckling load of the column.</u>

Any Loading



Case of beam

Due to Loading (any type)
There will be a moment about major axis x_x
and deflection

x_x is the major axis
y-y is the minor axis
Deflection is about major axis
movement in y_y direction

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Difference between beam buckling and column buckling

3.2 COLUMN BUCKLING

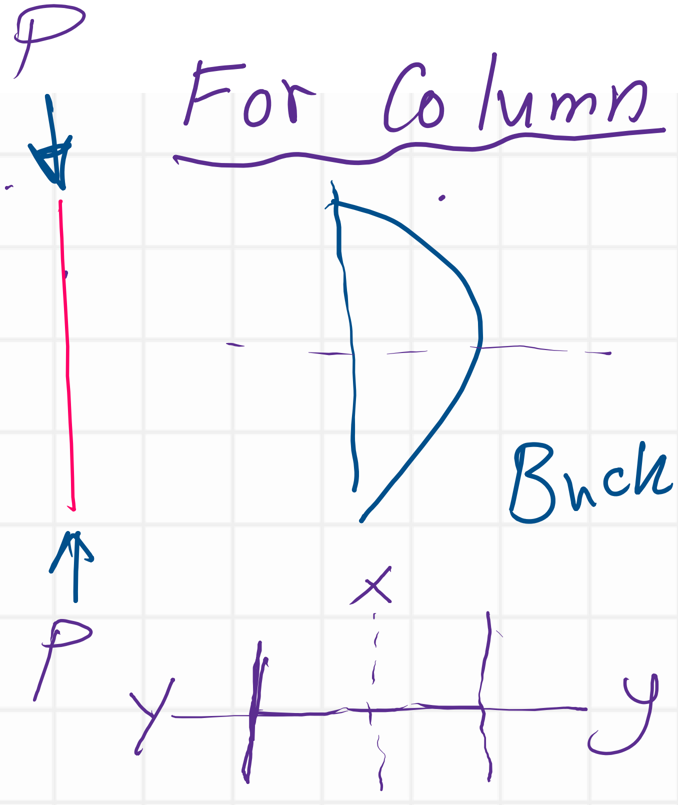
- Consider a long slender compression member. If an axial load P is applied and increased slowly, it will ultimately reach a value P_{cr} that will cause buckling of the column. P_{cr} is called the critical buckling load of the column.

Difference between buckling about strong/weak axis

Case of Column

Buckling occurs when a straight Column Under axial Compression Undergoes bending

For Column



Buckling shape

major axis

Movement of y Buckling ∂X-X

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Appendix 7-effective length method

APPENDIX 7

ALTERNATIVE METHODS OF DESIGN FOR STABILITY

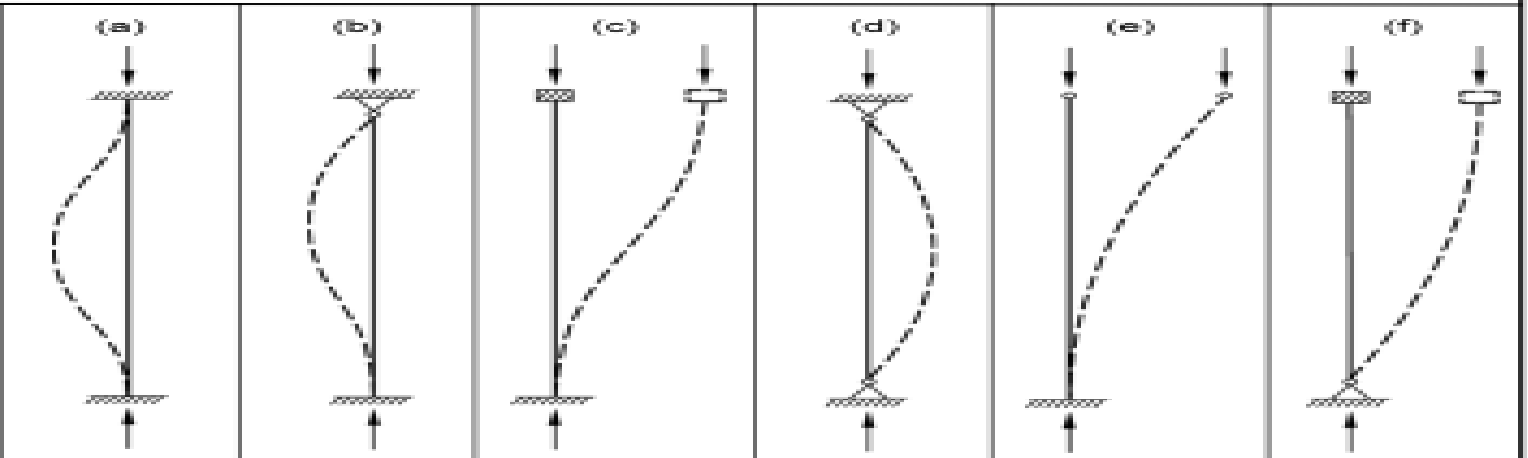
The effective length method and first-order analysis method are addressed in this Appendix as alternatives to the direct analysis method, which is presented in Chapter C. These alternative methods of design for stability can be used when the limits on their use as defined in Appendix 7, Sections 7.2.1 and 7.3.1, respectively, are satisfied.

The effective length, $L_c = KL$, for column buckling based upon elastic (or inelastic) stability theory, or alternatively the equivalent elastic column buckling stress, $F_e = \pi^2 E/(L_c/r)^2$, is used to calculate an axial compressive strength, P_c, through an empirical column curve that accounts for geometric imperfections and distributed yielding (including the effects of residual stresses). This column strength is then combined with the available flexural strength, M_c, and second-order member forces, P_r and M_r, in the beam-column interaction equations.

L_c	Effective length of member, in. (mm)	E2
L_{cx}	Effective length of member for buckling about x-axis, in. (mm)	E4
L_{cy}	Effective length of member for buckling about y-axis, in. (mm)	E4

Table CA-7.1

TABLE C-A-7.1
Approximate Values of Effective Length Factor, K

	(a)	(b)	(c)	(d)	(e)	(f)
Buckled shape of column is shown by dashed line						
Theoretical K value	0.5	0.7	1.0	1.0	2.0	2.0
Recommended design value when ideal conditions are approximated	0.65	0.80	1.2	1.0	2.1	2.0
End condition code	Rotation fixed and translation fixed Rotation free and translation fixed Rotation fixed and translation free Rotation free and translation free					

L_c	Effective length of member, in. (mm)	E2
L_{cx}	Effective length of member for buckling about x-axis, in. (mm)	E4
L_{cy}	Effective length of member for buckling about y-axis, in. (mm)	E4

F_e = elastic buckling stress determined according to Equation E3-4, as specified in Appendix 7, Section 7.2.3(b), or through an elastic buckling analysis, as applicable, ksi (MPa)

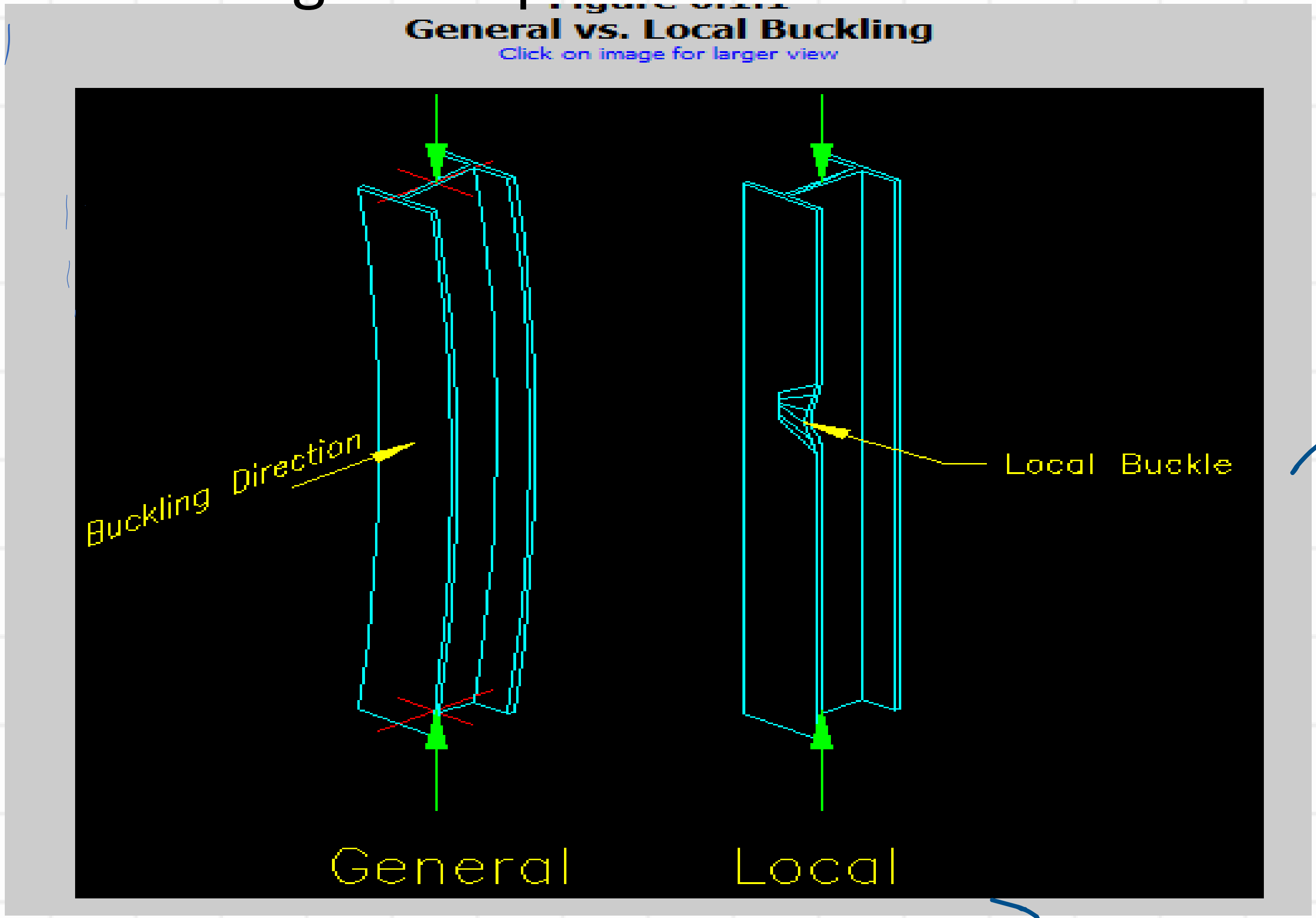
$$= \frac{\pi^2 E}{\left(\frac{L_c}{r}\right)^2} \quad \text{(E3-4)}$$

F_y = specified minimum yield stress of the type of steel being used, ksi (MPa)
r = radius of gyration, in. (mm)

Fe -Euler stress equation

http://www.bgstructuralengineering.com/BGSCM15/BGSCM006/index.htm

Buckling concepts



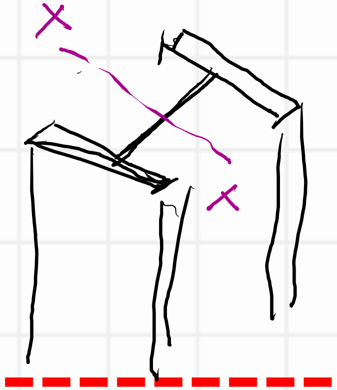
CM # 15

A Beginner's Guide to the Steel Construction Manual, 15th ed.

Chapter 6 - Buckling Concepts

This is a Local Buckling

This is a buckling about x - x axis



General

Difference between

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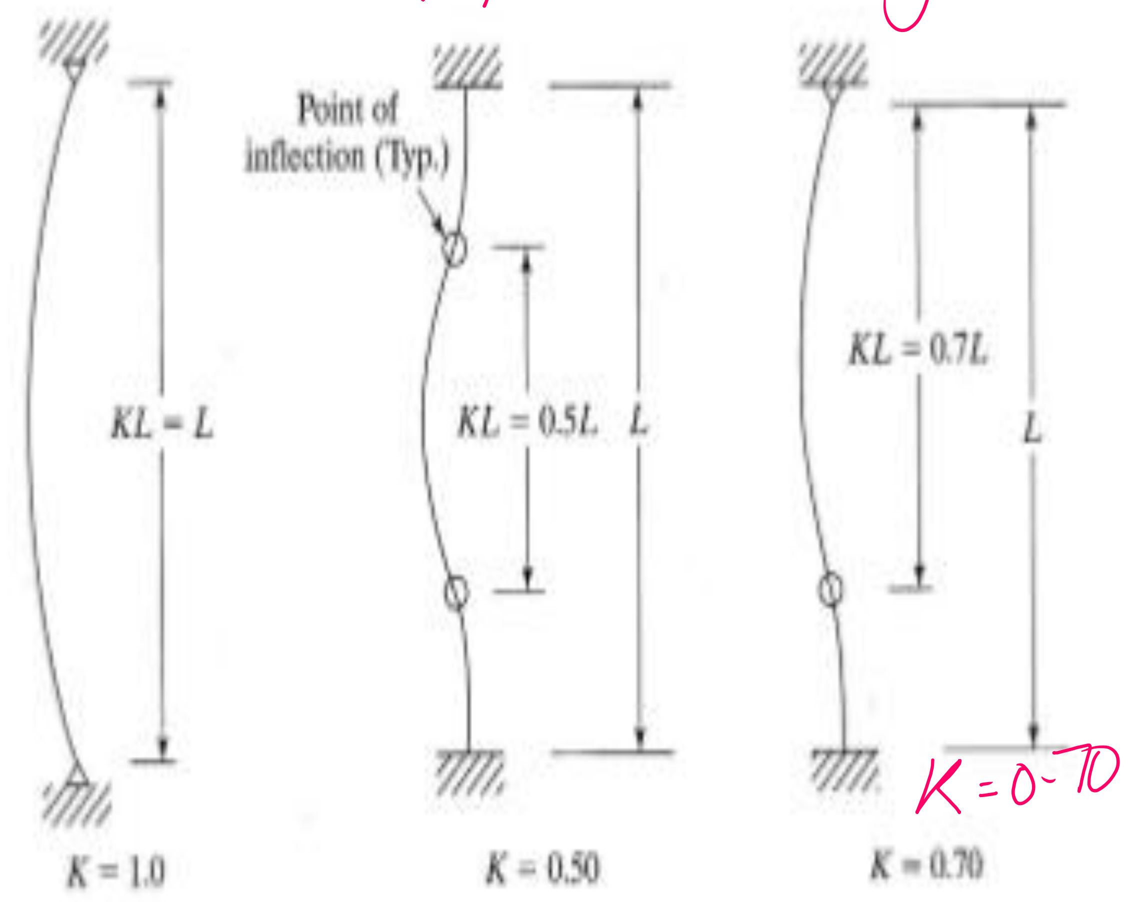
Different K values

Pinned Fixed hinged



K = 0.70

Pinned Fixed Fixed

K = 1.0 K = 0.5

Difference between X-X & Y-Y axes

Figure 6.2.1
Compression Member Principle Axis
Click on image for larger view

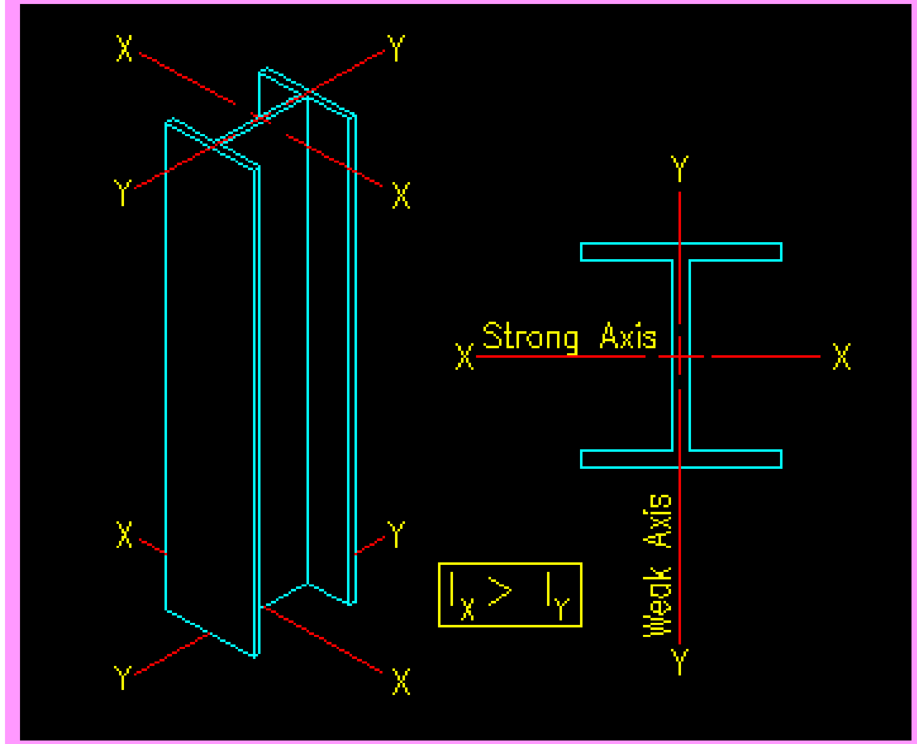


Figure 6.2.2
Compression Member Principle Planes

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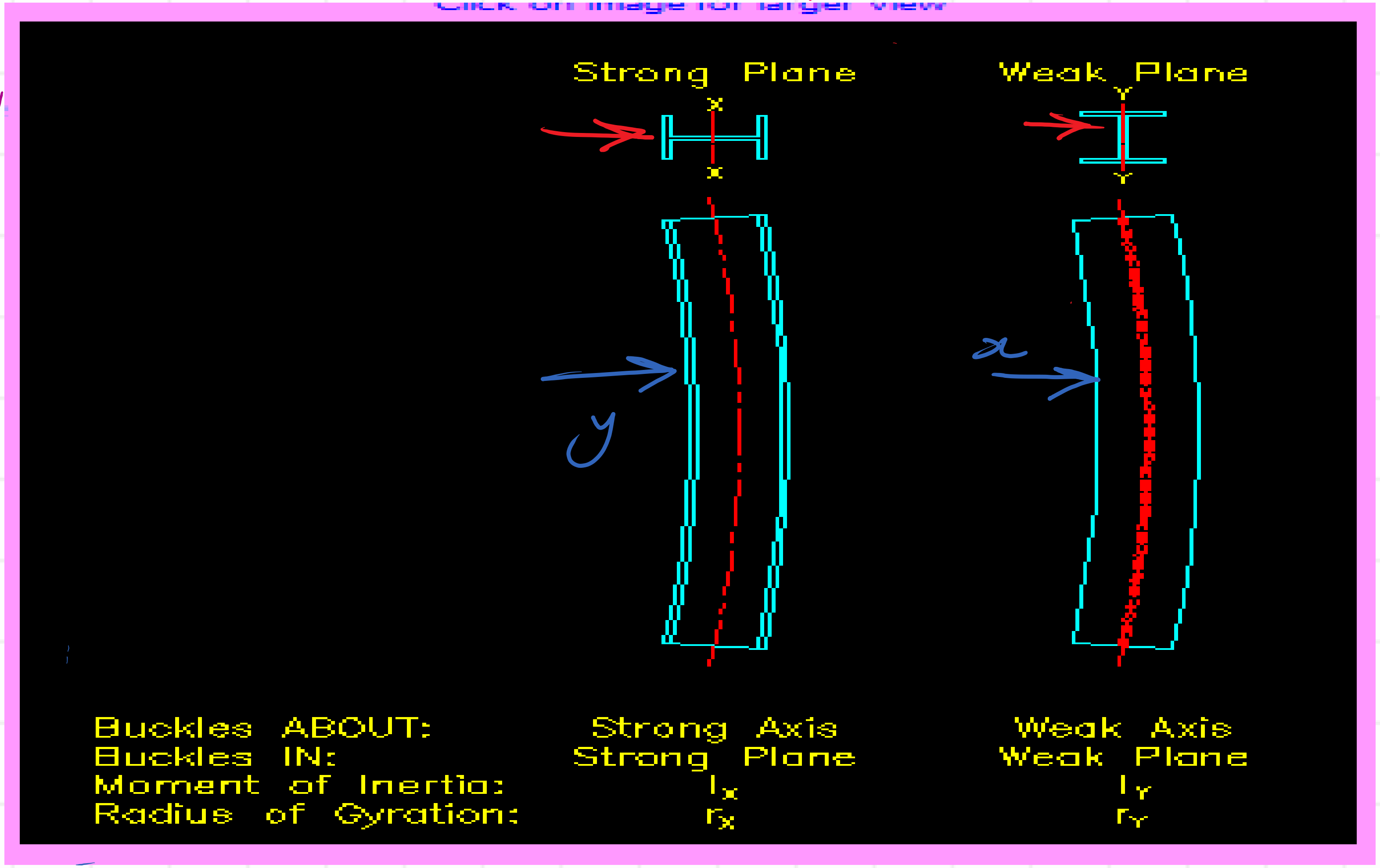
X-X major
Y-Y minor

Strong axis Buckling

Movement in y



Weak axis buckling

Accompanied by movement in X-direction

General buckling

Differentiate between strong/weak axis buckling

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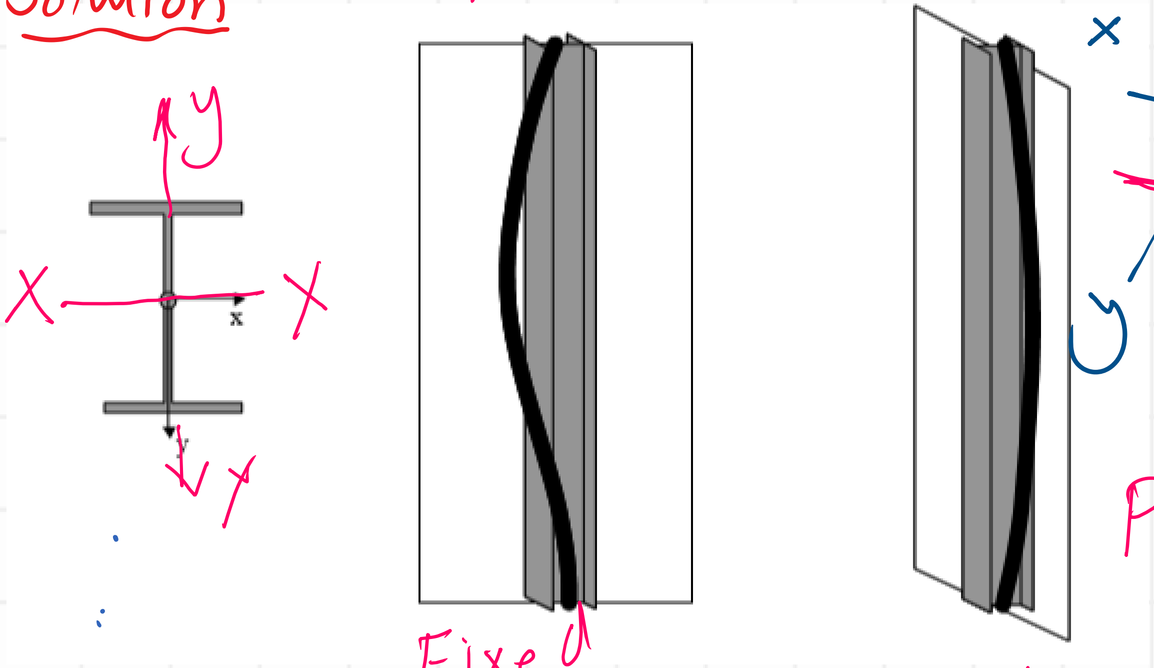
Determine the buckling strength of a W12 x 50 column. Its length is 20 Ft. For minor axis buckling, it is pinned at both ends. For major buckling, is it pinned at one end and fixed at the other end.

Solution

$\boxed{W12 \times 50}$ $h = 20'$

Pinned Pinned



Fixed Pinned

Buckling strength for a column

movement in x-direction → Bending about y-y

minor buckling

$K = 0.70$ $K = 1$

$K = 0.80$

$(KL)_x = 0.8(20) = 16'$

$(KL)_y = 1(20) = 20'$

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W12 x 50

Table 1-1 (continued)
W-Shapes
Properties

W14-W12

Nom-inal Wt.	Compact Section Criteria		Axis X-X				Axis Y-Y				r_{ts}	h_o	Torsional Properties	
	$\frac{b_f}{2t_f}$	$\frac{h}{t_w}$	I	S	r	Z	I	S	r	Z			J	C_w
lb/ft			in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	in.	in.^{3}	in.	in.	in.^{4}	in.^{6}
58	7.82	27.0	475	78.0	5.28	86.4	107	21.4	2.51	32.5	2.81	11.6	2.10	3570
53	8.69	28.1	425	70.6	5.23	77.9	95.8	19.2	2.48	29.1	2.79	11.5	1.58	3160
50	6.31	26.8	391	64.2	5.18	71.9	56.3	13.9	1.96	21.3	2.25	11.6	1.71	1880

From Table 1-1

$I_x = 391$ inch^4

$I_y = 56.3$ inch^4

$A = 14.60$ inch^2

$A r_x^2 = I_x$

$L = 20'$

E Value $= 29000$ ksi

$$P_{cr_x} = \frac{\pi^2 E I_x}{(KL)_x^2}$$

Buckling about X-X major

$K = 0.80$ $(KL)_x = (0.8)(20)(12) = 192''$

$P_{cr\,x} = (3.14159)^2(29)(10^3)(391) / (192)^2 = 3035.90$ kips

Critical load-x direction

Prepared by Eng.Maged Kamel.

Critical load-y direction

Critical load-y direction

Table 1-1 (continued)

W-Shapes

Properties

W14-W12

W12 x 50

Nominal Wt.	Compact Section Criteria		Axis X-X				Axis Y-Y				r_{ts}	h_o	Torsional Properties	
	$\frac{b_f}{2t_f}$	$\frac{h}{t_w}$	I	S	r	Z	I	S	r	Z			J	C_w
lb/ft			in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	in.	in.^{3}	in.	in.	in.^{4}	in.^{6}
58	7.82	27.0	475	78.0	5.28	86.4	107	21.4	2.51	32.5	2.81	11.6	2.10	3570
53	8.69	28.1	425	70.6	5.23	77.9	95.8	19.2	2.48	29.1	2.79	11.5	1.58	3160
50	6.31	26.8	391	64.2	5.18	71.9	56.3	13.9	1.96	21.3	2.25	11.6	1.71	1880

From Table 1-1

$A = 14.60$ inch^2

$I_x = 391$ inch^4

$I_y = 56.3$ inch^4

$A r_x^2 = I_x$

$L = 20'$

E value $= 29000$ ksi

$$P_{cr_y} = \frac{\pi^2 E I_y}{(KL)_y^2}$$

Buckling about Y-Y minor

$K = 1$

$(KL)_y = 1\ (20)(12) = 240''$

$P_{cry} = (3.14159)^2 (29)(10^3)(56.3) / (240)^2 = 279.76$ kips

$P_{c_F} = \min(3035.90, 279.76) = 279.75$ kips

Buckling @ Y governs

Prepared by Eng.Maged Kamel.

Case of yielding prior to buckling

W 12x50

In the previous Example $P_{cry} = 279.76$ kips

Area = 14.60 inch^2

$(F_E)_y = 279.76 / 14.60 = 19.60$ ksi $< F_y$

where $F_y = 50$ ksi   Buckling occurs prior to Buckling

Case of yielding prior to buckling

But if Column is reduced to 10' For same problem

$$F_E = \frac{\pi^2 E I_y}{(KL)^2 A} = \frac{\pi^2 (29000)(56.30)}{(120)^2 (14.6)} = 76.65 \text{ ksi} > 50 \text{ ksi}$$

- ***Notes:***

Case of yielding prior to buckling

- *Minor axis buckling usually governs for all doubly symmetric cross-sections. However, for some cases, major (x) axis buckling can govern.*
- *Note that the steel yield stress was irrelevant for calculating this buckling strength.*

3.3 INELASTIC COLUMN BUCKLING

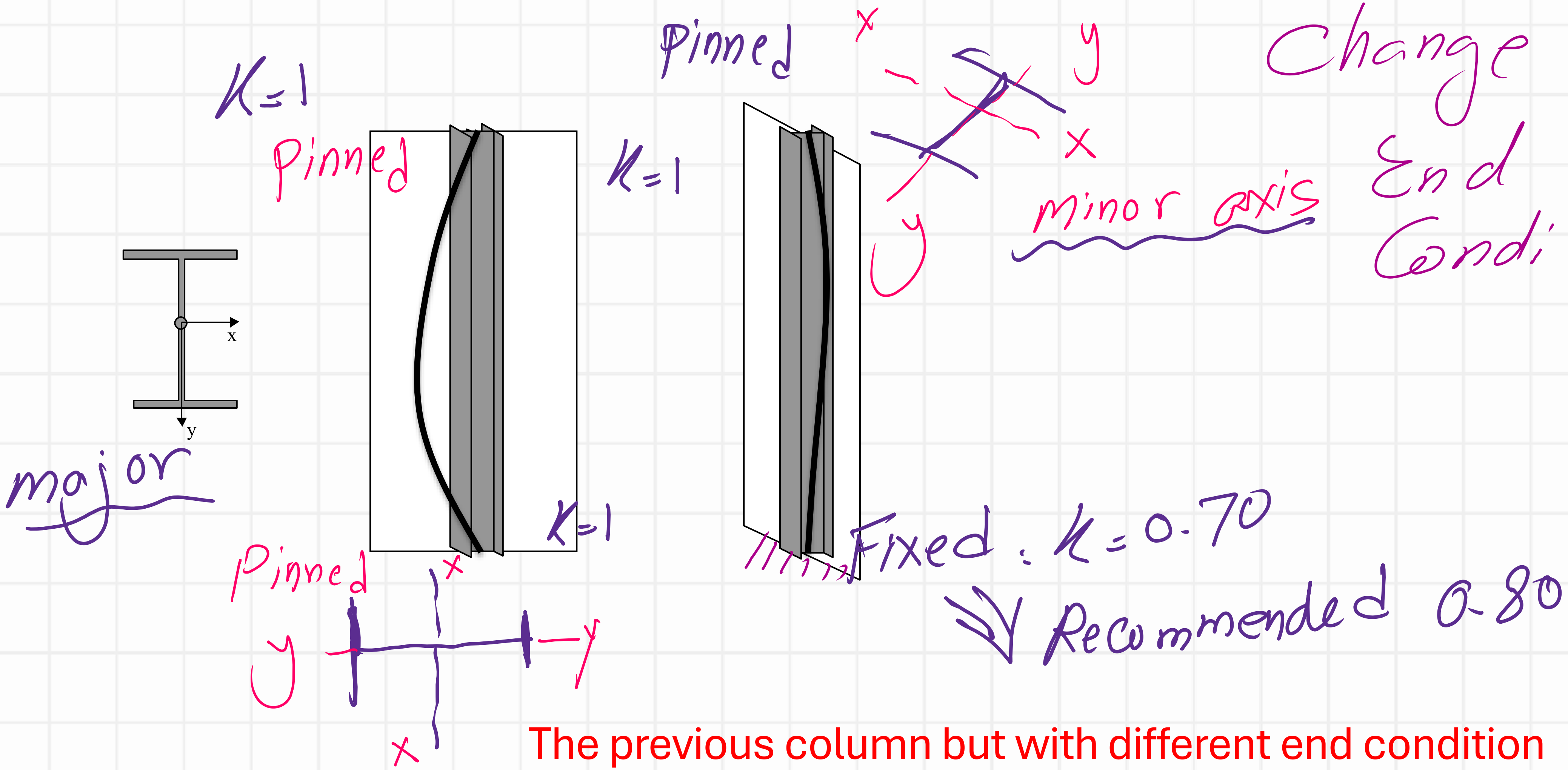
Prof. Varma notes

- Let us consider the previous example. According to our calculations P_{cr} = 279.8 kips. This will cause a uniform stress $f = P_{cr}/A$ in the cross-section
- For W12 x 50, A = 14.6 in^2. Therefore, for P_{cr} = 279.8 kips; f = 19.16 ksi

  The calculated value of f is within the elastic range for a 50 ksi yield stress material.
- However, if the unsupported length was only 10 ft., $P_{cr} = \dfrac{\pi^2 E I_y}{(K_y L_y)^2}$ would be calculated as 1119 kips, and f = 76.6 kips.

Check whether yielding occur prior to buckling

Determine the buckling strength of a W12 x 50 column. Its length is 20 ft. For major axis buckling, it is pinned at both ends. For minor buckling, it is pinned at one end and fixed at the other end.



Change End Conditions

The previous column but with different end condition

Table 1-1 (continued)
W-Shapes
Properties

W14-W12

W12 x 50

Nom-inal Wt.	Compact Section Criteria		Axis X-X				Axis Y-Y				r_{ts}	h_o	Torsional Properties	
	$\frac{b_f}{2t_f}$	$\frac{h}{t_w}$	I	S	r	Z	I	S	r	Z			J	C_w
lb/ft			in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	in.	in.^{3}	in.	in.	in.^{4}	in.^{6}
58	7.82	27.0	475	78.0	5.28	86.4	107	21.4	2.51	32.5	2.81	11.6	2.10	3570
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50	6.31	26.8	391	64.2	5.18	71.9	56.3	13.9	1.96	21.3	2.25	11.6	1.71	1880

From Table 1-1

$I_x = 391 \text{ inch}^4$

$I_y = 56.3 \text{ inch}^4$

$A = 14.60 \text{ inch}^2$

$A r_x^2 = I_x$

$L = 20'$

E value = 29000 ksi

$$P_{cr_x} = \frac{\pi^2 E I_x}{(KL)_x^2}$$

Buckling about x-x major

$K = 1$ $\quad (KL)_x = (1)(20)(12) = 240''$

$P_{crx} = (3.14159)^2 (29)(10^3)(391) / (240)^2 = 1942.90$ kips

Critical load-x direction

Prepared by Eng.Maged Kamel.

Final load

Final load

W12 X 50

Table 1-1 (continued)
W-Shapes
Properties

W14-W12

Nom-inal Wt.	Compact Section Criteria		Axis X-X				Axis Y-Y				r_{ts}	h_o	Torsional Properties	
	$\frac{b_f}{2t_f}$	$\frac{h}{t_w}$	I	S	r	Z	I	S	r	Z			J	C_w
lb/ft			in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	in.	in.^{3}	in.	in.	in.^{4}	in.^{6}
58	7.82	27.0	475	78.0	5.28	86.4	107	21.4	2.51	32.5	2.81	11.6	2.10	3570
53	8.69	28.1	425	70.6	5.23	77.9	95.8	19.2	2.48	29.1	2.79	11.5	1.58	3160
50	6.31	26.8	391	64.2	5.18	71.9	56.3	13.9	1.96	21.3	2.25	11.6	1.71	1880

From Table 1-1

$I_x = 391$ inch^4

$I_y = 56.3$ inch^4

$A = 14.60$ inch^2

$A r_x^2 = I_x$

$L = 20'$

E value $= 29000$ ksi

$$P_{cr_y} = \frac{\pi^2 E I_y}{(KL)_y^2}$$

Buckling about Y-Y minor

$K = 0.80 \quad (KL)_y = 0.8\,(20)(12) = 192''$

$P_{cry} = (3.14159)^2 (29)(10^3)(56.3) / (192)^2 = 437.12\,K$

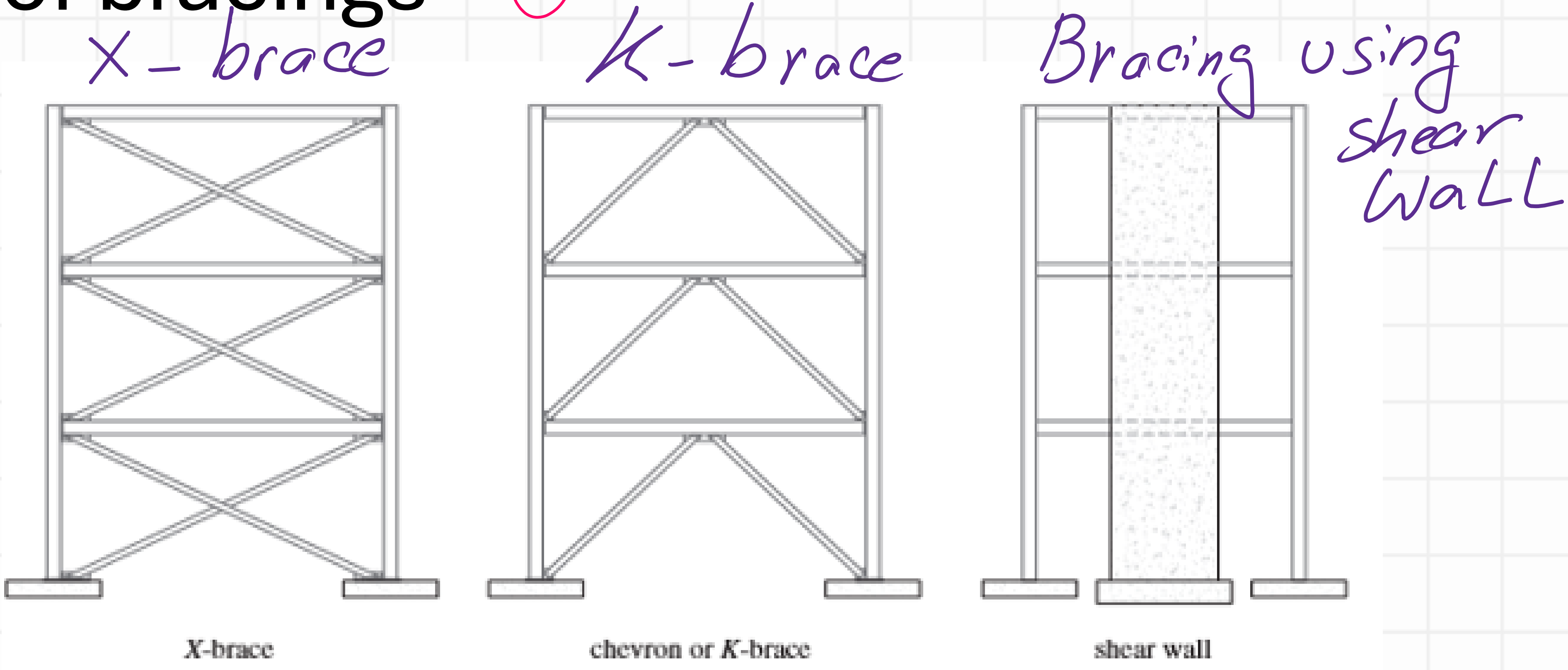
$P_{c_F} = \min(1942.9,\ 437.12)$
$= 437.12\,K$

Buckling to Y governs

Prepared by Eng.Maged Kamel.

Types of bracings

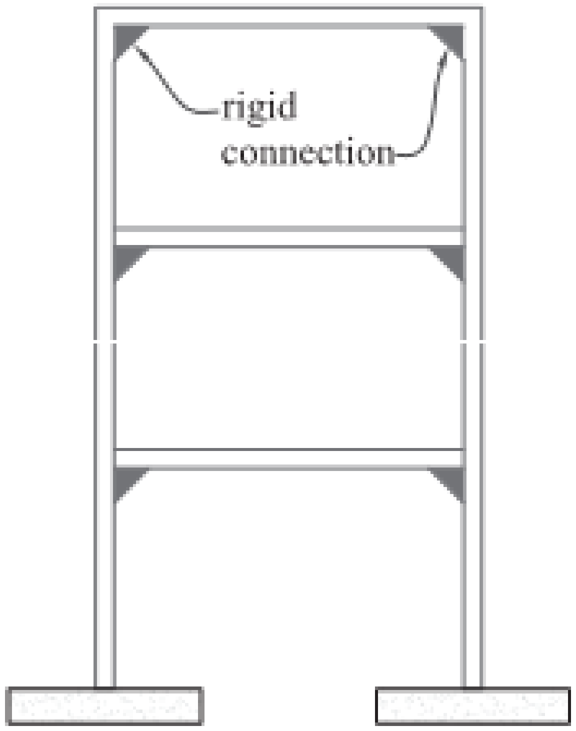
Types of bracing



a. braced frames

Prepared by Eng.Maged Kamel.

Braced and unbraced frames

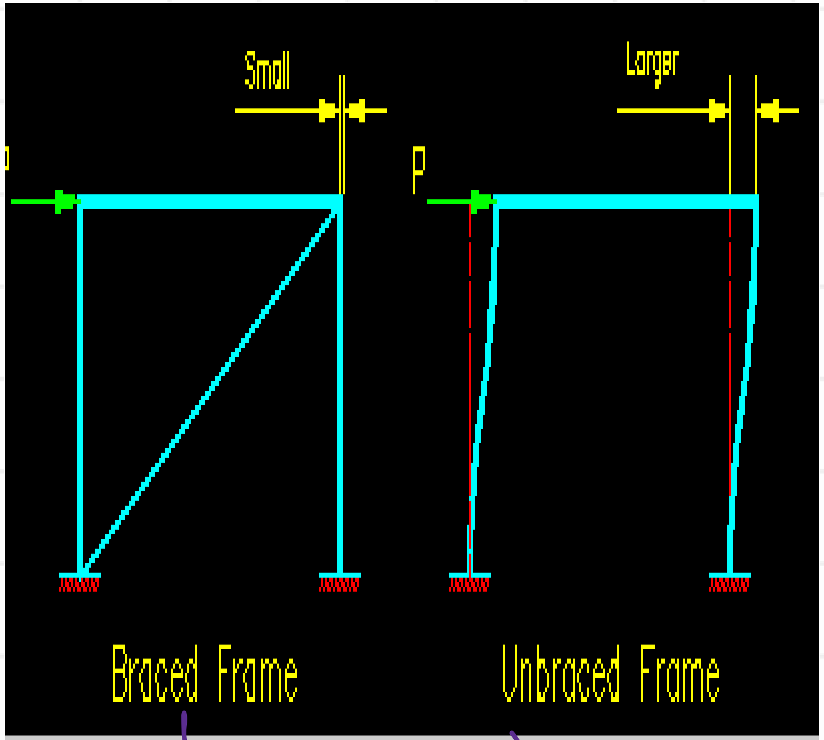


b. unbraced frames

Figure 5-4 Braced and unbraced frames.

Small deformation

Large deformation



Unbraced Frame