Lect.9

Compression Members

Compression members are structural elements that subjected to compression forces. These forces applied along longitudinal axis through centroid of the cross section.

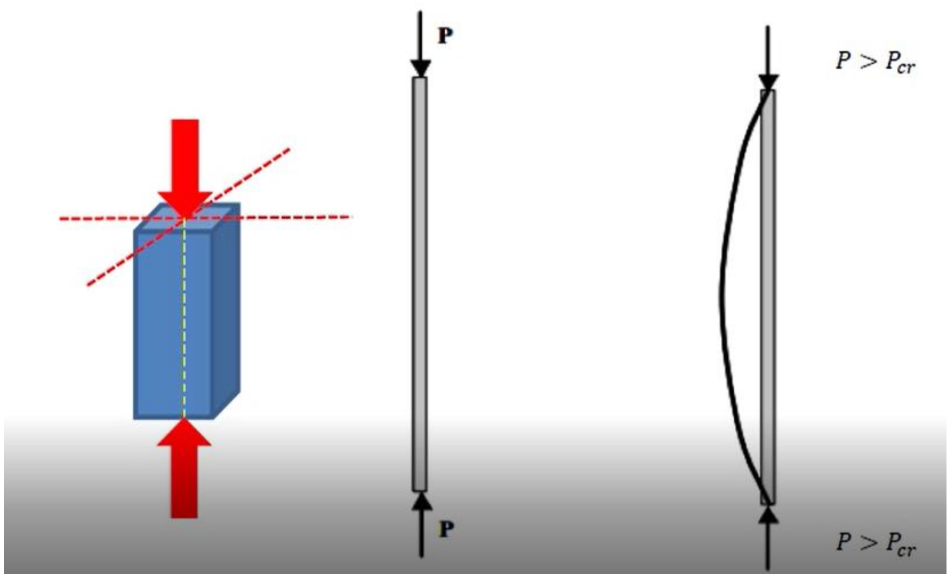
Modes of failure

There are three general modes by which axially loaded columns can fail. These are:-

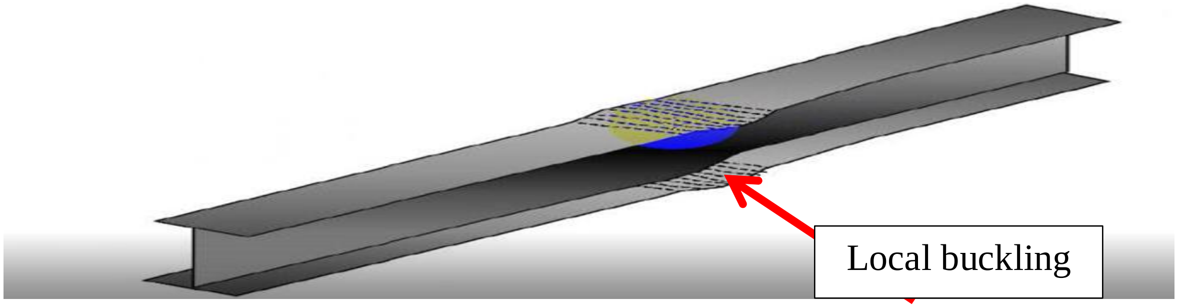
1) **Flexural Buckling:** (also called **Euler Buckling**): is the primary type of buckling. Members are subject to flexure, or bending, when they become unstable.

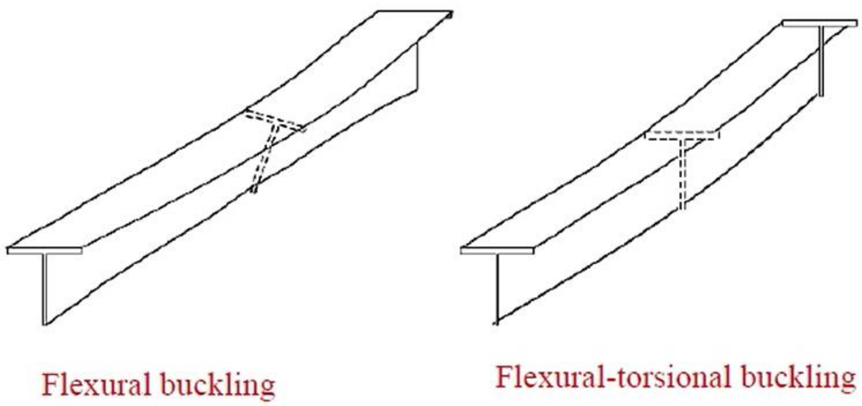
2) **Local Buckling**: occurs when some part or parts of the cross section of a column are so thin that they buckle locally in compression before the other modes of buckling can occur. The susceptibility of a column to local buckling is measured by the width – thickness ratios of the parts of its cross section.

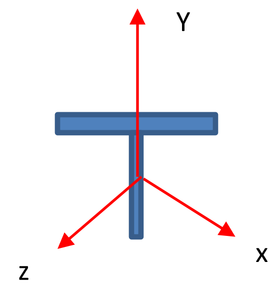
3) **Flexural-Torsional Buckling**: may occur in columns that have certain cross – sectional configurations. These columns fail by twisting (torsion) or by a combination of torsional and flexural buckling.



Buckling







Flexural buckling (occurs about x-axis)

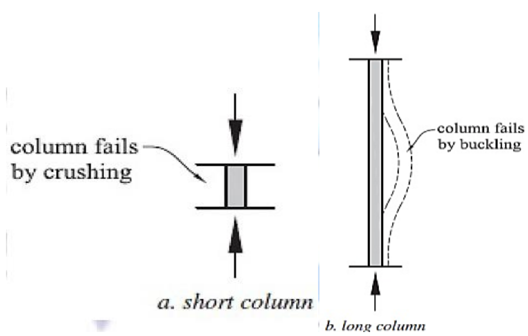
Flexural-torsional buckling (occurs about y and z-axes)

Column Critical Buckling Load:

There are two types of columns:

1) **Short Column**: the failure mode is crushing compression as shown in figure below (a).

2) **Long Column**: the failure mode is buckling at the mid-span of the member as shown in figure below (b).



This is called a slender, or long, column, intermediate column fail by a combination of buckling and compression.

►Euler Formula

For a pure compression member, the axial load at which the column begins to bow outward is called the Euler Critical Buckling Load. The Euler critical buckling load for a column with pinned ends is:

$$P_e = \frac{\pi^2 EI}{L^2} \qquad \textbf{(4-1)}$$

Where

P_e= Elastic critical buckling load, lb.
E = Modulus of elasticity, 29000 ksi.
I =Moment of inertia (in^4).
L= Length of the column brace points (in).
Knowing that $\boldsymbol{I}$=$\boldsymbol{Ar^2}$ and that the compression stress on any member is $\boldsymbol{fc}$=$\boldsymbol{P/A}$**,** we can express the Euler critical buckling load in terms of stress as:

$$F_e = \frac{\pi^2 E}{(L/r)^2} \qquad \textbf{(4-2)}$$

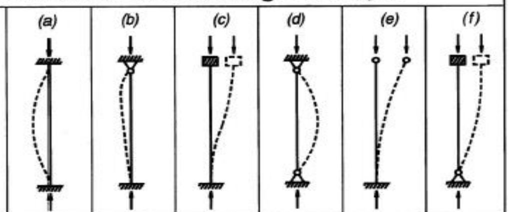
Where, $\boldsymbol{F_e}$= Euler elastic critical buckling stress (psi), ***A***= Cross- sectional area (in^2), r= Radius of gyration.
The Euler equations above assumed that the ends of the column are pinned. For other end conditions, an adjustment or effective length factor (***K***) is applied to the column length.

The effective length of a column is defined as ***KL, where *K* is usually determined by one of two methods:

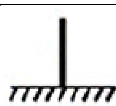
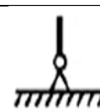
1) AISC **Table C–C2.2,** this table is especially useful for preliminary design when the size of the beams, girders, and columns are still unknown. (page 240)

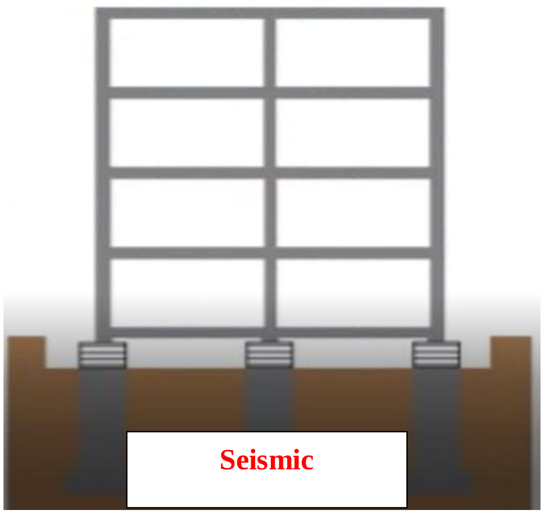
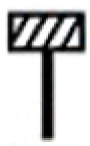
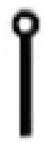
240 CALCULATION OF REQUIRED STRENGTHS [Comm. C2.

TABLE C-C2.2
Approximate Values of Effective Length Factor, *K*



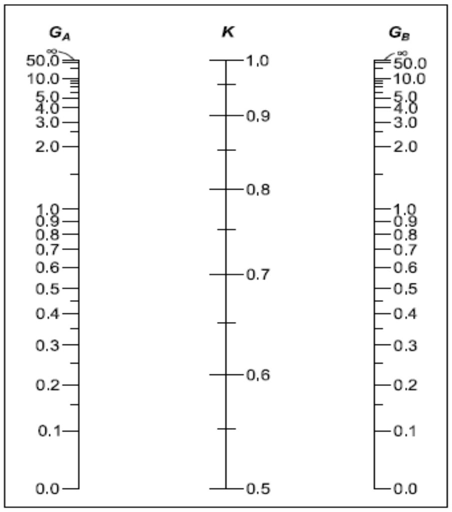
Buckled shape of column is shown by dashed line.	(a)	(b)	(c)	(d)	(e)	(f)
Theoretical *K* value	0.5	0.7	1.0	1.0	2.0	2.0
Recommended design value when ideal conditions are approximated	0.65	0.80	1.2	1.0	2.10	2.0
End condition code	Rotation fixed and translation fixed Rotation free and translation fixed Rotation fixed and translation free Rotation free and translation free					

	
 Rotation fixed and translation fixed	 Rotation free translation fixed

	
 Rotation fixed and translation free	 Rotation free and translation free

2) Alignment charts (AISC **Table C–C2.3** and **C–C2.4**), they provide more accurate values for the effective length factor than AISC **Table C–C2.2**, but the process of obtaining these values is more tedious than the first method, and the alignment charts can only be used if the initial sizes of the columns and girders are known.

$$G_{top.} = G_{bot.} = \frac{\sum I/L)column}{\sum I/L)beam\ or\ girder}$$



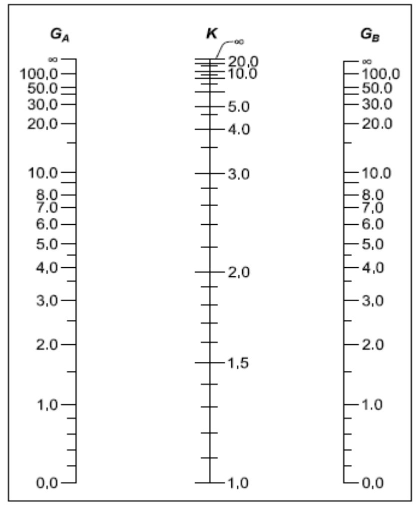
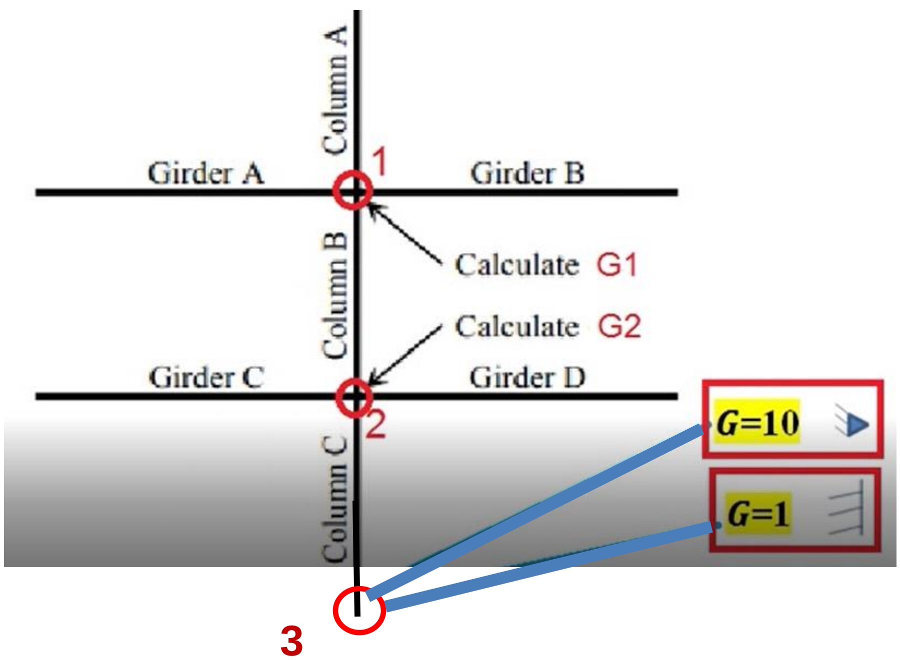


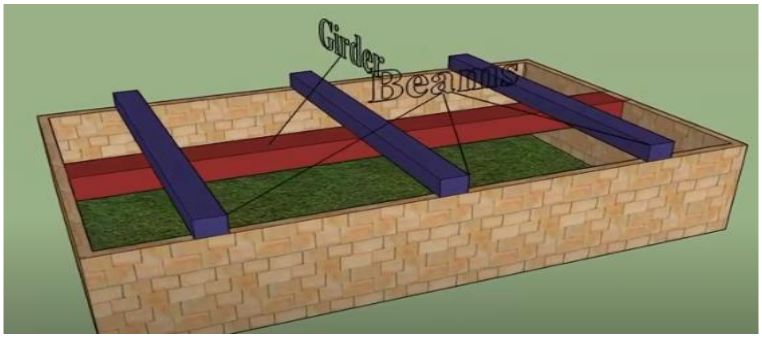
Fig. C-C2.3.Alignment chart- sidesway inhibited (braced frame).	***Fig. C-C2.4. Alignment chart- sidesway uninhibited (moment frame).*** → ***un-braced***



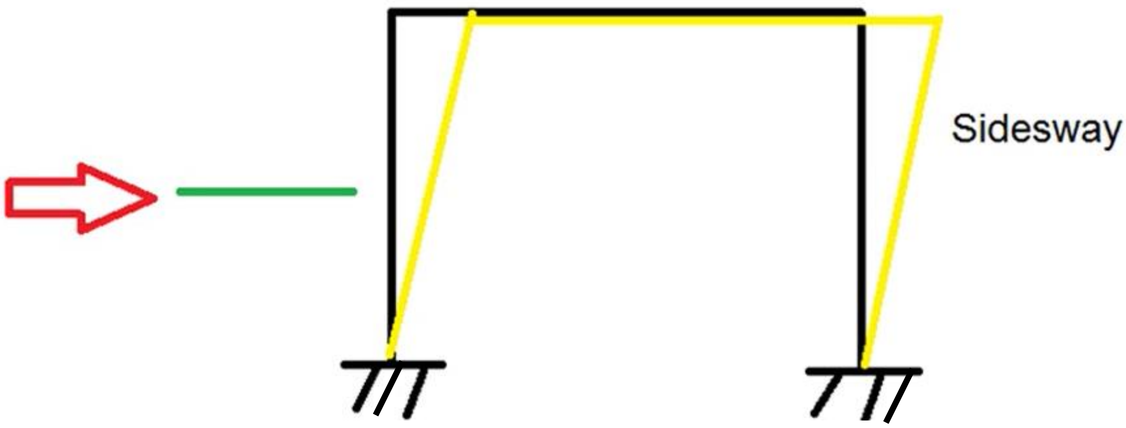
<u>Note:</u> *G*=10 if the support pinned (Hinged) end column.
***G*=1 if the support fixed and rigid end column.**

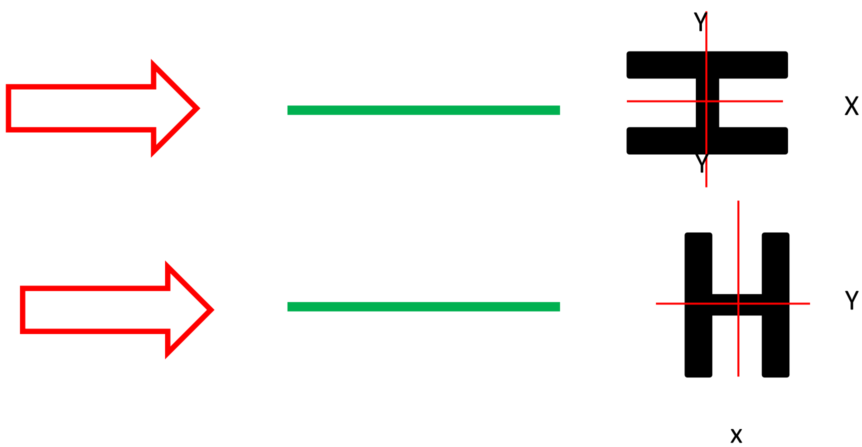
$$G_{top.} = G_{bot.} = \frac{\sum I/L)column}{\sum I/L)beam\ or\ girder}$$

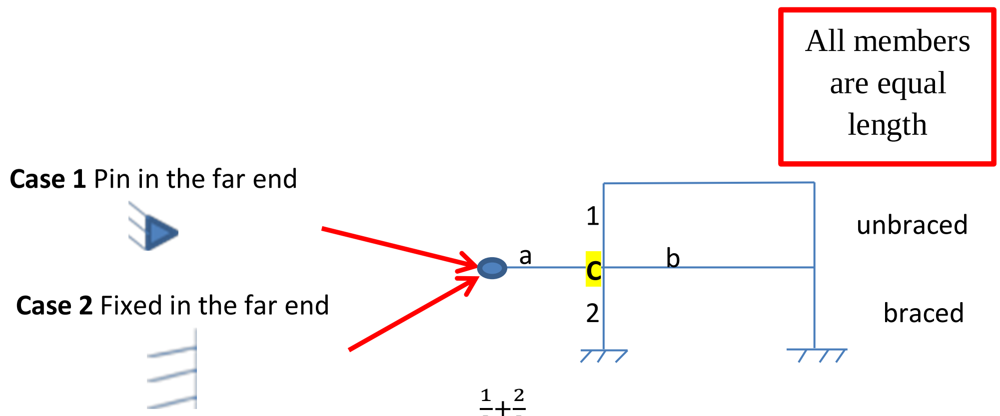
Beam and girder



the frame is braced only in plane perpendicular to the frame direction.







$$G_C = \frac{\frac{1}{L}+\frac{2}{L}}{\frac{b}{L}+\frac{a}{L}\times\boldsymbol{\alpha}}$$ **Case 1 α=1.5 (from table below)**

$$G_{top.} = G_{bot.} = \frac{\sum I/L)column}{\sum I/L)beam\ or\ girder}$$

$$G_C = \frac{\frac{1}{L}+\frac{2}{L}}{\frac{b}{L}+\frac{a}{L}\times\boldsymbol{\alpha}}$$ **Case2 $\alpha = 2$(from table below)**

Factors consider far end condition of beam (α)

Case	Hinged far end of beam	Fixed far end of beam
Sidesway is prevented	**1.5**	**2**
Sidesway is not prevented	**0.5**	**0.67**

Note: **1.** if the sentence (the frame braced) ⇨ **K=1**

2. Truss $K_x = K_y = 1$

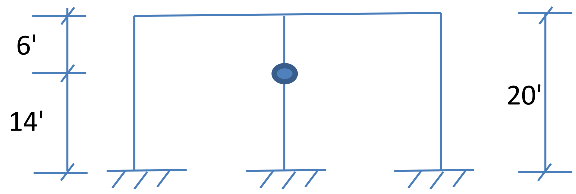
When the column end conditions are other than pinned, equations (4-1) and (4-2) are modified as follows:

$$P_e = \frac{\pi^2 EI}{(KL)^2} \qquad \textbf{(4-3)}$$

$$F_e = \frac{\pi^2 E}{(KL/r)^2} \qquad \textbf{(4-4)}$$

The term ***KL/r*** is called the slenderness ratio, and the AISC Specification recommends limiting the column slenderness ratio such that: $\boldsymbol{KL/r} \leq \mathbf{200}$.

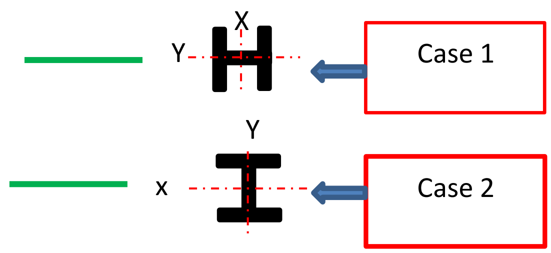
Example: the frame is braced only in plane perpendicular to the frame direction.

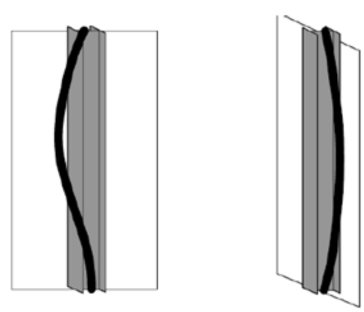


Case 1/ $l_x = 20', l_y = 14', \ l_y = 6'$

Case 2/ $l_x = 14', l_x = 6', l_y = 20'$

Braced case taken the largest value of l (worst case)





(a) (b)

Case 1: (a) major-axis buckling=x; (b) minor-axis buckling=y

Example phrase in the question: Assume the major axis bending occurs only in the plane of the frame.

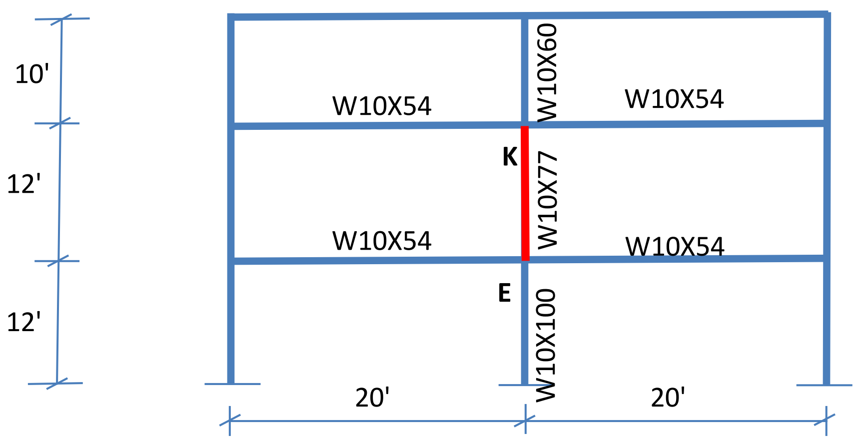
Ky=1.0

Kx=?

Strong axis=x

Weak axis=y

Example 1/ Find the effective length factor for the member KE for the frame shown below assuming that <u>the frame is braced only in plane perpendicular to the frame direction</u>.



Sol: $K_y = 1$ (<u>the frame is braced only in plane perpendicular to the frame direction</u>.)

Sec.	Length	I_x
W10X60	10	341
W10X77	12	455
W10X100	12	623
W10X54	20	303

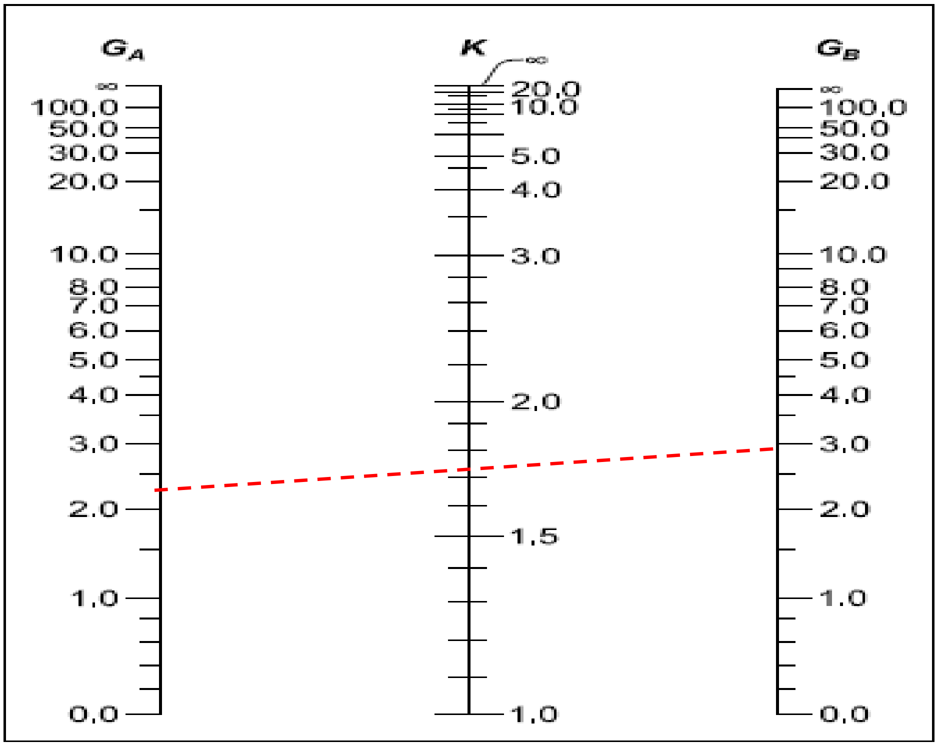
$$G_{top.} = G_{bot.} = \frac{\sum I/L)column}{\sum I/L)beam\ or\ girder}$$

$$G_K = \frac{\frac{341}{10}+\frac{455}{12}}{2(\frac{303}{20})} = 2.37$$

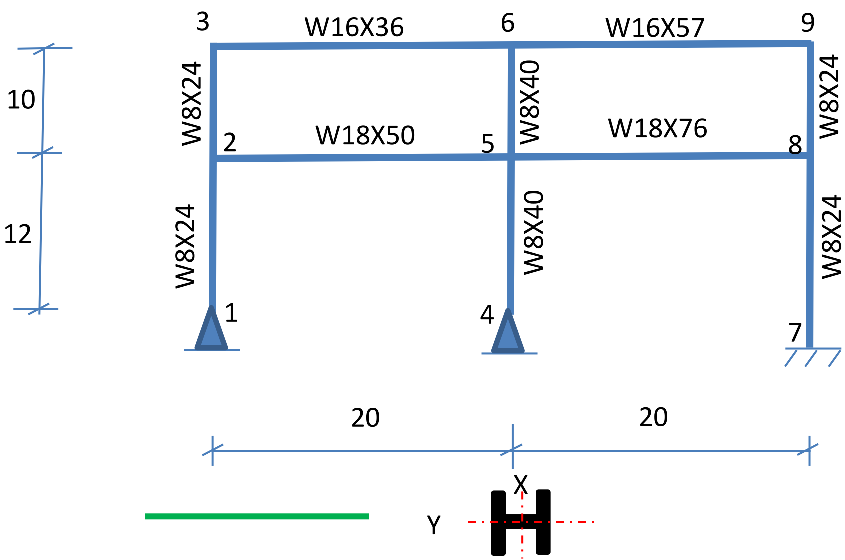
$$G_E = \frac{\frac{455}{12}+\frac{623}{12}}{2(\frac{303}{20})} = 2.96$$

Fig. C-C2.4. Alignment chart-sidesway uninhibited (moment frame)

K_x=1.71


G_A
K
G_B
∞
100.0
50.0
30.0
20.0
10.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
∞
20.0
10.0
5.0
4.0
3.0
2.0
1.5
1.0

Example 2/ Find the effective length factor for the member **1-2** for the frame shown below assuming that the frame is braced only in weak direction which is perpendicular to the frame direction.



Sol: $K_y = 1$ (the frame is braced only in weak direction which is perpendicular to the frame direction.)

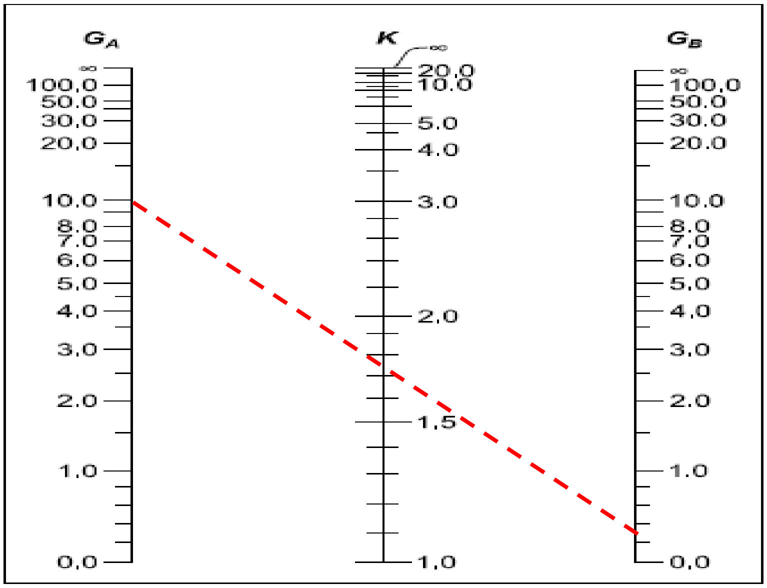
Sec.	Length	I_x
W8X24	10	82.7
W8X24	12	82.7
W18X50	20	800

$G_1 = 10$ (pinned or hinged).

$$G_2 = \frac{\frac{82.7}{10} + \frac{82.7}{12}}{(\frac{800}{20})} = 0.38$$

Fig.C-C2.4. Alignment chart-sidesway uninhibited (moment frame)

K_x=1.75



H.W. / Find effective length factor for member 2-3, 4-5,5-6,7-8,8-9, respectively.

Note: if the member in example 1 and 2 was as figure below:

$\boldsymbol{K_x = 1}$,

and $\boldsymbol{K_y}$ ***Goto Fig. C-C2.4. Alignment chart-sidesway uninhibited (moment frame)***