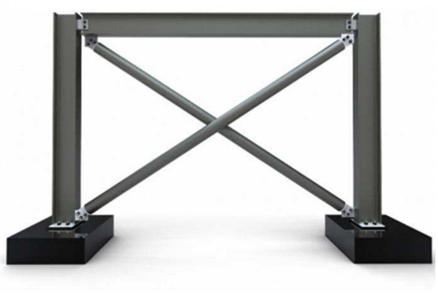


Timber and Steel Design

Lecture 12 – Frame Design

- Forces on Structures
- Braced Frame
- Rigid Frame
- Portal Frame

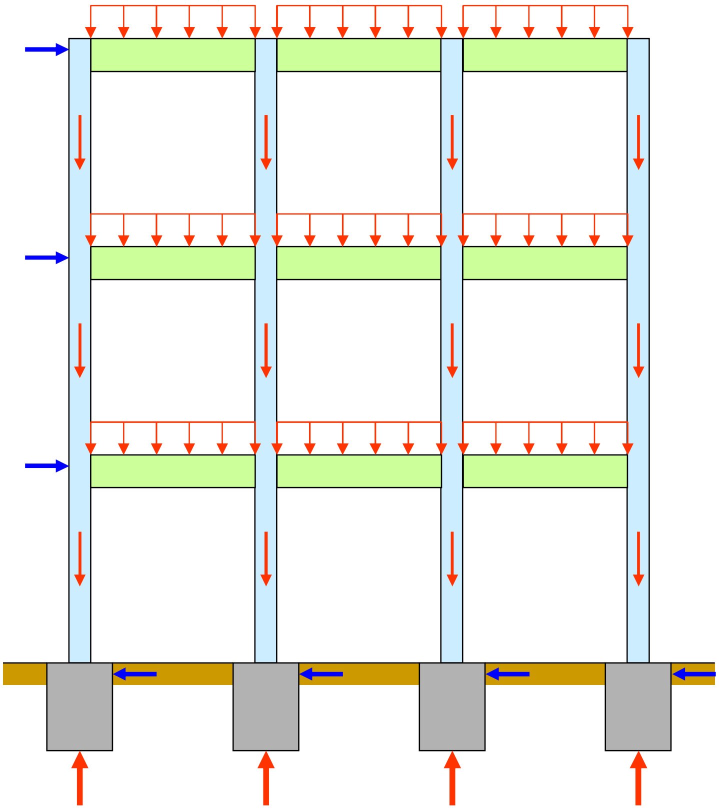
Mongkol JIRAVACHARADET

SURANAREE UNIVERSITY OF TECHNOLOGY

INSTITUTE OF ENGINEERING

SCHOOL OF CIVIL ENGINEERING

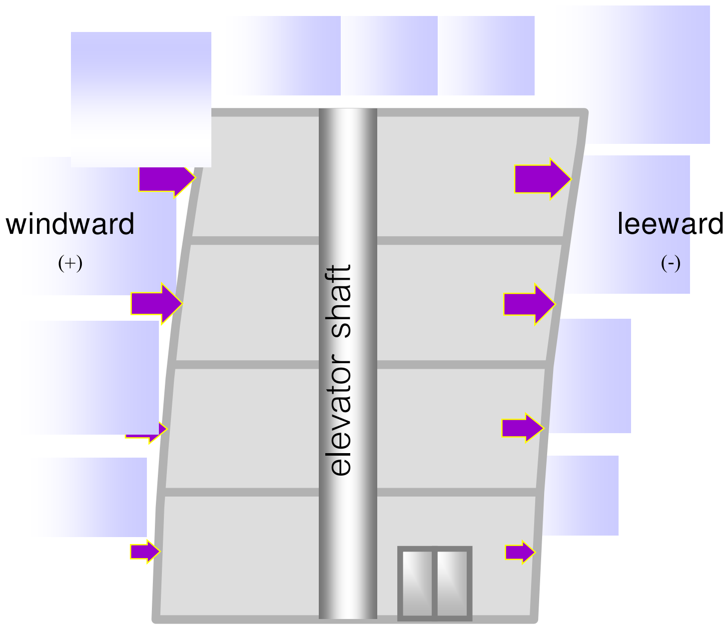
Forces on Structures

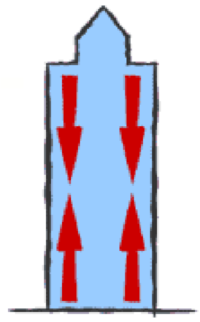


Structural Steel Frame Elevation

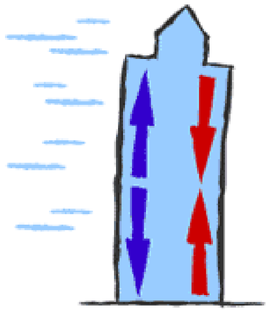
- Forces that act vertically are gravity loads
- Gravity loads are transfered from beams → columns → footing
- Forces that act horizontally, such as stability, wind and seismic events (the focus of this discussion) require lateral load resisting systems to be built into structures

Wind & Building Pressure





Windward columns in tension



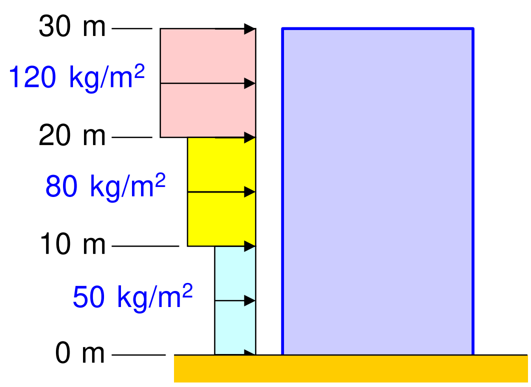
Leeward columns in compression

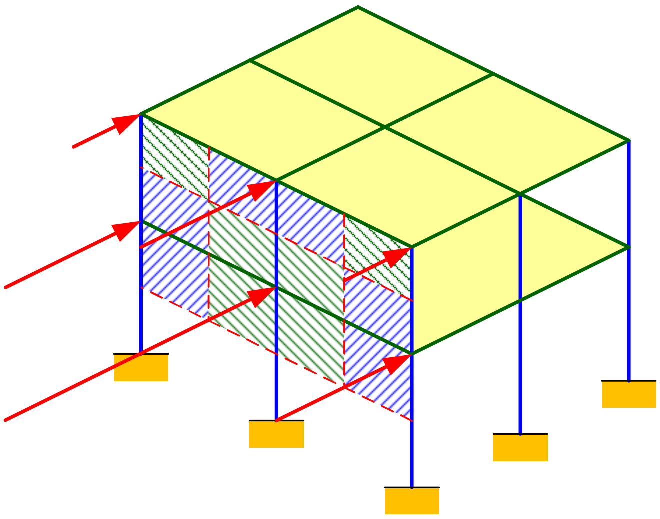
Wind pressure “pushes” outdoor air into the windward side of the building and “pulls” indoor air from the leeward side

Wind Load on Building

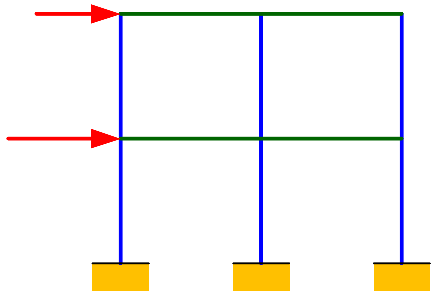
แรงลมตาม พ.ร.บ. ควบคุมอาคาร พ.ศ. 2522

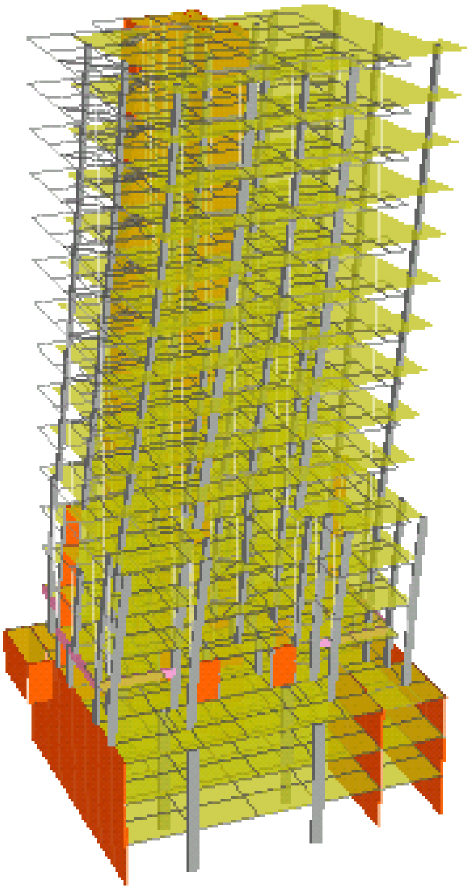
ความสูงอาคาร (เมตร)	หน่วยแรงลม (กก./ตร.ม.)
น้อยกว่า 10	50
10 < *h* < 20	80
20 < *h* < 40	120
มากกว่า 40	160





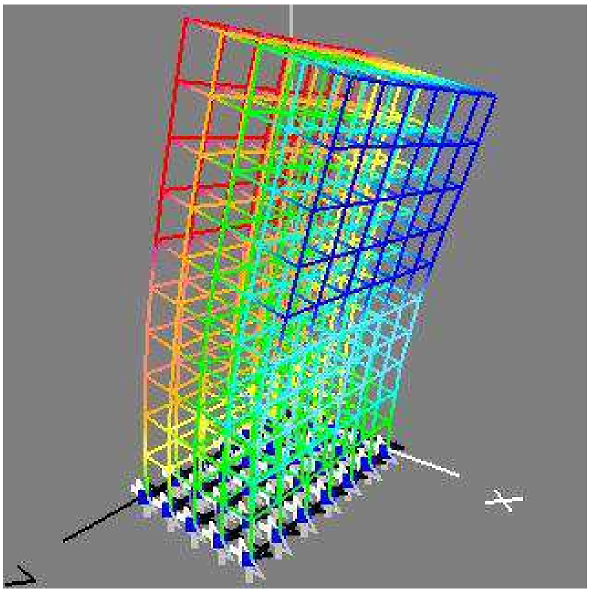
Wind load on joint =
Wind pressure × Tributary area





Sidesway of Buildings

Without bracing building may have excessive deformation



Braced Frames and Rigid Frames

Rigid Frames

- Rigid frames, utilizing moment connections, are well suited for specific types of buildings where diagonal bracing is not feasible or does not fit the architectural design
- Rigid frames generally cost more than braced frames

Braced Frames

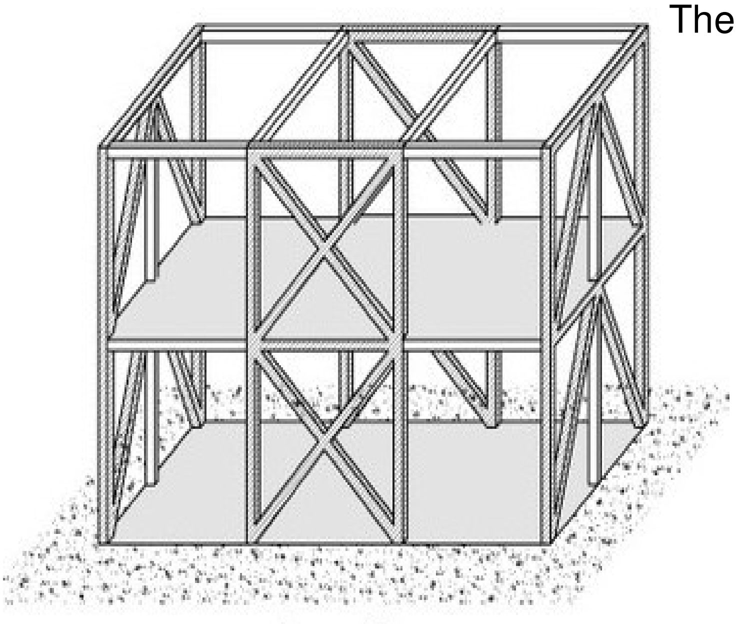
- Diagonal bracing creates stable triangular configurations within the steel building frame
- Braced frames are often the most economical method of resisting wind loads in multi-story buildings.
- Some structures, like the one pictured above, are designed with a combination braced and rigid frame to take advantage of the benefits of both

Temporary Bracing

- Structural steel frames require temporary bracing during construction
- Temporary bracing is placed before plumbing up the structural frame
- This gives the structure temporary lateral stability
- Temporary bracing is removed by the erector

Braced Frames

A framework of beams and columns in which inclined, often diagonal, structural members brace the building and provide strength and rigidity.



The bracing can take a variety of forms.

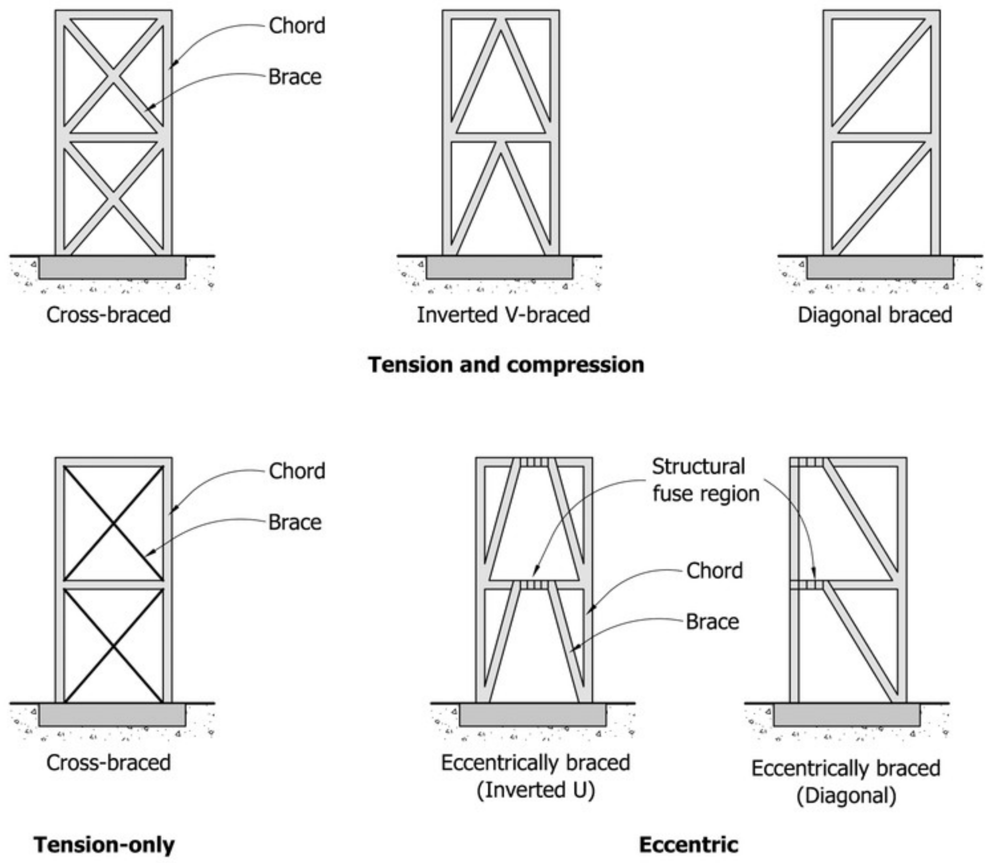
Dual function

If diagonal members are stocky they resist both tension and compression forces.

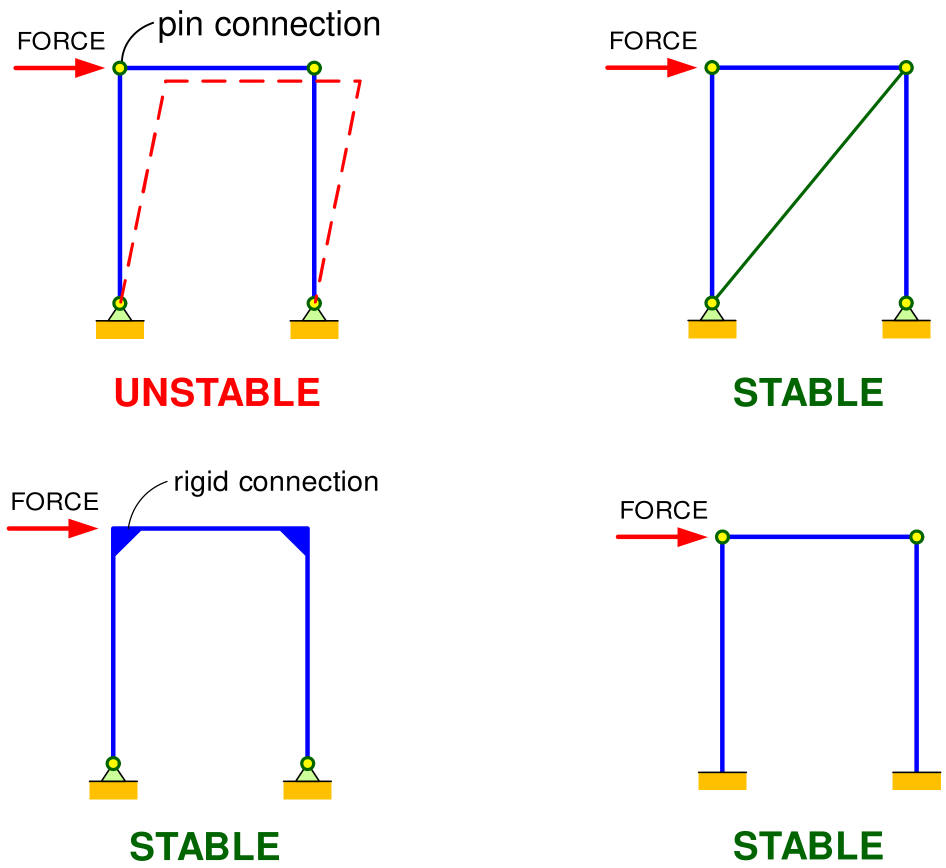
Tension-only

However if slender, they resist tension forces only.

Types of Braced Frames

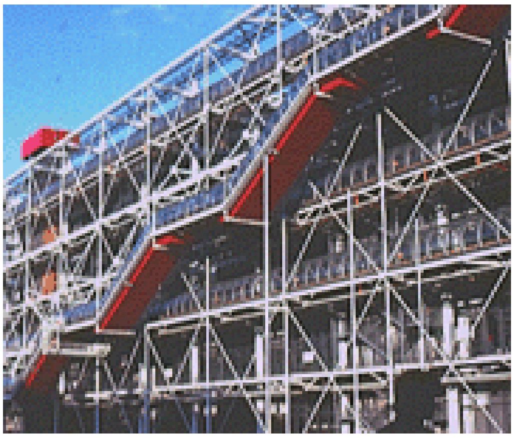


Stable & Unstable Frames

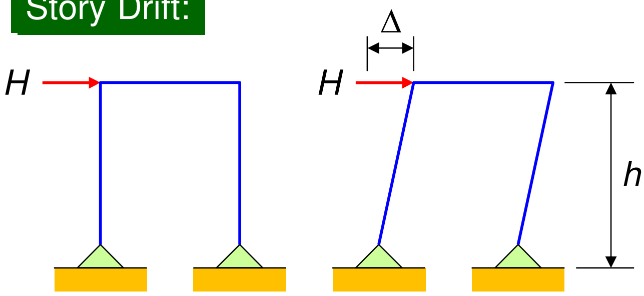


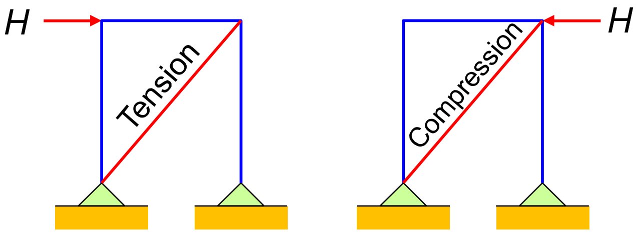
Basic of Bracing

Dual-functioning Bracing:

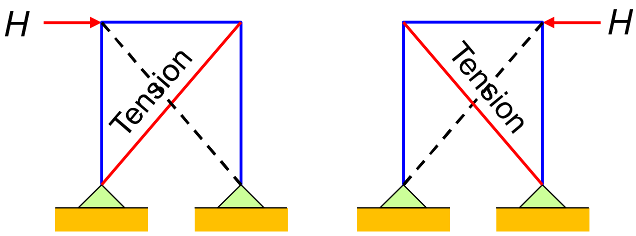


Story Drift:

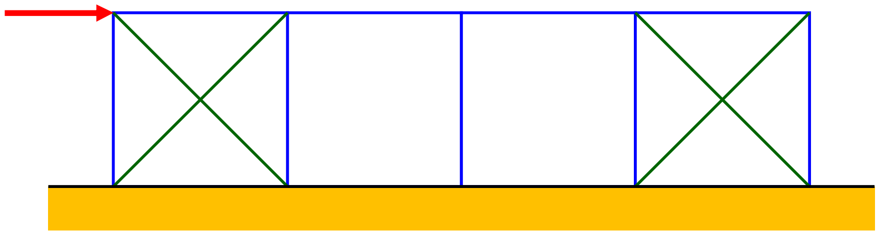




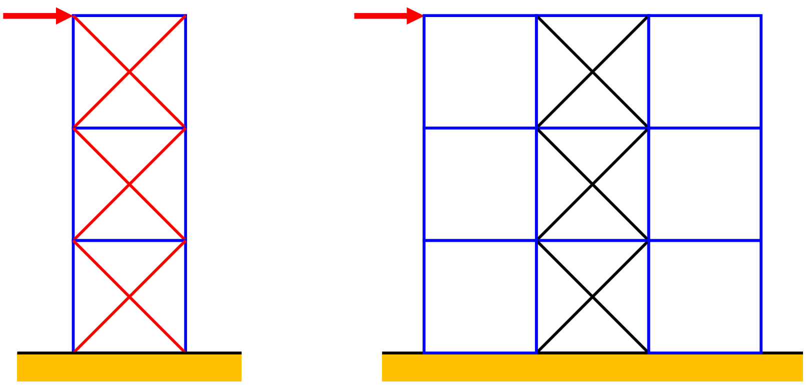
X-bracing:



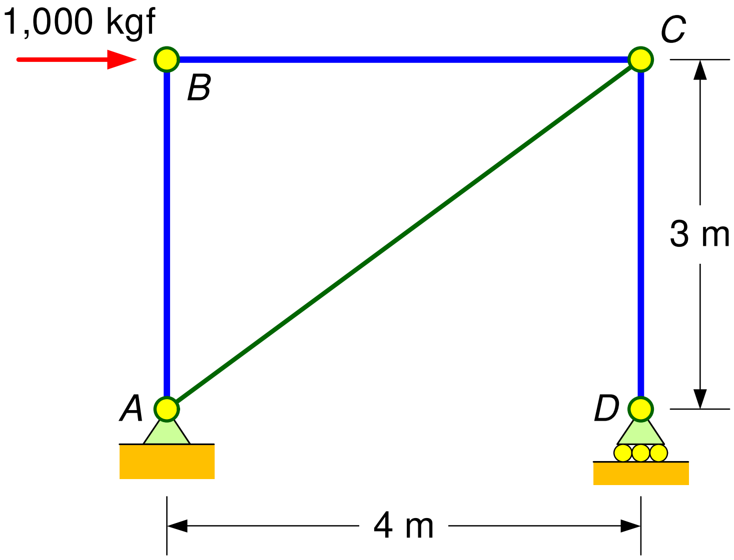
Single-story Multi-bay Bracing:

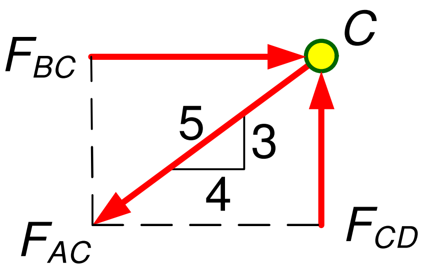


Bracing multistory buildings:



Example 1 : Force in Diagonal Bracing



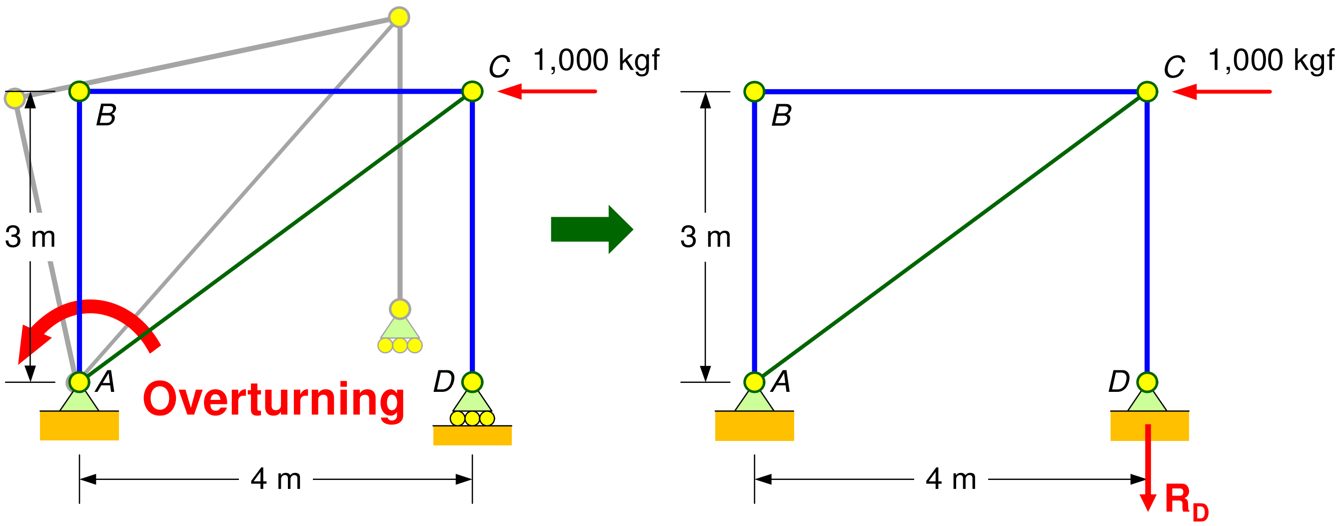


$$F_{AC} = (5/4)F_{BC}$$

$$= (5/4)\times 1{,}000$$

$$= 1{,}250 \text{ kgf } (\mathbf{T})$$

On the same frame, force applies in opposite direction.

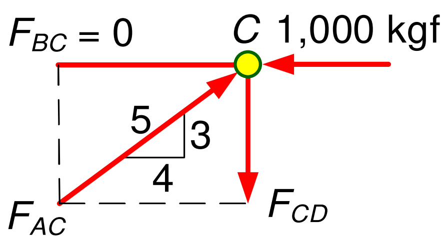


$$[\Sigma M_A = 0] \quad R_D = 1{,}000\times 3/4 = 750 \text{ kgf}$$

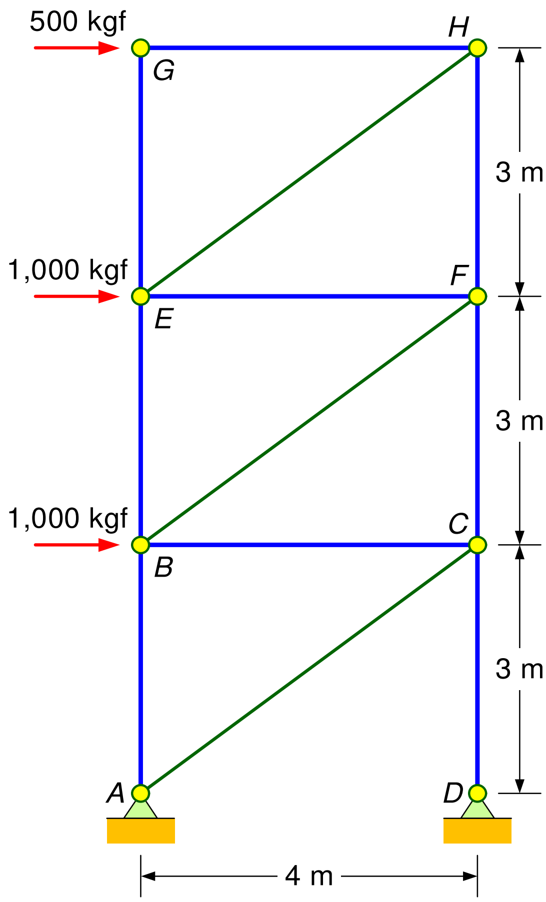
$$F_{AC} = (5/3)\, F_{CD}$$

$$= (5/3)\times 750$$

$$= 1{,}250 \text{ kgf } (\mathbf{C})$$



Example 2 : Diagonal Braced Frame



@ G : $F_{GH} = 500$ kgf (C)

$F_{EG} = 0$

@ H : $F_{EH} = 500(5/4) = 625$ kgf (T)

$F_{FH} = 500(3/4) = 375$ kgf (C)

@ E : $F_{EF} = 1{,}000 + 625(4/5) = 1{,}500$ kgf (C)

$F_{BE} = 625(3/5) = 375$ kgf (T)

@ F : $F_{BF} = 1{,}500(5/4) = 1{,}875$ (T)

$F_{CF} = 375 + 1{,}875(3/5) = 1{,}500$ kgf (C)

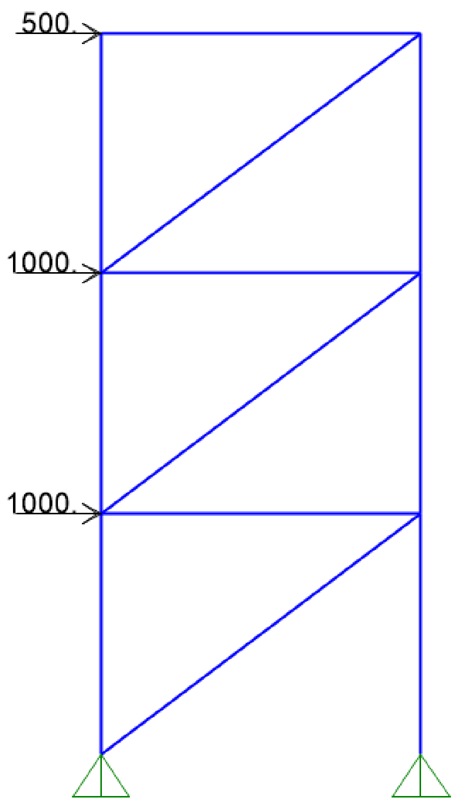
@ B : $F_{BC} = 1{,}000 + 1{,}875(4/5) = 2{,}500$ kgf (C)

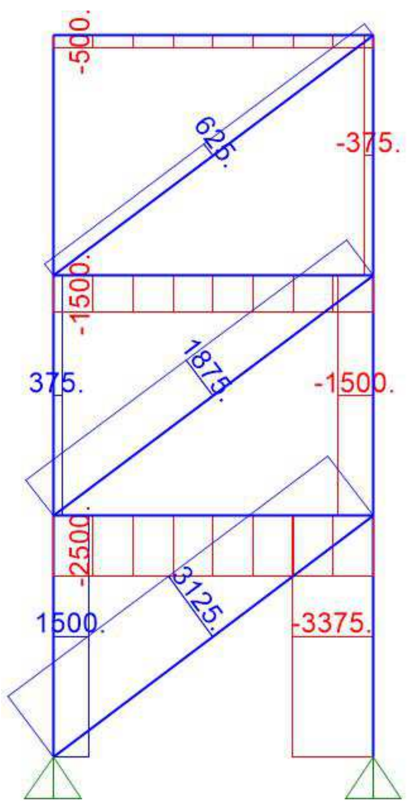
$F_{AB} = 375 + 1{,}875(3/5) = 1{,}500$ kgf (T)

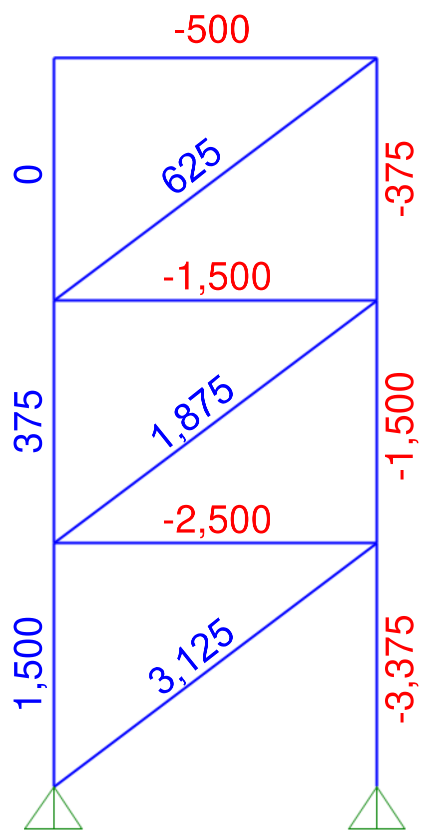
@ C : $F_{AC} = 2{,}500(5/4) = 3{,}125$ (T)

$F_{CD} = 1{,}500 + 3{,}125(3/5) = 3{,}375$ kgf (C)

Diagonal Braced Frame Analysis by SAP2000

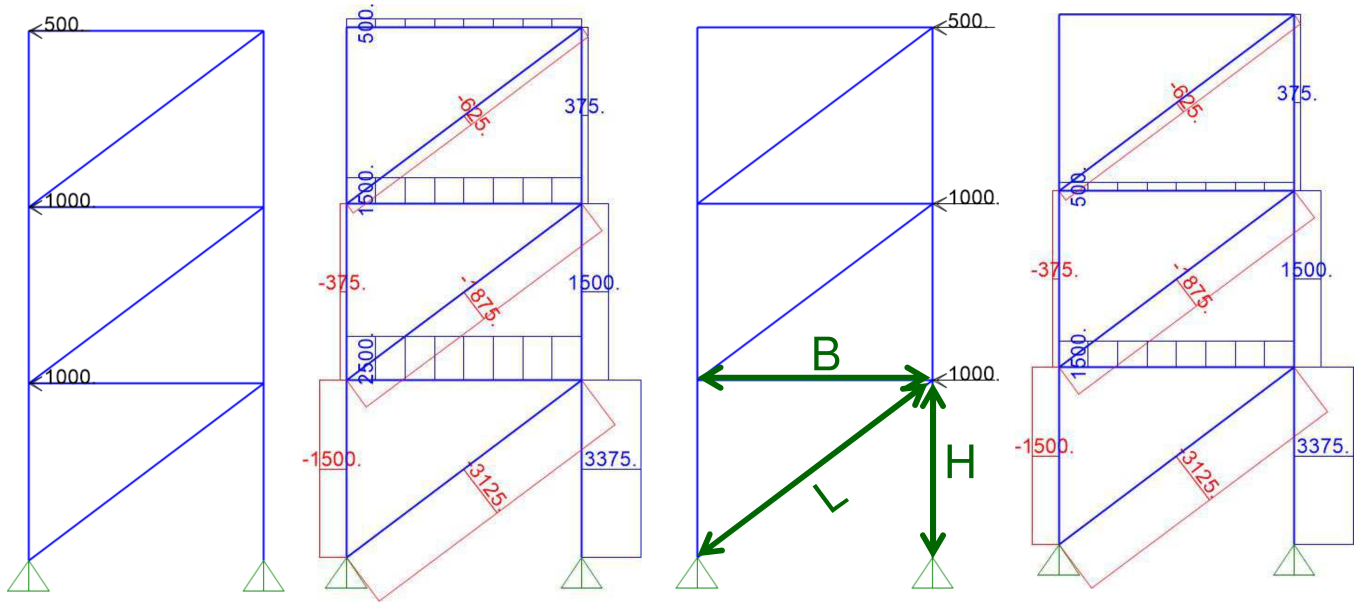






By SAP2000 **By HAND**

Reverse load or forces on opposite direction



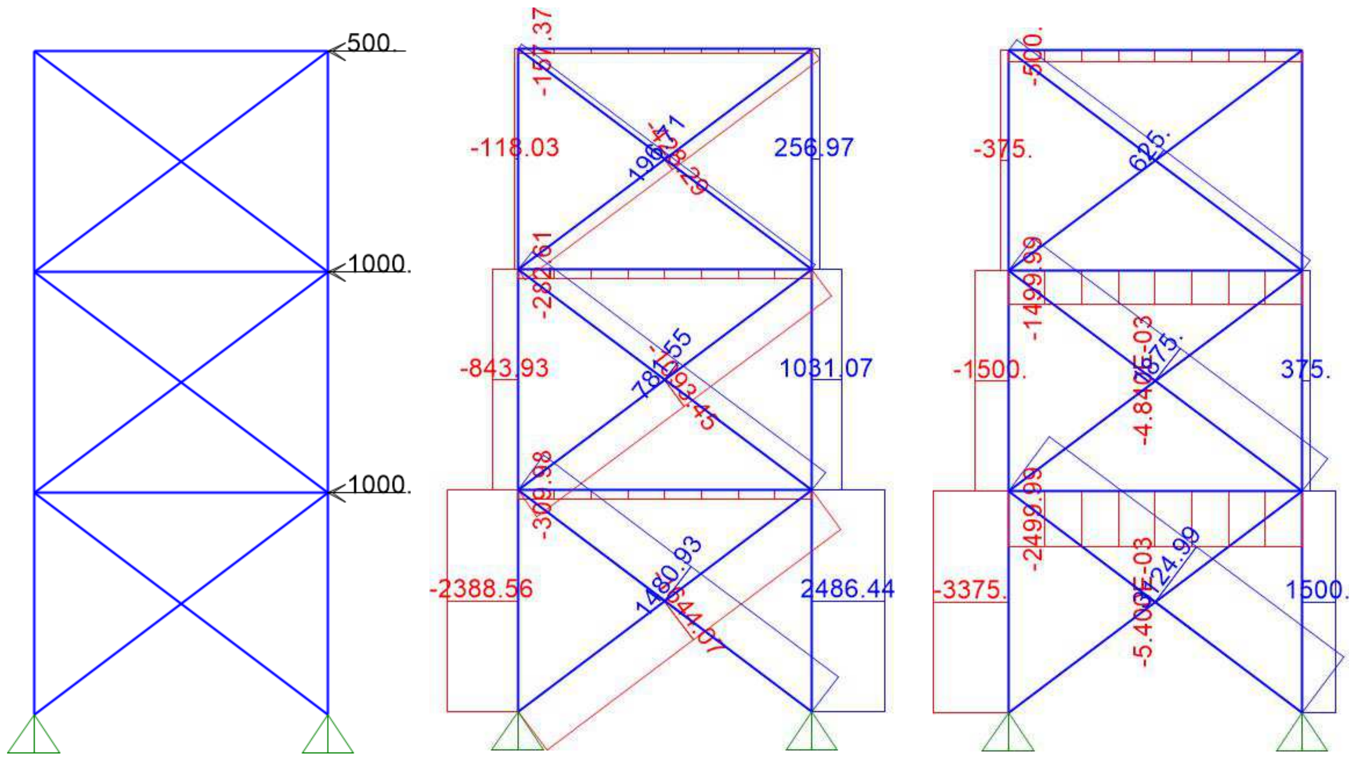
Same forces in bracings and columns but different in beams

Force in bracing = V L / B $\quad$ 500 × 5 / 4 = 625

1,500 × 5 / 4 = 1,875

2,500 × 5 / 4 = 3,125

X Braced Frame

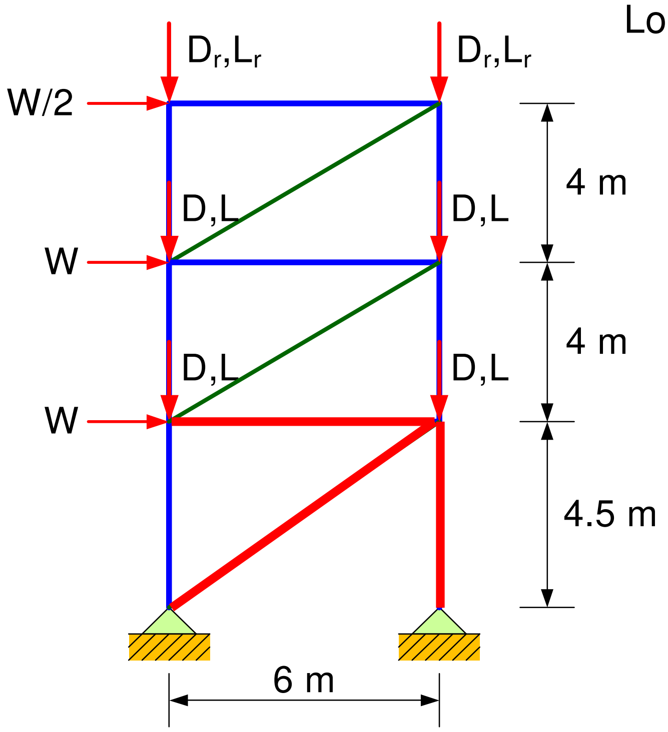


Dual action

Tension-only

= Diagonal bracing

Example 12-3 The braced frame shown below is subjected to the service (unfactored) loads given. Assume that all of the joints are pinned connections. Determine the maximum forces in beam, column and bracing.



Loadings : $D = 50$ t, $D_r = 25$ t

$L = 20$ t, $L_r = 10$ t, $W = 10$ t

วิธีทำ แรงมากที่สุดเกิดขึ้นที่ชั้น 1

$$F_{beam} = 2.5W = \mathbf{25\ t\ (C)}$$

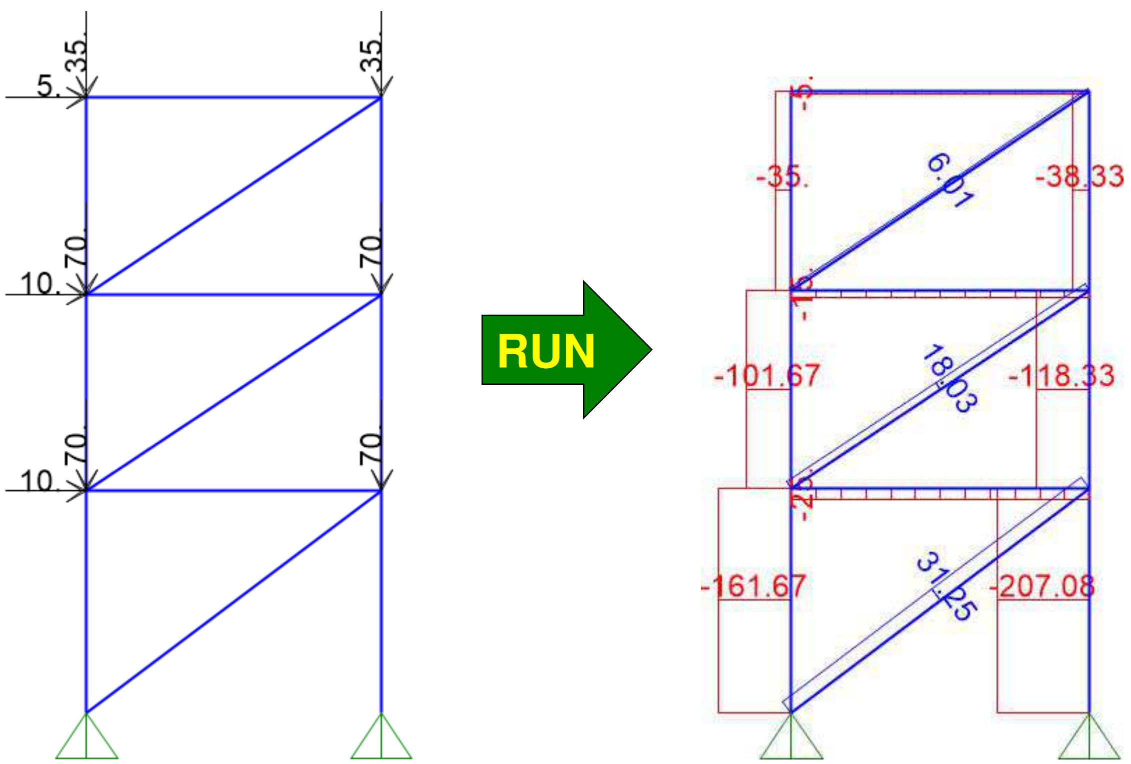
$$L = \sqrt{6^2 + 4.5^2} = 7.5\ m$$

$$F_{brace} = 25 \times 7.5 / 6 = \mathbf{31.25\ t\ (T)}$$

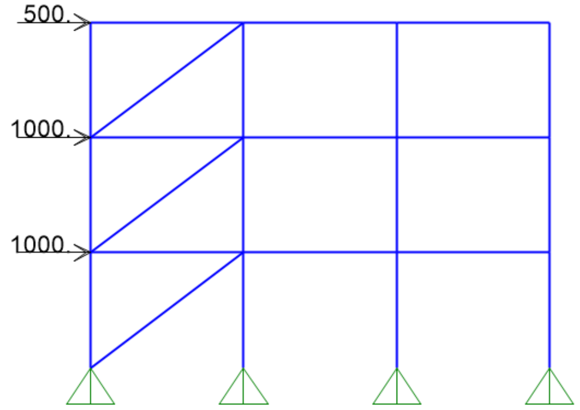
$$F_{col} = (W/2 \times 12.5 + W \times 8.5 + W \times 4.5)/6 + 25 + 10 + 50 + 20 + 50 + 20$$

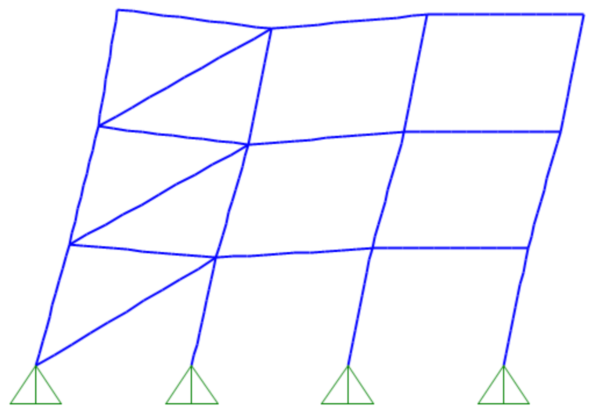
$$= \mathbf{207\ t\ (C)}$$

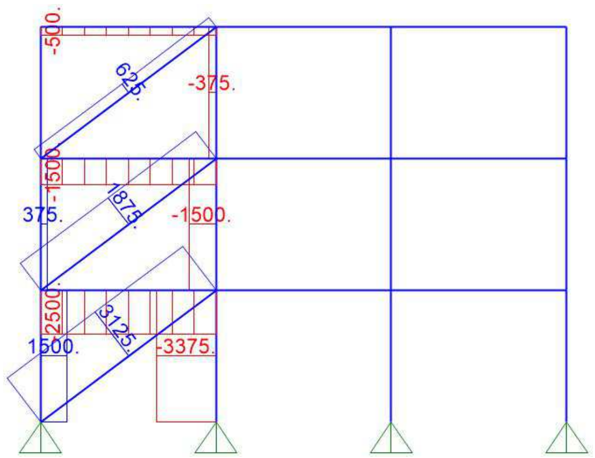
Check by SAP2000



Multi-Bay Braced Frame





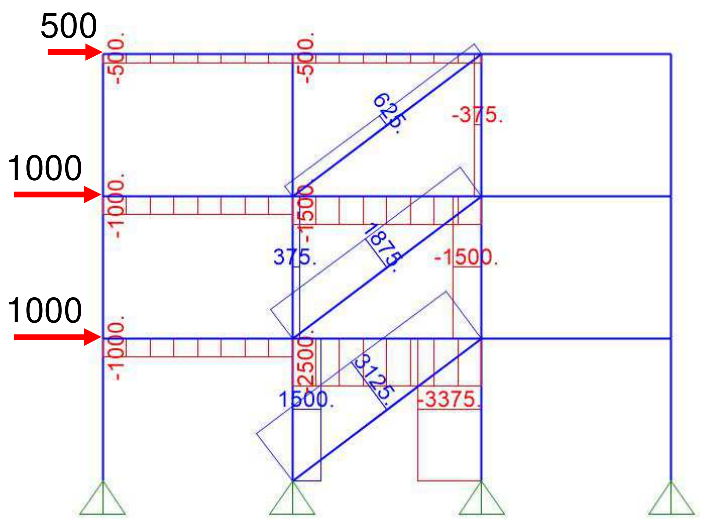


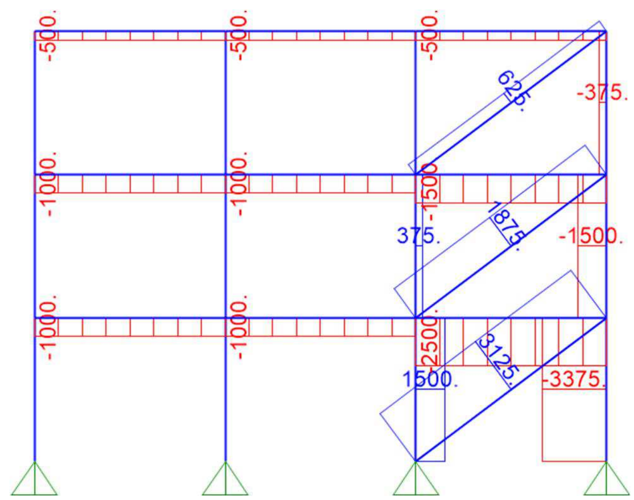
Same result !!!

Only braced bay take lateral load.

Multi-Bay Braced Frame

Change braced bay position

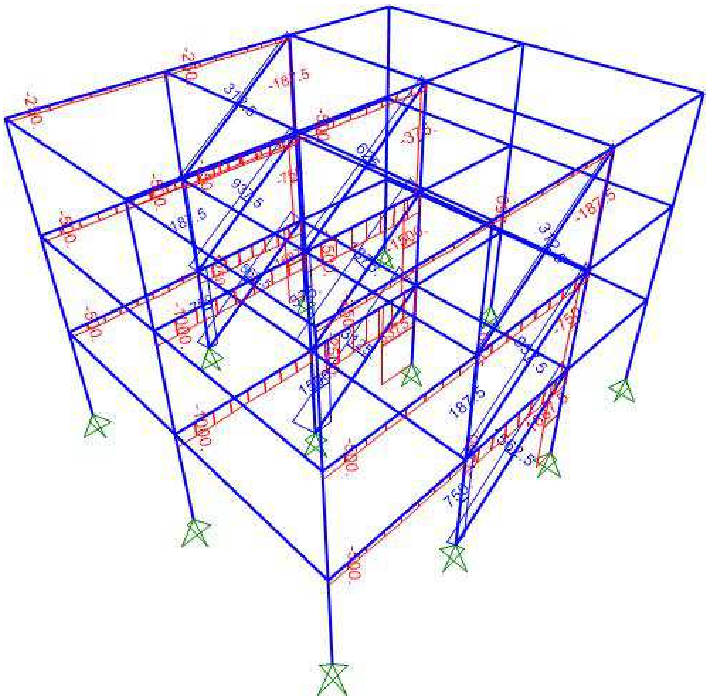


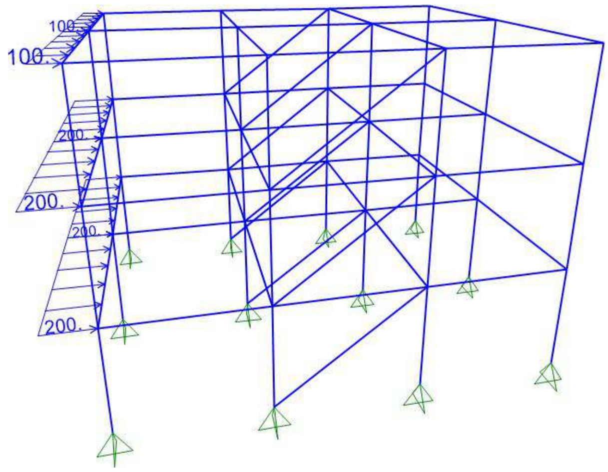


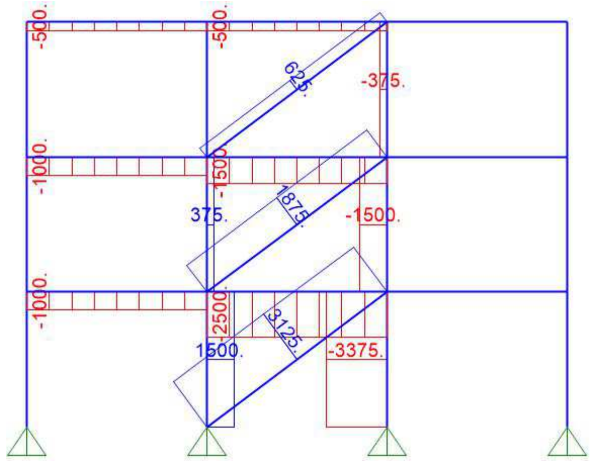
Same result for column and bracing

but more beam in compression !!!

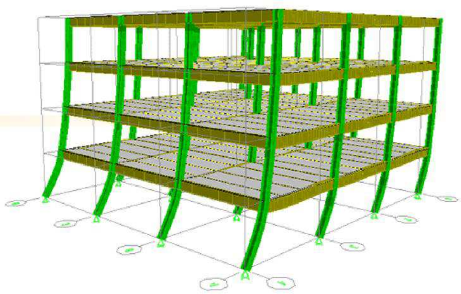
3-D Braced Frame







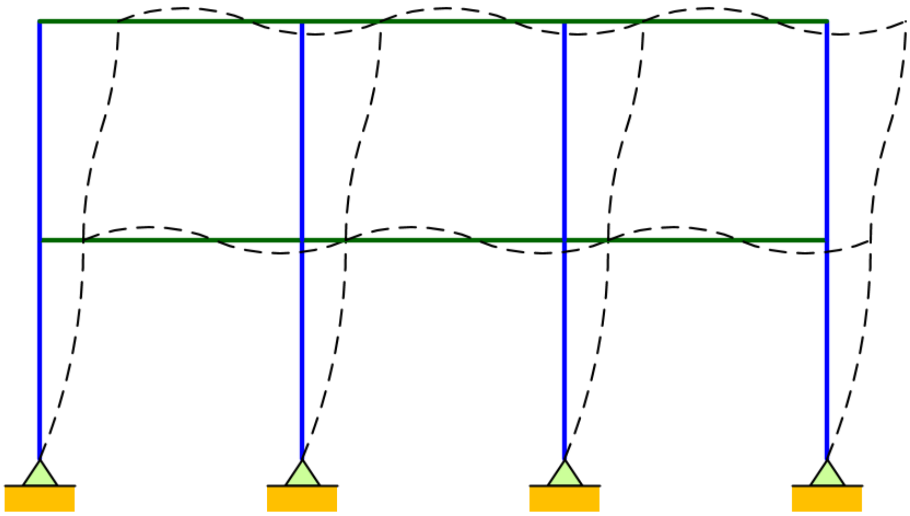
Rigid Frame



Subject to moments and axial load transferred from

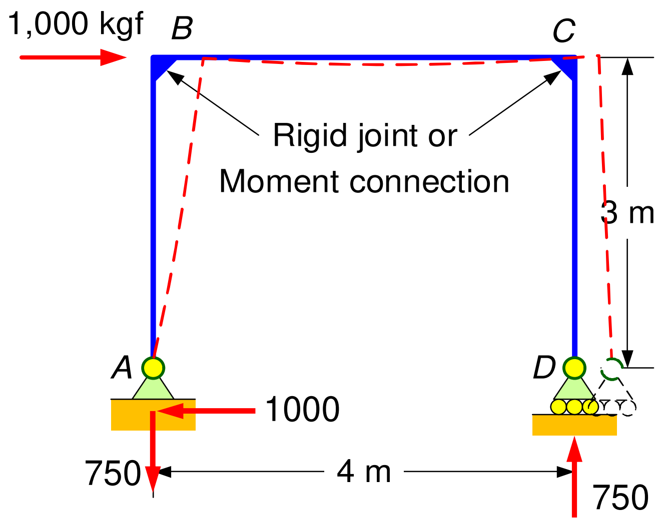
Gravity loads : Dead Load & Live Load

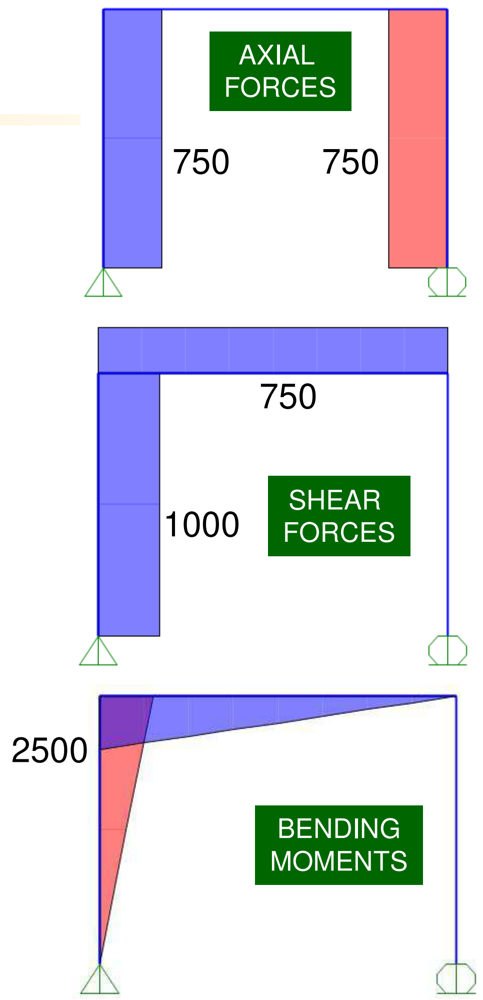
Lateral loads : Earthquake & Wind Load



Rigid Portal Frame

Pinned and Roller Supports

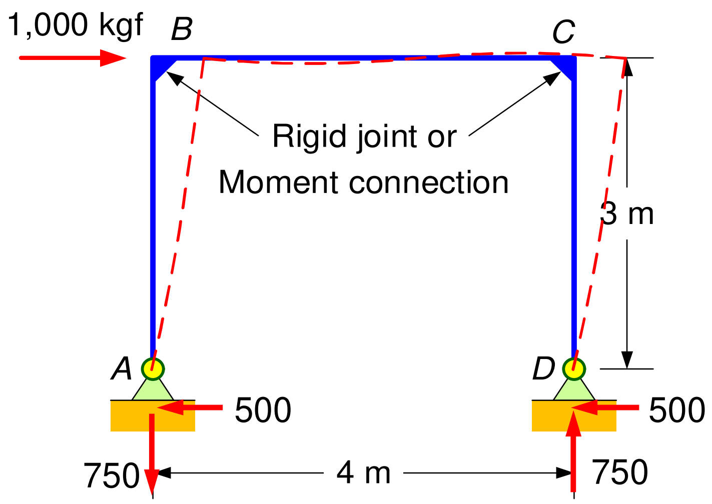


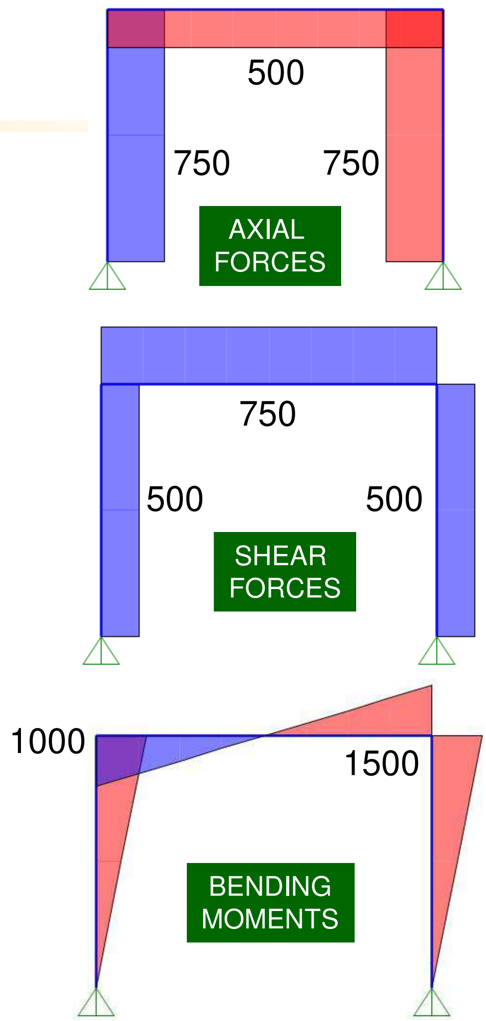


No shear and moment in column on roller support

Rigid Portal Frame

Pinned Supports

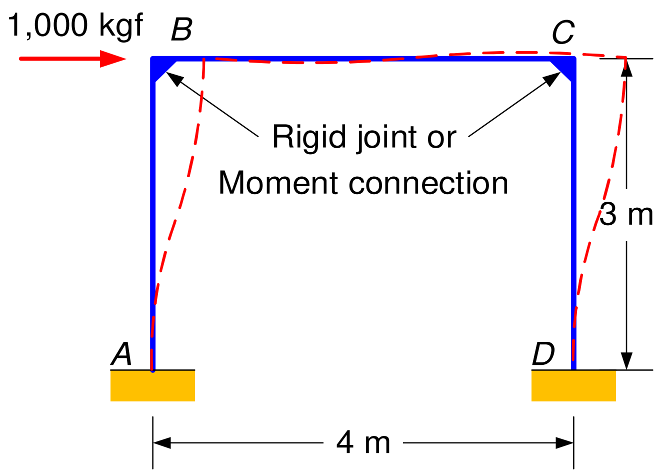


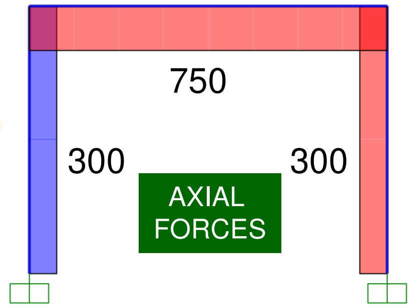


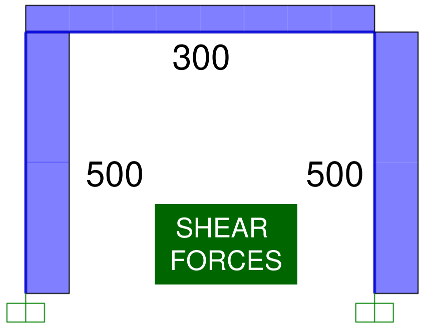
Half lateral force = Equal shear in each column

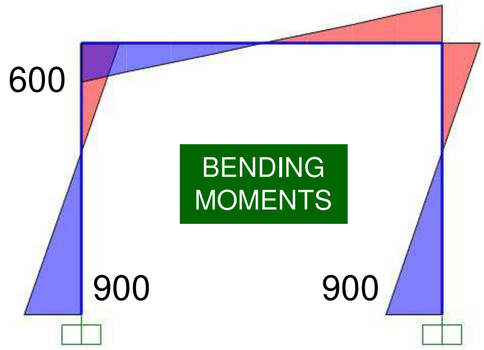
Rigid Portal Frame

Fixed Supports



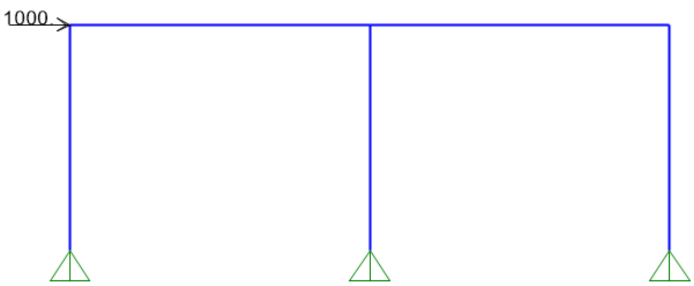


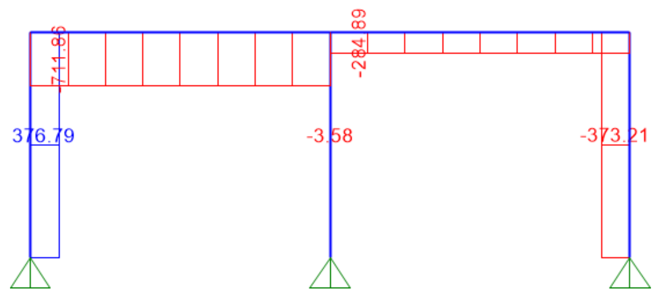


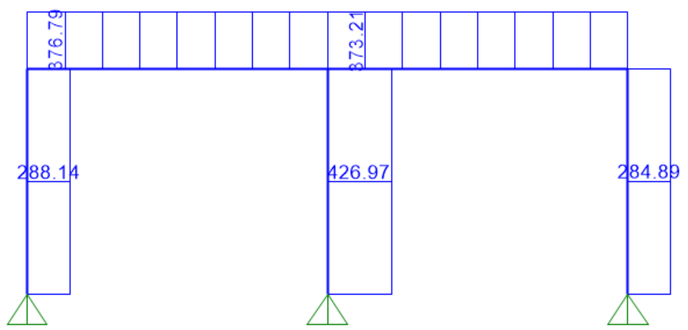


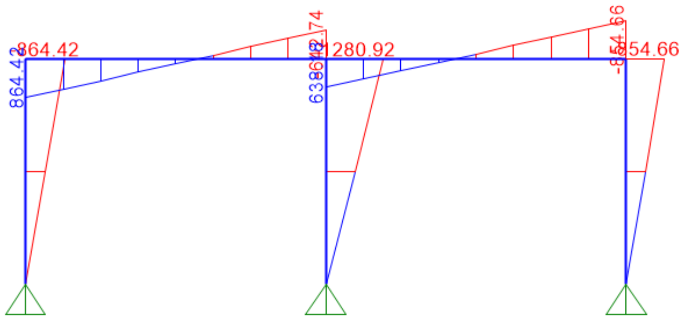
Less moment in columns but need moment connection @ supports

2 Portals Frame



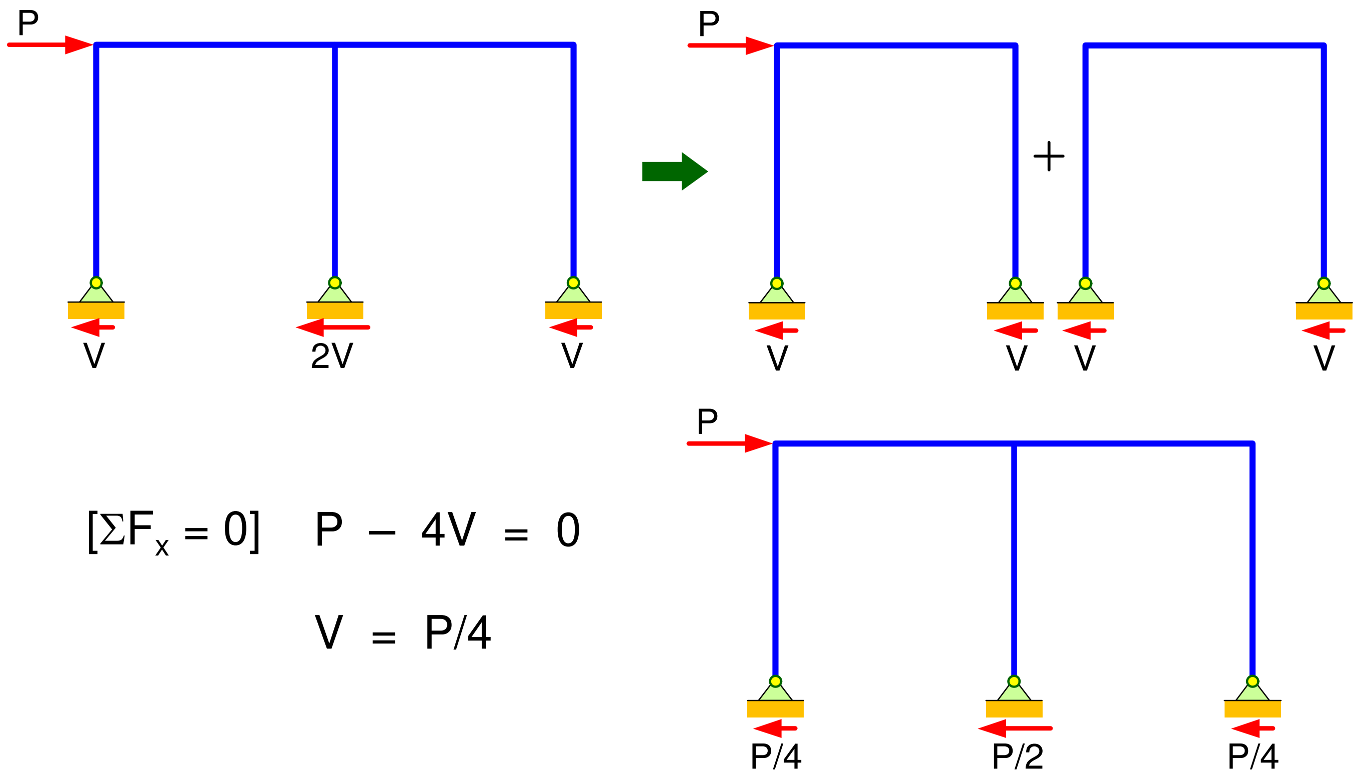






Portals Frame Approximations

- Equal shear in each portal

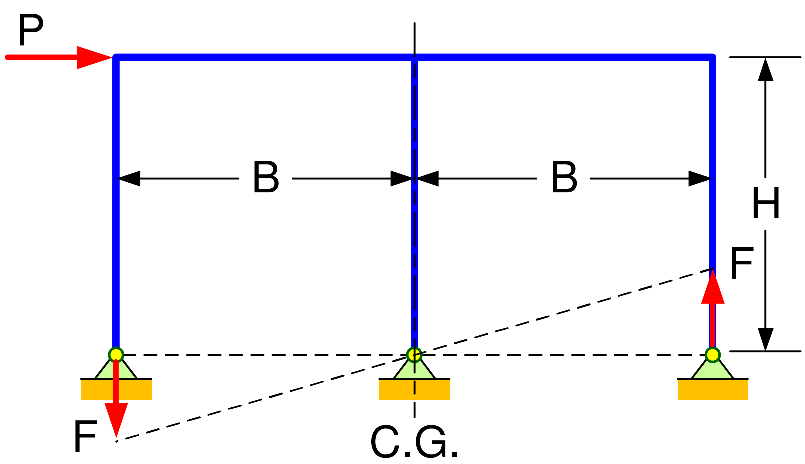


$[\Sigma F_x = 0] \quad P - 4V = 0$

$V = P/4$

Portals Frame Approximations

- Axial force in columns vary by distance from C.G.

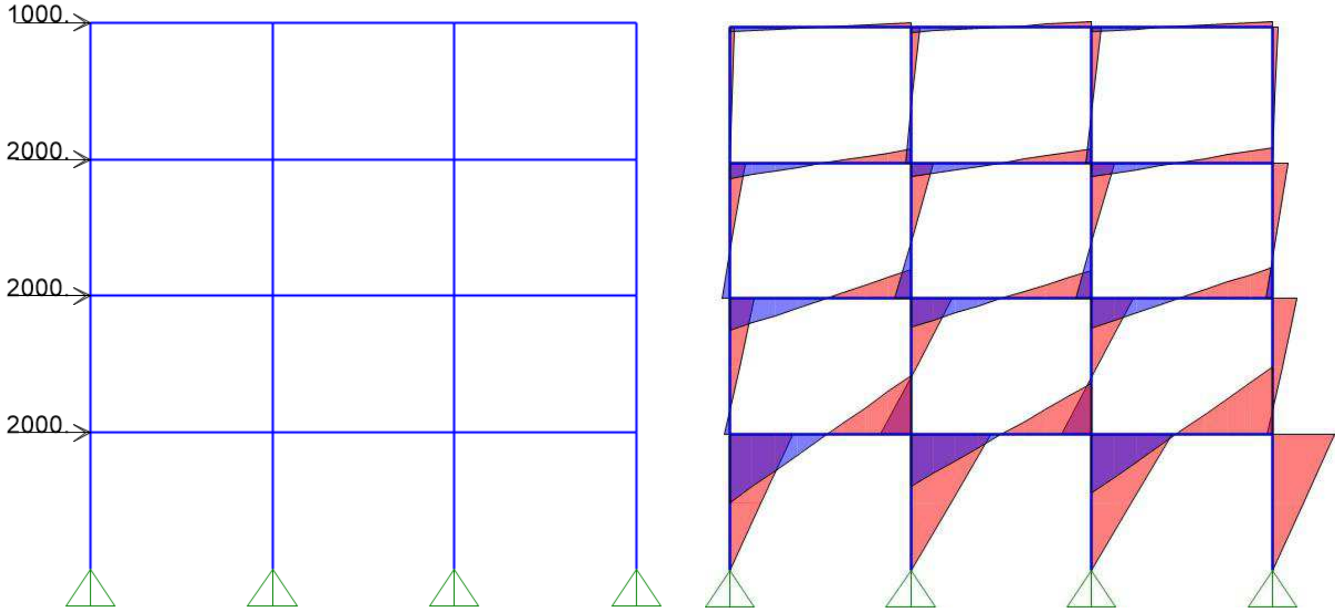


$[\Sigma M_{CG} = 0] \quad PH - 2FB = 0$

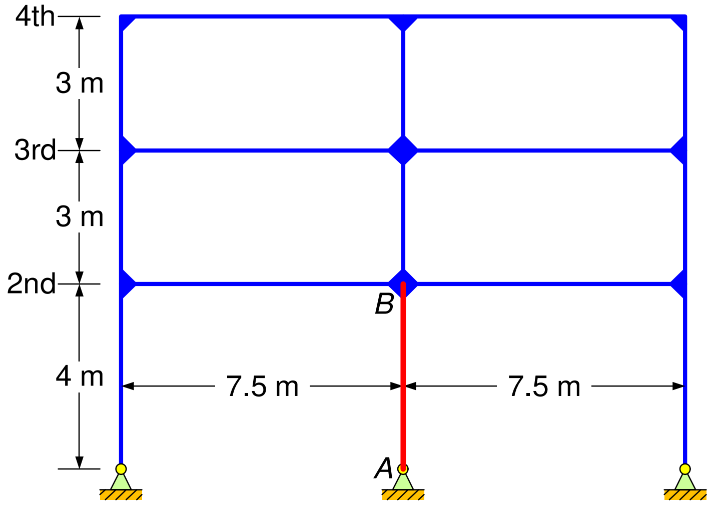
$F = PH / (2B)$

Portals Frame Approximations

- Inflection Point = Zero Moment @ Mid-Span & Mid-Height



ตัวอย่างที่ 12-4 จงออกแบบเสา AB ในโครงข้อแข็งดังในรูป ระยะห่างระหว่างโครง 6 เมตร พื้นคอนกรีตหนา 15 ซม. น้ำหนักจร 300 กก./ตรม., น้ำหนักคงที่เพิ่มเติม 100 กก./ตรม., น้ำหนักผนัง 100 กก./ตรม. แรงลมด้านข้าง 50 กก./ตรม. ใช้ Alignment chart โดยสมมุติว่า $I_g / I_c = 1.5$ และใช้เหล็ก A36



Wind load :

4^{th} floor : $W_4 = 50\times6\times1.5 = 450$ kgf

3^{rd} floor : $W_3 = 50\times6\times3 = 900$ kgf

2^{nd} floor : $W_2 = 50\times6\times3.5 = 1{,}050$ kgf

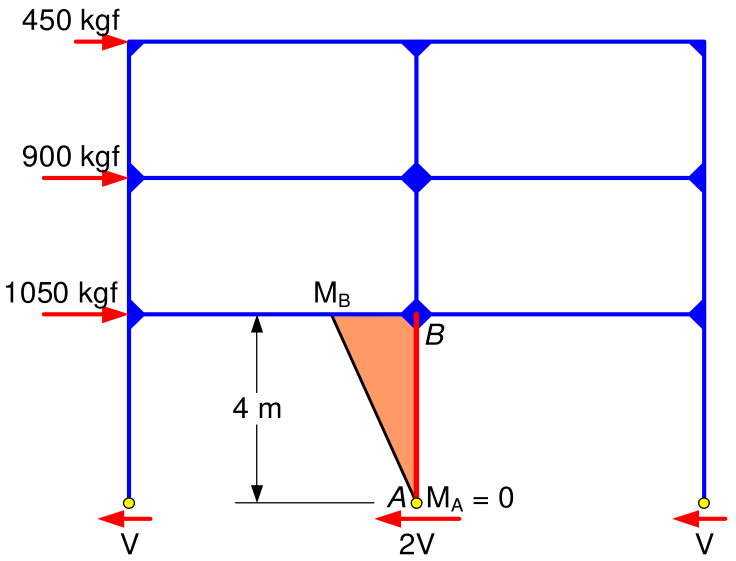
Floor load :

Concrete slab = 2400×0.15	= 360 kg/m²
Live load	= 300 kg/m²
Super imposed DL	= 100 kg/m²
Partition load	= 100 kg/m²
Total load	= **860 kg/m²**

Column load AB :

$P_{AB} = 0.86\times7.5\times6\times3 = 116$ ton

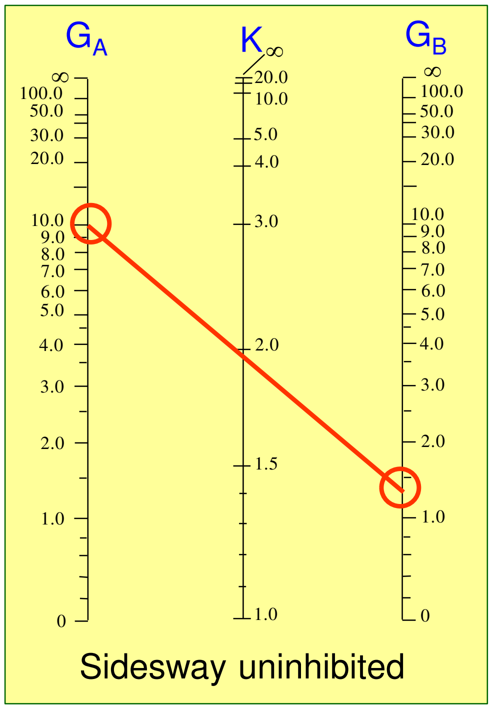
+ beam & column weight say **120 ton**



Moment :

$$V_{AB} = (450+900+1050)/2 = 1{,}200 \text{ kgf}$$

$$M_B = 1.2 \times 4.0 = 4.8 \text{ t-m}$$



Alignment chart :

สมมุติว่า $I_g / I_c = 1.5$

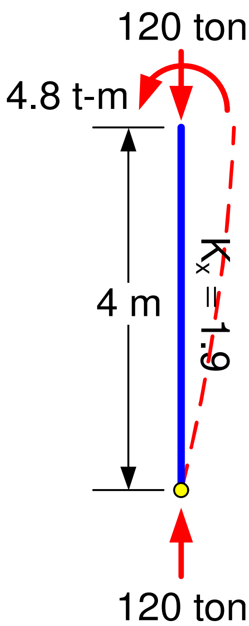
$$G_B = \frac{\Sigma(I/L)_{col}}{\Sigma(I/L)_{beam}} = \frac{I/3.5 + I/4}{2 \times 1.5I/7.5} = 1.34$$

$$G_A = 10 \text{ (pin end)}$$

From sway chart : **$K = 1.9$**

Beam-Column Design :

โครงมีการโยกตัวด้านข้างค่า $C_{mx} = 0.85$



ใช้วิธีแรงตามแนวแกนเทียบเท่า ใช้ค่าเริ่มต้น $m = 8.5$

$$P_{eff} = P_0 + M_x m = 120 + 4.8 \times 8.5 = 160.8 \text{ ton}$$

สมมุติหน่วยแรงอัดที่ยอมให้ $F_a = 1{,}000$ กก./ซม.^{2}

$$A_{req'd} = \frac{160.8}{1.0} = 160.8 \text{ cm}^2$$

เลือกหน้าตัด W350×137 ($A = 173.6$ cm^2, $m = 6.6$)

$$P_{eff} = 120 + 4.8 \times 6.6 = 151.7 \text{ ton}$$

ตรวจสอบหน้าตัด W350×137 ($S_x = 2{,}300$ cm^3, $r_x = 15.2$ cm, $L_c = 4.45$ m, $L_u = 10.64$ m)

$$f_a = 120 \times 10^3 / 173.6 = 691 \text{ กก./ซม.}^2$$

$$K_x L_x / r_x = 1.9(400) / 15.2 = 50 \rightarrow F_a = 1{,}281 \text{ กก./ซม.}^2$$

$f_a / F_a = 691 / 1{,}281 = 0.54 > 0.15$ ดังนั้นใช้สมการ (H1-1) และ (H1-2)

$$f_{bx} = 4.8 \times 10^5 / 2{,}300 = 209 \text{ กก./ซม.}^2$$

$F_{bx} = 0.60F_y$ ที่กลางช่วง $= 1{,}500$ กก./ซม.^{2} เนื่องจาก $L_c < L < L_u$

$F_{bx} = 0.66F_y = 1{,}650$ กก./ซม.^{2} ที่ปลาย

$$F'_{ex} = \frac{12\pi^2(2.1\times10^6)}{23(50)^2} = 4{,}326 \text{ kg/cm}^2$$

$$\frac{C_{mx}}{1-\frac{f_a}{F'_{ex}}} = \frac{0.85}{1-\frac{691}{4{,}326}} = 1.012 > 1.0$$

แทนค่าลงในสมการ (H1-1) และ (H1-2)

$$\text{(H1-1)}: \frac{f_a}{F_a} + \frac{C_{mx}f_{bx}}{\left(1-\frac{f_a}{F'_{ex}}\right)F_{bx}} = \frac{691}{1{,}281} + \frac{(1.012)(209)}{1{,}500} = 0.68 < 1.0 \quad \textbf{OK}$$

$$\text{(H1-2)}: \frac{f_a}{0.60F_y} + \frac{f_{bx}}{F_{bx}} = \frac{691}{1{,}500} + \frac{209}{1{,}650} = 0.59 < 1.0 \quad \textbf{OK}$$

$\therefore$ เลือกใช้หน้าตัดเสา **W350×137**