CE 3213 Structural Analysis & Design –II

Lecture: 3 hrs/week Credits: 3.00

Prereq. CE 3111

Approximate analysis of statically indeterminate structures, deflection of beams, frames and trusses by virtual work method, two hinged arches, influence line for indeterminate structures, wind and earth-quake analysis. ~~composite structures~~.

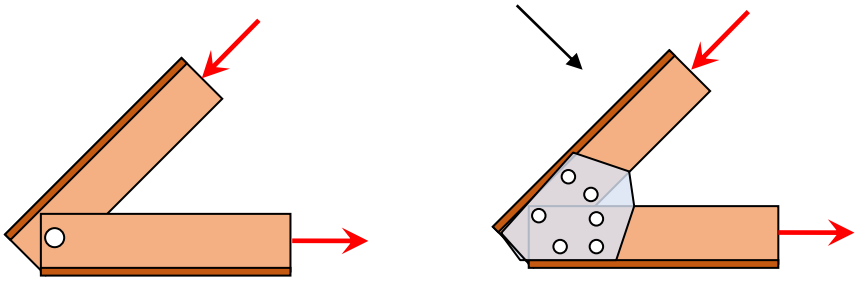
Approximate analysis of statically indeterminate structures

1. **Approximate analysis due to vertical load**
2. **Portal Method**
3. **Cantilever Method**
4. ~~**Factor Method**~~

The analysis of every structure depends on assumptions in order to carry out the analysis.

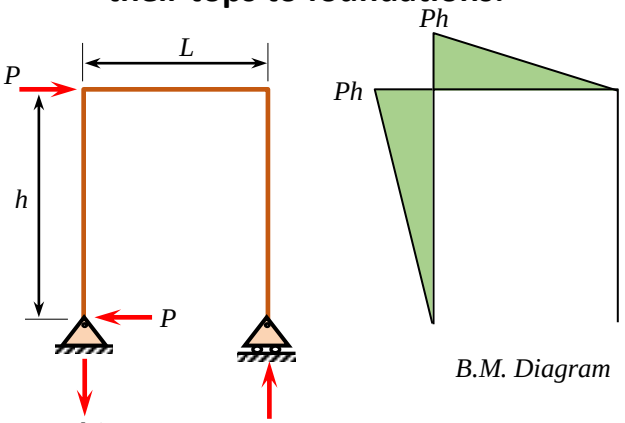
For example truss

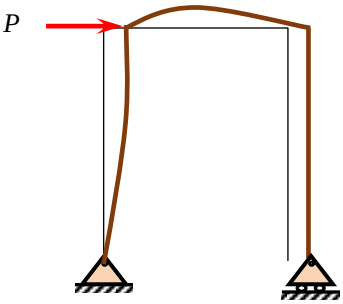
Pin-connected
Pins are frictionless
So that the truss members carry axial force only.
Pin cannot be frictionless. Some degree of restrain always exists in real frame. However, for simplicity of analysis it is neglected.

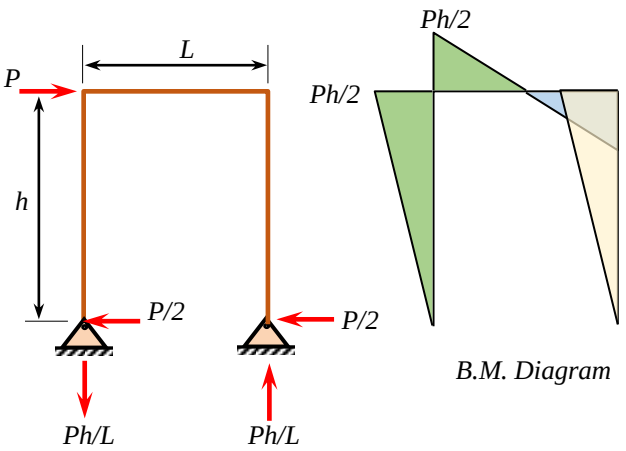


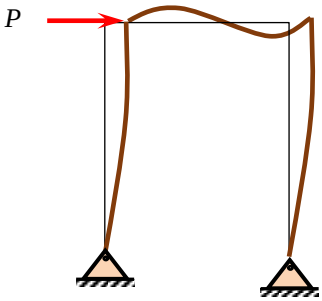
Portals

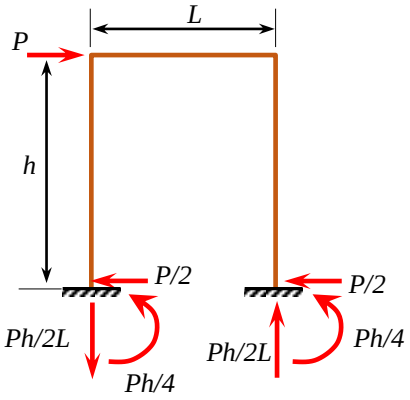
Portal structures generally used to transfer the horizontal loads applied at their tops to foundations.

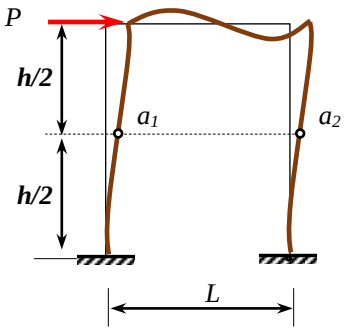


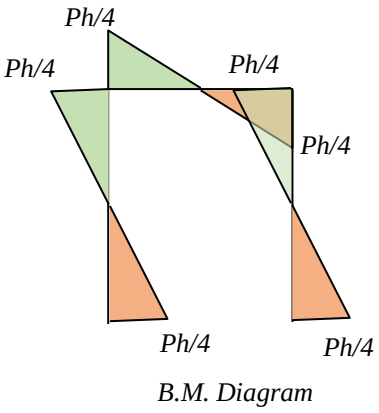


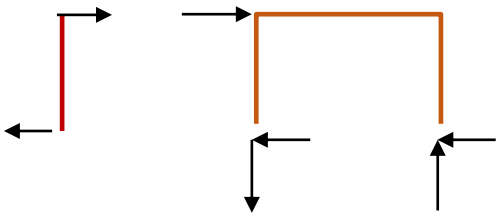












Degree of Indeterminacy and Number of Assumptions

The degree indeterminacy,

$$NI = NF\text{-}NP$$

Where, NF = twice the number of members

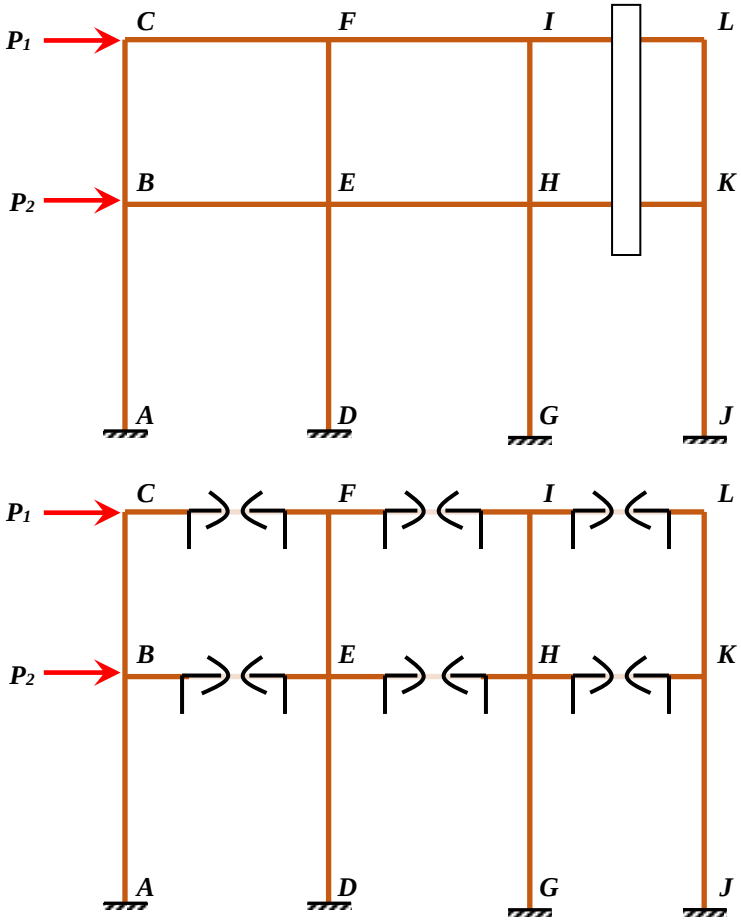
NP = sum of unknown joint rotation and sidesway.

Above case,

NF = 2*14 = 28

NP = 8(joint rotation) + 2(sidesway) = 10

So, NI = 28-10 = 18



For each cut, three pairs of unknown,
Three numbers of compatibility conditions/ degrees of freedom
– one vertical displacement, one horizontal displacement and one slope/ rotation
The degree of indeterminacy = 3 for each cut
Total degrees of indeterminacy =3*6 = 18

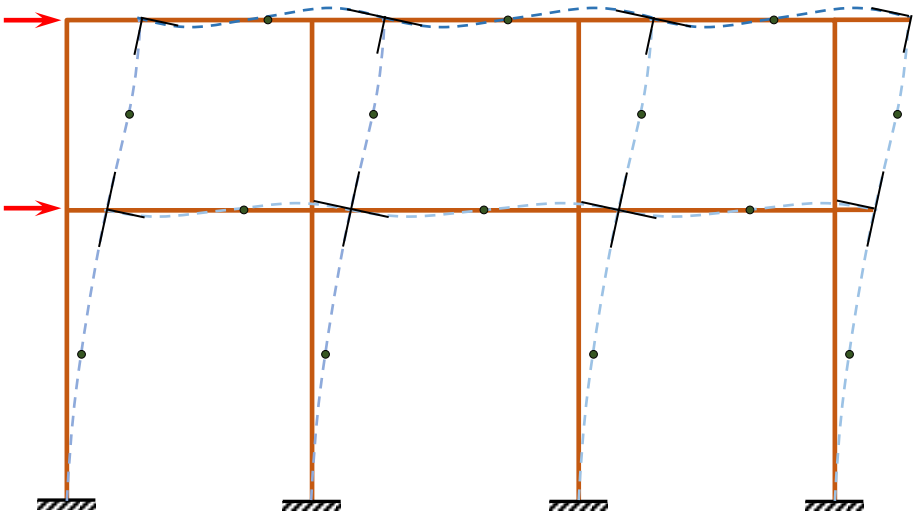
For rectangular building,
Degree of Indeterminacy,

NI = 3* NB*NS

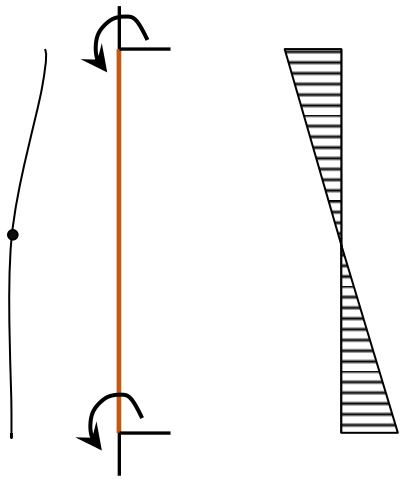
NB = No of bays, NS = No. of Story

Assumptions for Lateral Load Analysis

1. The amount of side sway increases rather fast from the lower toward the upper stories; all joint rotations are clockwise for later loading coming from the left.
2. All column end moments are counter-clockwise, producing horizontal shears from right to left at lower ends; there is one point of inflection in each column.
3. All beam end moments are clockwise, producing vertical shears downward at the left end and upward at the right end; there is one point of inflection in each beam.



Response of frame subjected lateral loads.



Typical column with BM diagram

The numbers of independently unknown end moments = 28

The equations of statics = 10

The degree of indeterminacy = 18

The 10 equations of statics are as follows

1. At each of the eight joints, the numerical sum of the counterclockwise column-end moments must be equal to the numerical sum of the clockwise beam-end moments (The counterclockwise or clockwise sense refers to the action on the member end)
2. The sum of the resisting horizontal shears at the lower ends of all columns in each of the two stories must be equal to the total lateral load above the level of the resisting horizontal shears.

The number of assumptions are required to solve = 18

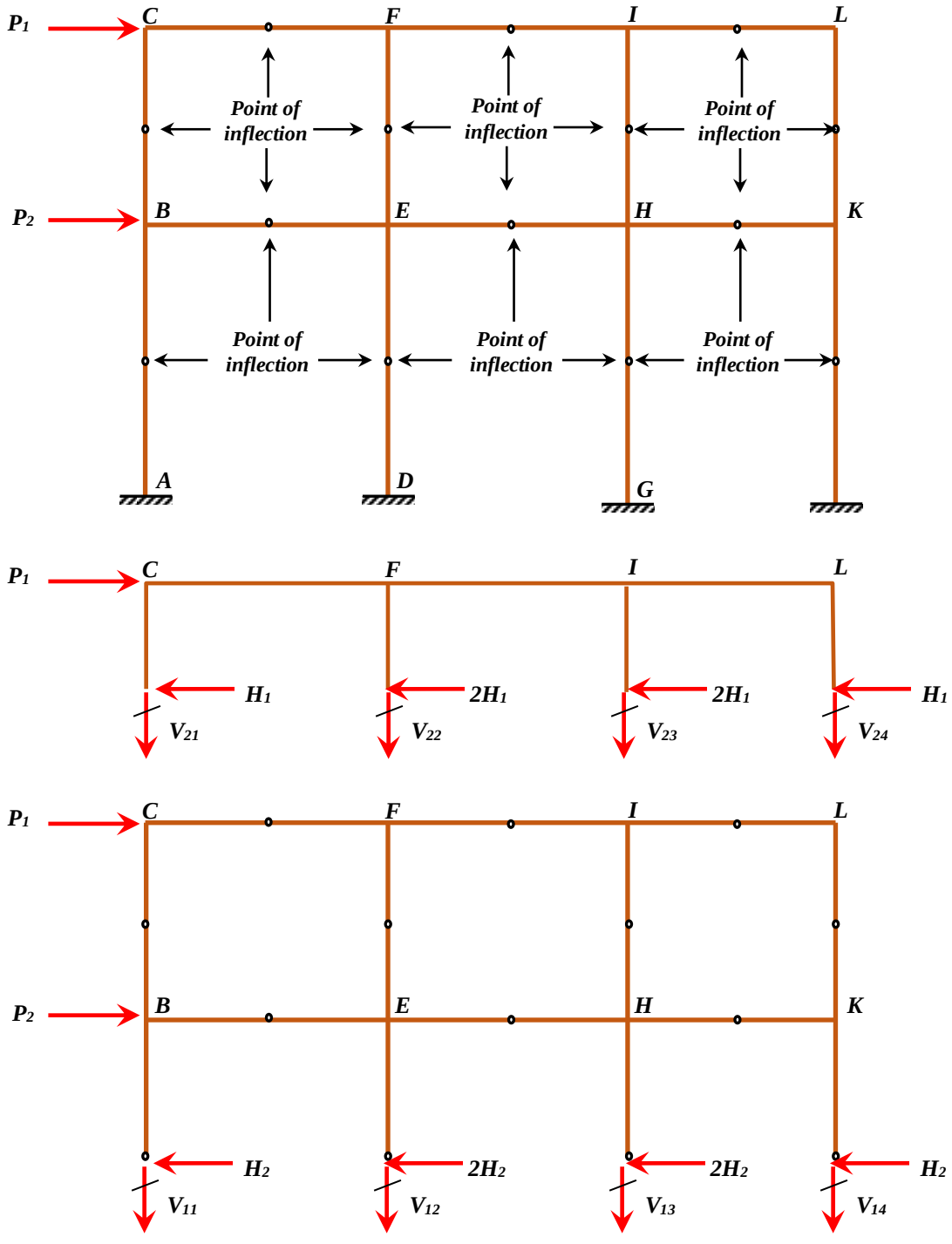
The points of inflection are at the midpoints of all column of all columns and beams provide/fulfill 14 assumptions.

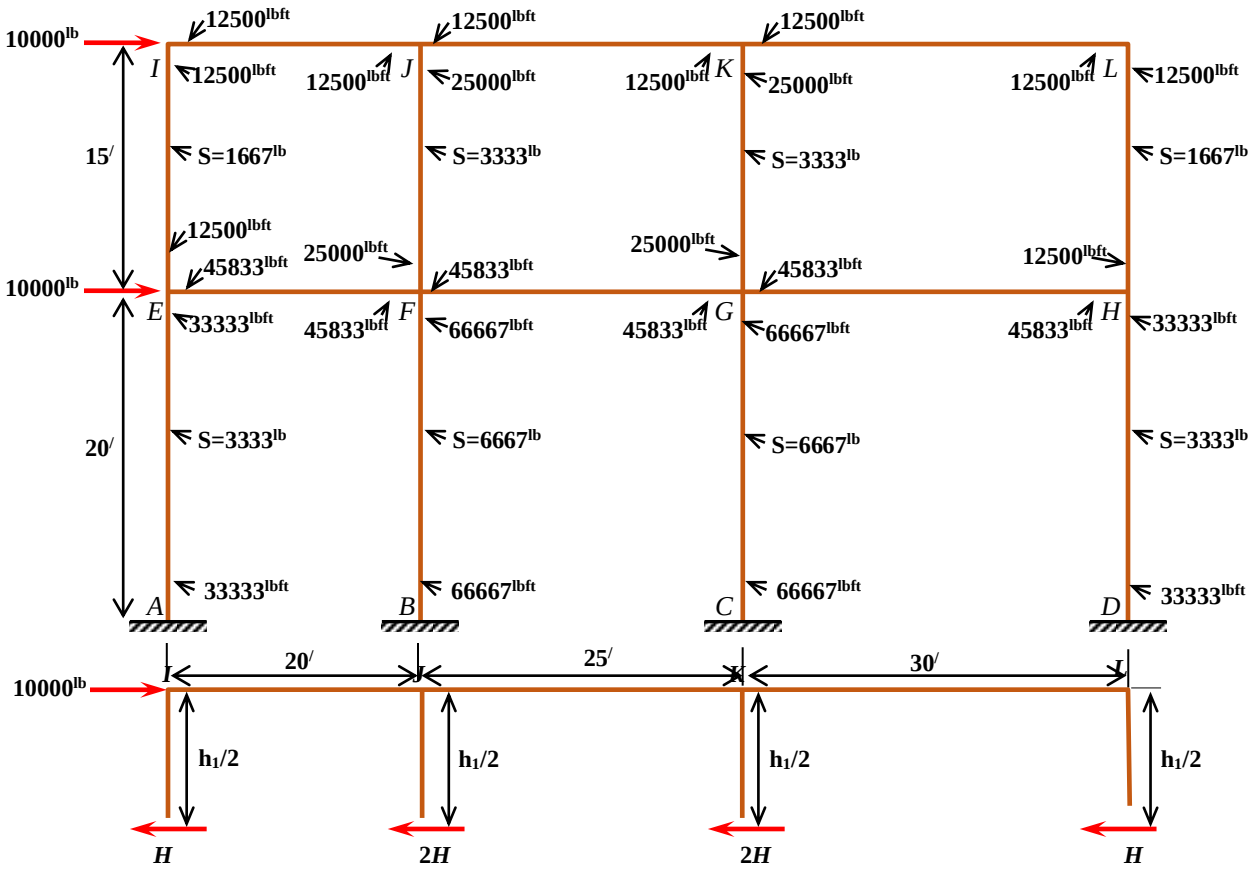
The relative magnitudes of the vertical shear forces in the beams in each story = 2

Therefore, total no. of assumption due to vertical shear = 2*2= 4

Portal Method

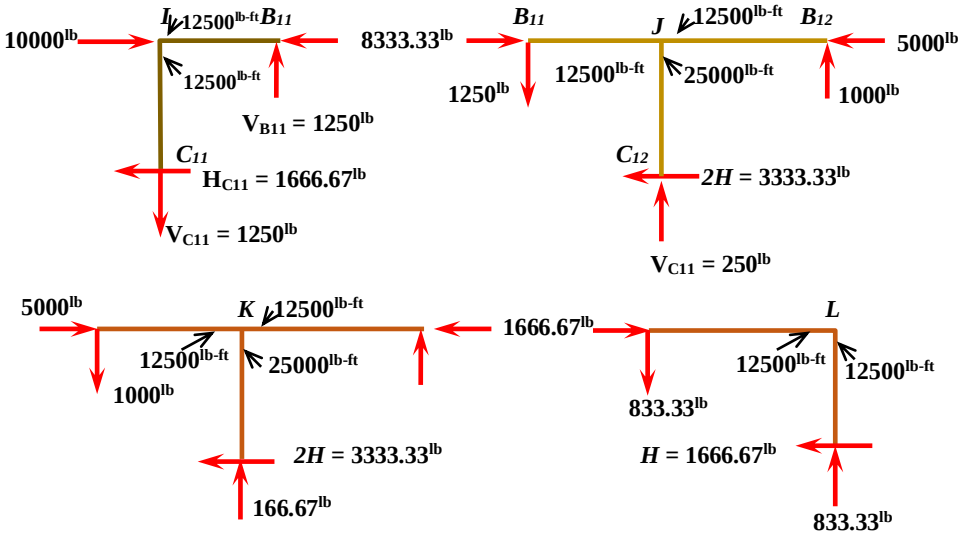
1. There is a point of inflection at the center of each girder.
2. There is a point of inflection at the center of each column.
3. Total horizontal shear on each story is divided between the columns of that story in a manner such that each interior column carries twice as much shear as each exterior column.

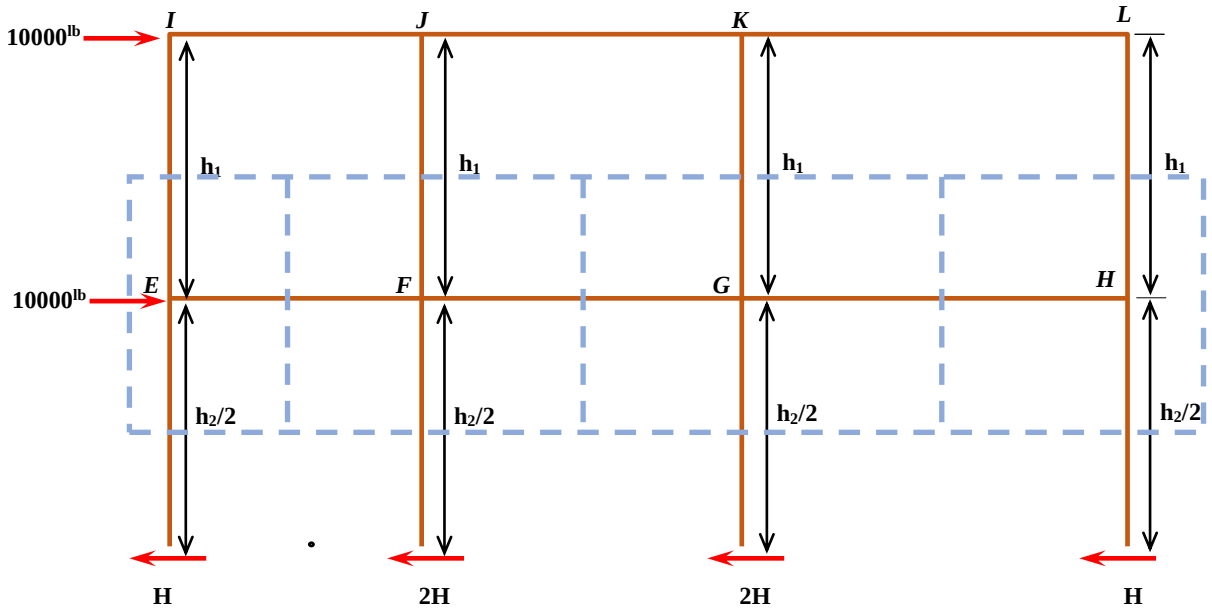




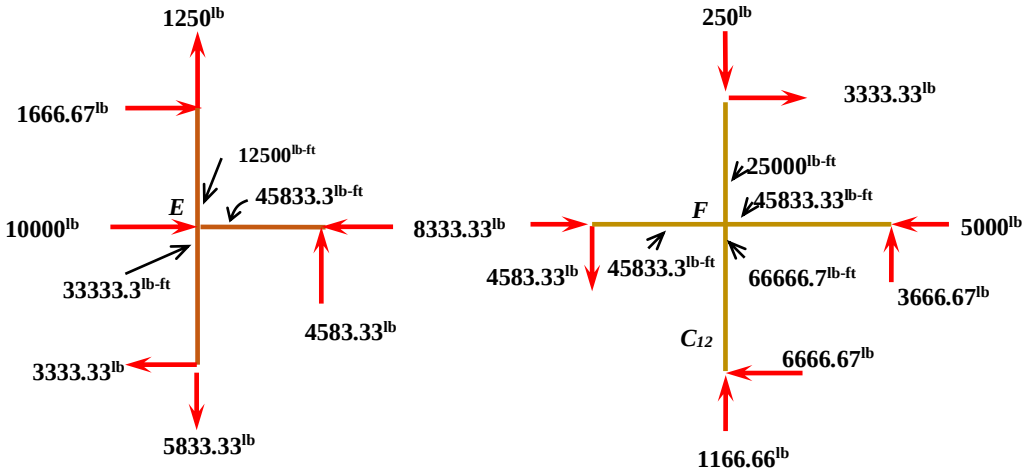
$$\sum F_x = 10000 - H - 2H - 2H - H = 0; \qquad H = 1666.67^{lb}$$

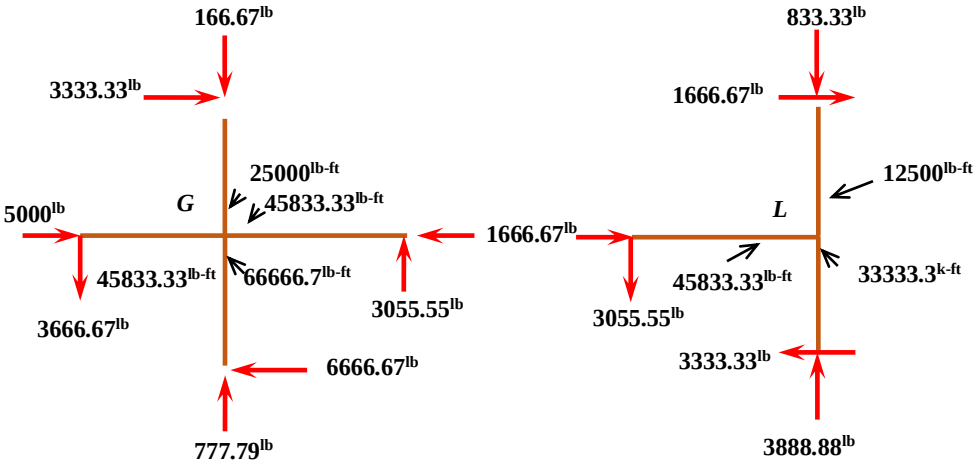
$$\sum M_{B_{11}} = 1666.67 * 7.5 - V_{C_{11}} * 10 = 0; \qquad V_{C_{11}} = 1250^{lb}$$



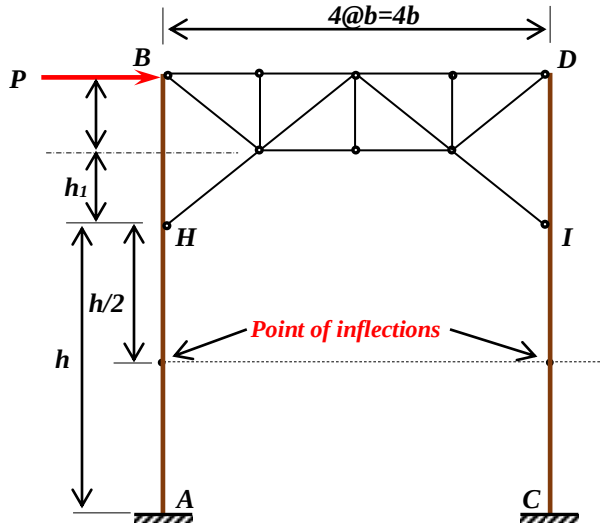


$$\sum F_x = 10000 + 10000 - H - 2H - 2H - H = 0; \qquad H = 3333.33^{lb}; \quad 2H = 6666.67^{lb}$$



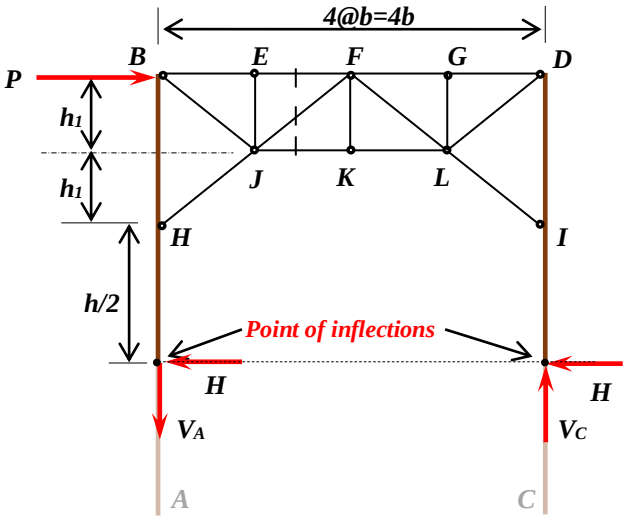

166.67lb
3333.33lb
25000lb-ft
G
45833.33lb-ft
5000lb
45833.33lb-ft
66666.7lb-ft
3055.55lb
3666.67lb
6666.67lb
777.79lb
833.33lb
1666.67lb
12500lb-ft
L
1666.67lb
45833.33lb-ft
33333.3k-ft
3055.55lb
3333.33lb
3888.88lb

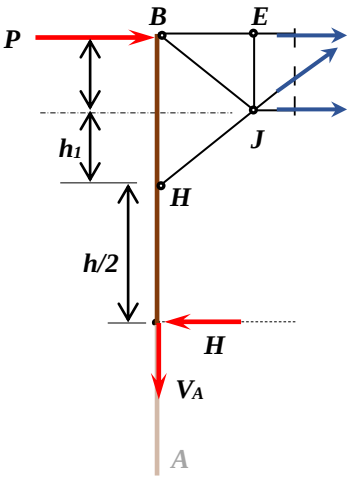
Portals for bridges are often arranged in a manner as follows

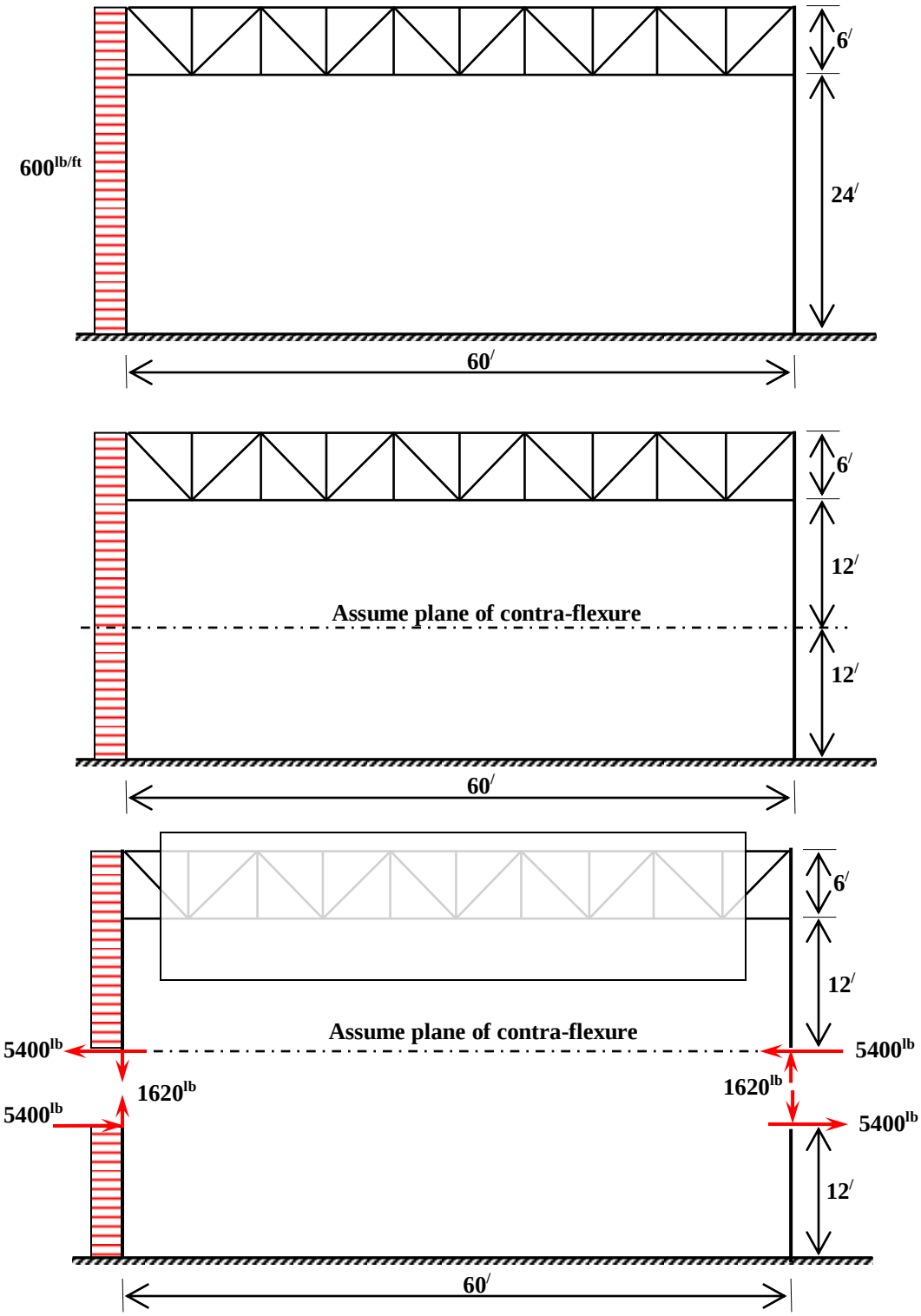


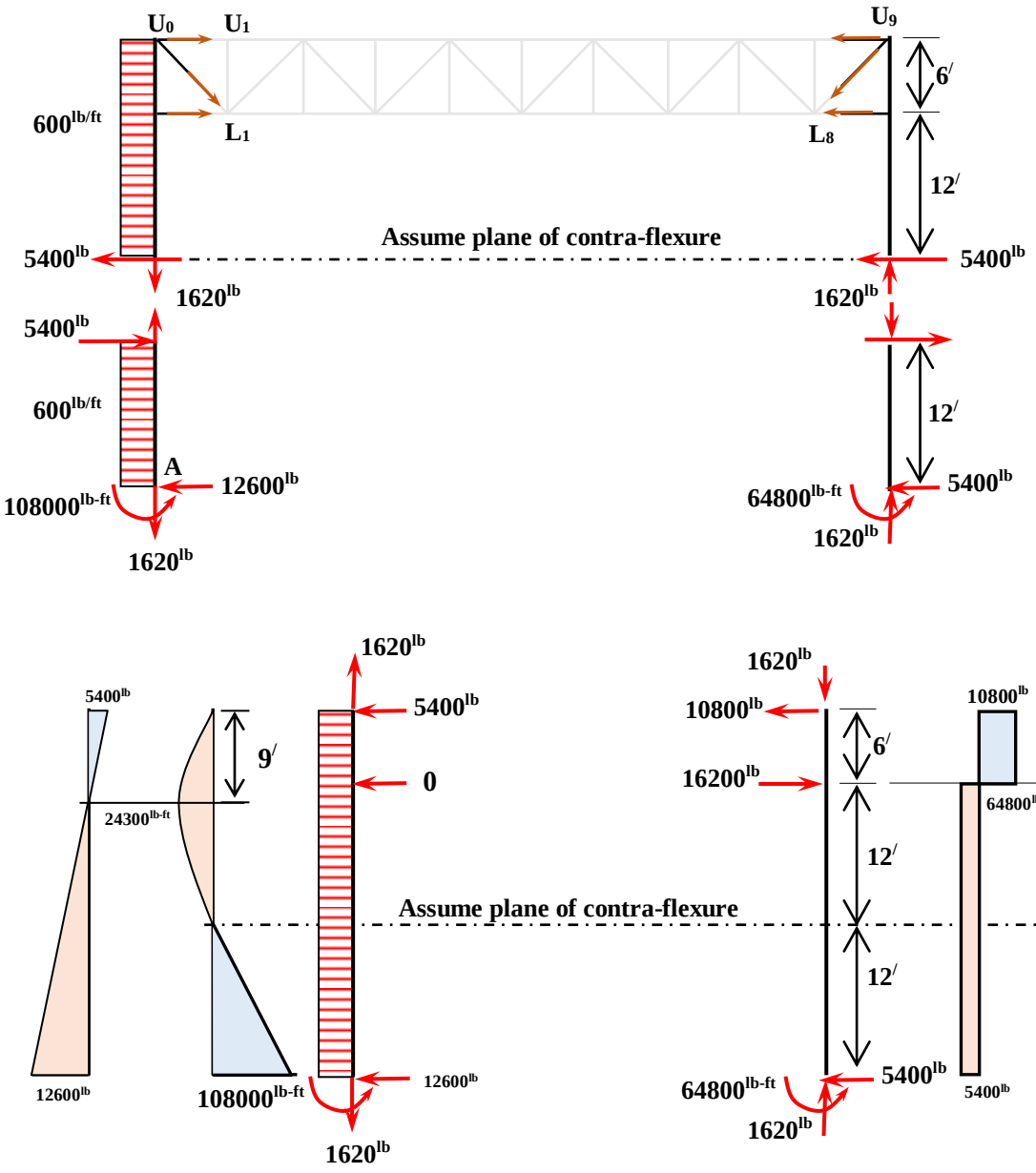
Assumptions

1. Horizontal reactions are equal.
2. A point of inflection occurs midway between the base *A* of the leg *AB* and the end *H* of the knee brace for leg *AB*. (Half of AH)
3. A point of inflection occurs midway between the base *C* of the leg *CD* and the end *I* of the knee brace for leg *CD*.

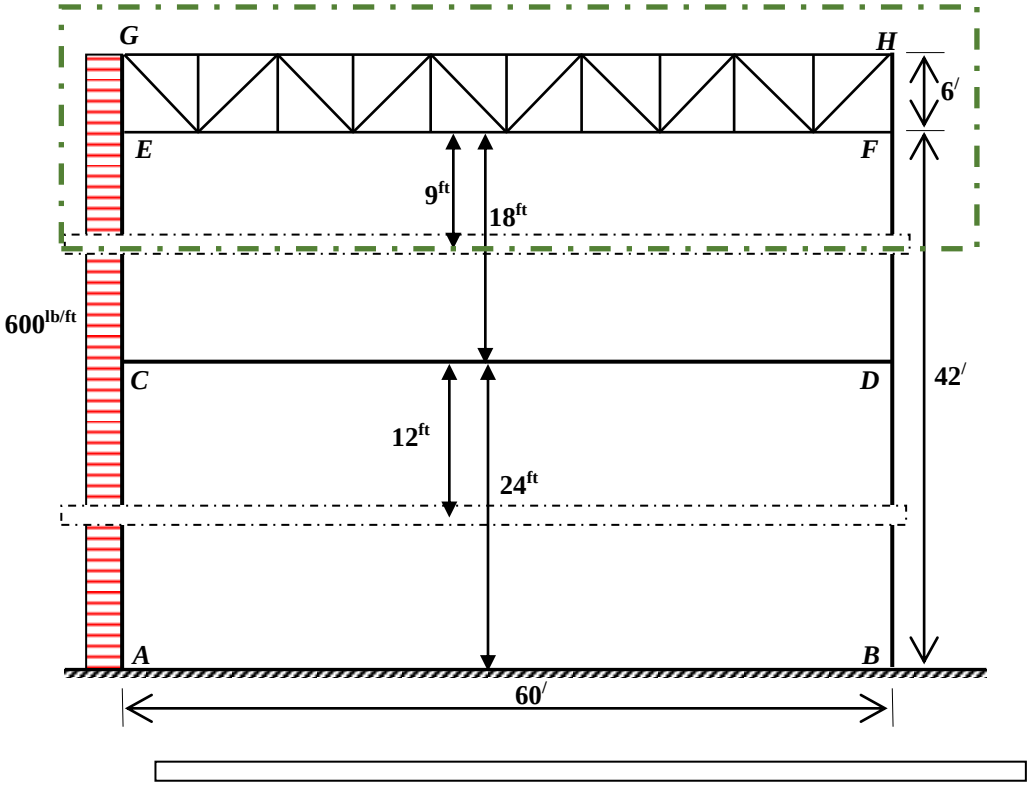


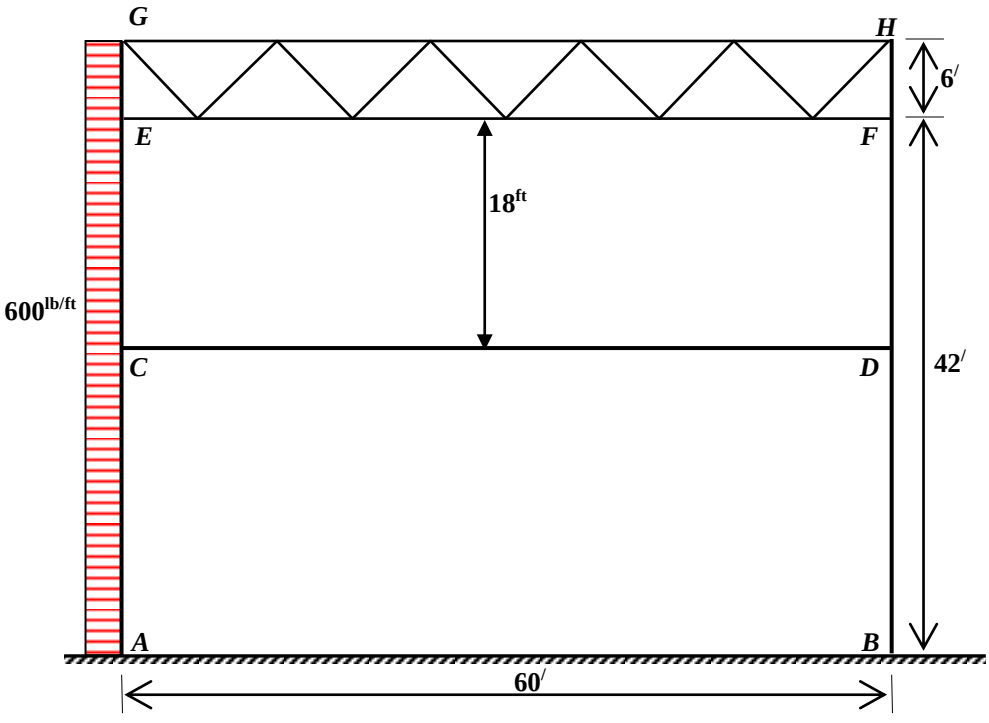


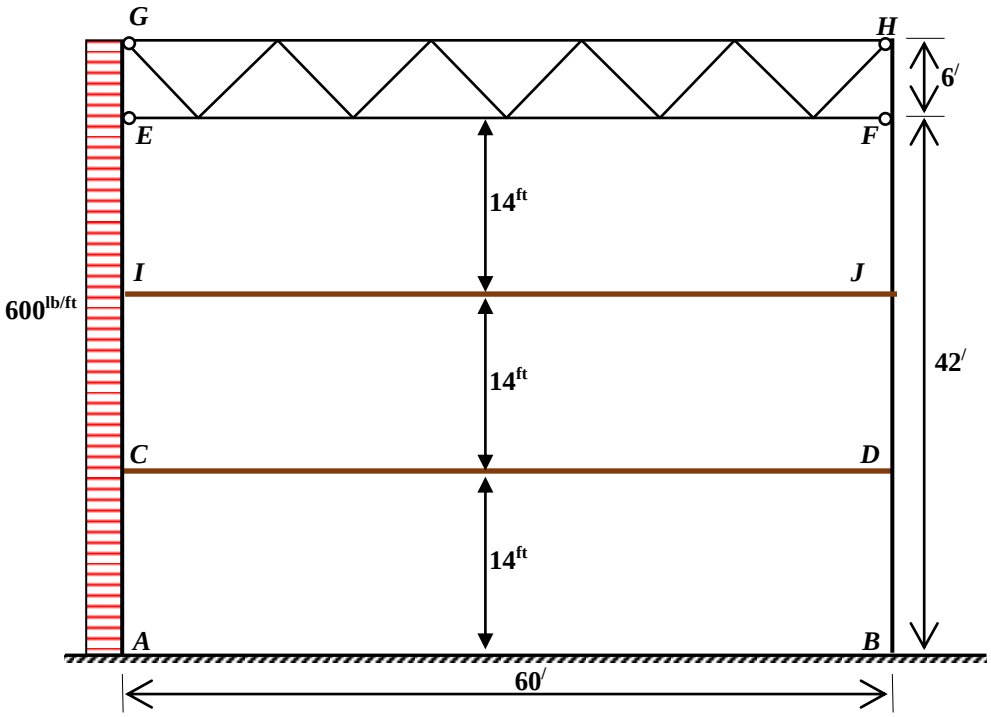

600lb/ft
6′
24′
60′
6′
12′
Assume plane of contra-flexure
12′
60′
6′
12′
Assume plane of contra-flexure
5400lb
1620lb
5400lb
1620lb
5400lb
12′
12′
60′



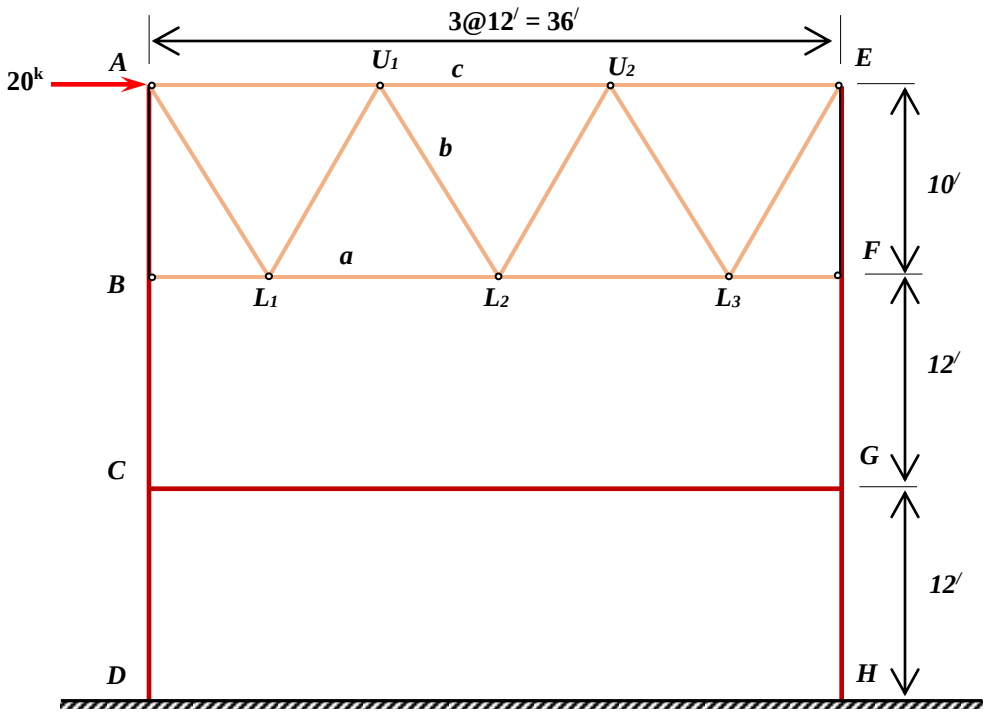
Solve the above problem considering hinges at the bases of columns.

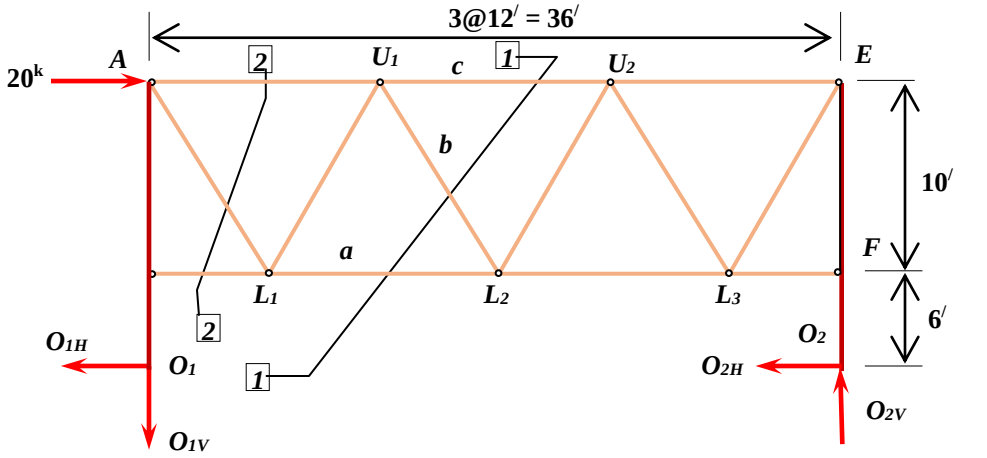

G
H
6/
E
F
9ft
18ft
600lb/ft
C
D
42/
12ft
24ft
A
B
60/


G
H
6/
E
F
18ft
600lb/ft
C
D
42/
A
B
60/


G
H
6′
E
F
14ft
I
J
600lb/ft
14ft
42′
C
D
14ft
A
B
60′

Example 5 Determine the stresses in the members *a*, *b*, and *c* of the portal frame as shown in figure below. Also draw SF and BM diagram of vertical members.



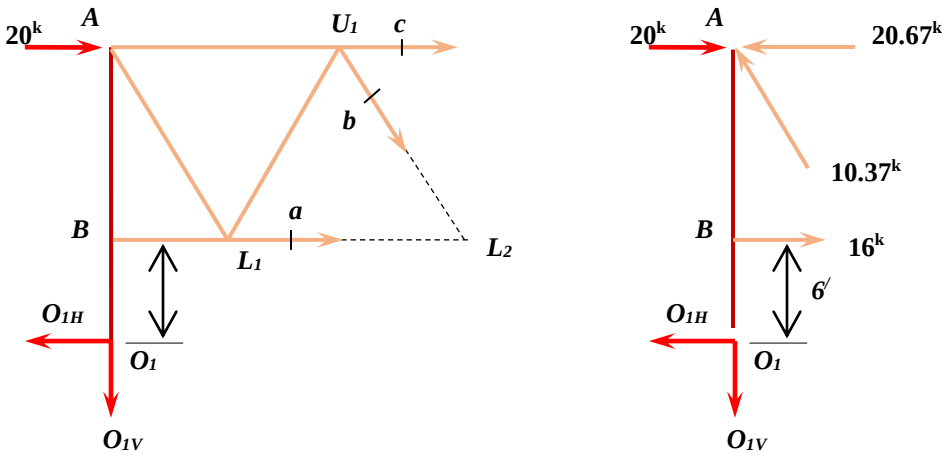


$$\sum F_x = 20 - O_{1H} - O_{2H} = 20 - 2 * O_{1H} = 0; \qquad O_{1H} = 10^k = O_{2H}$$

$$\sum M_{O_2} = 20 * 16 - O_{1V} * 36 = 0; \qquad O_{1V} = 8.89^k$$

$$\sum F_y = 8.89 - O_{2V} = 0; \qquad O_{2V} = 8.89^k$$

Considering left side of section 1-1

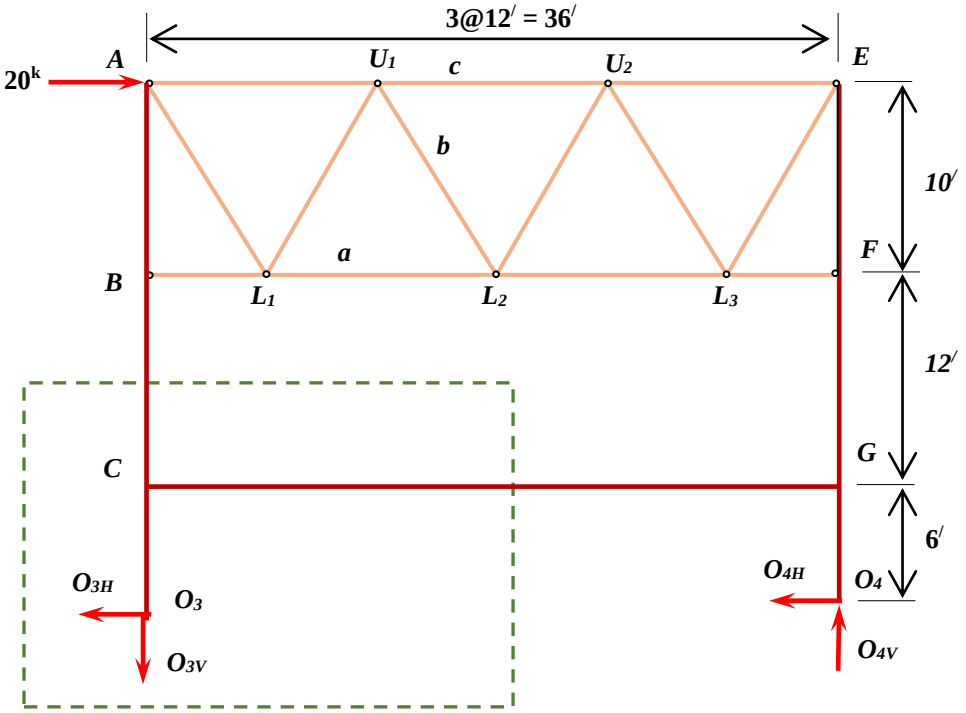


$$\sum M_{U_1} = 10*16 - 8..89*12 - F_a*10 = 0; \qquad F_a = 5.33^k(T)$$

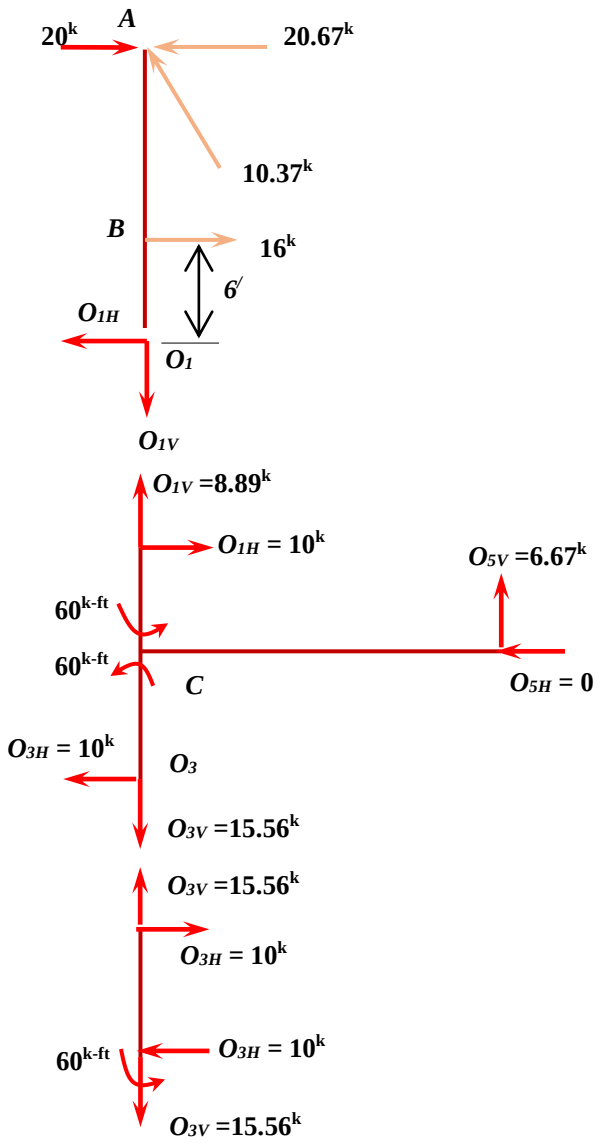
$$\sum F_y = F_{bV} + 8.89 = 0; \qquad F_{bV} = -10.34^k(C)$$

$$\sum M_{L_2} = 20*10 + 10*6 - 8.89*18 + F_c*10 = 0; \qquad F_c = -9.99^k(C)$$

Considering left of section 2-2



$$\sum M_{O_4} = 20*28 - O_{3V}*36 = 0; \qquad O_{3V} = 15.56^{k}; \qquad O_{4V} = 15.56^{k}$$



Prob. 6 Determine stresses in members a, b, c, and d. Also draw SF and BM diagram of columns and girders.

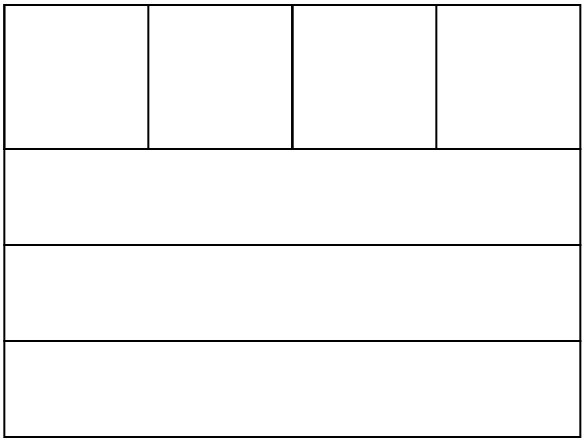
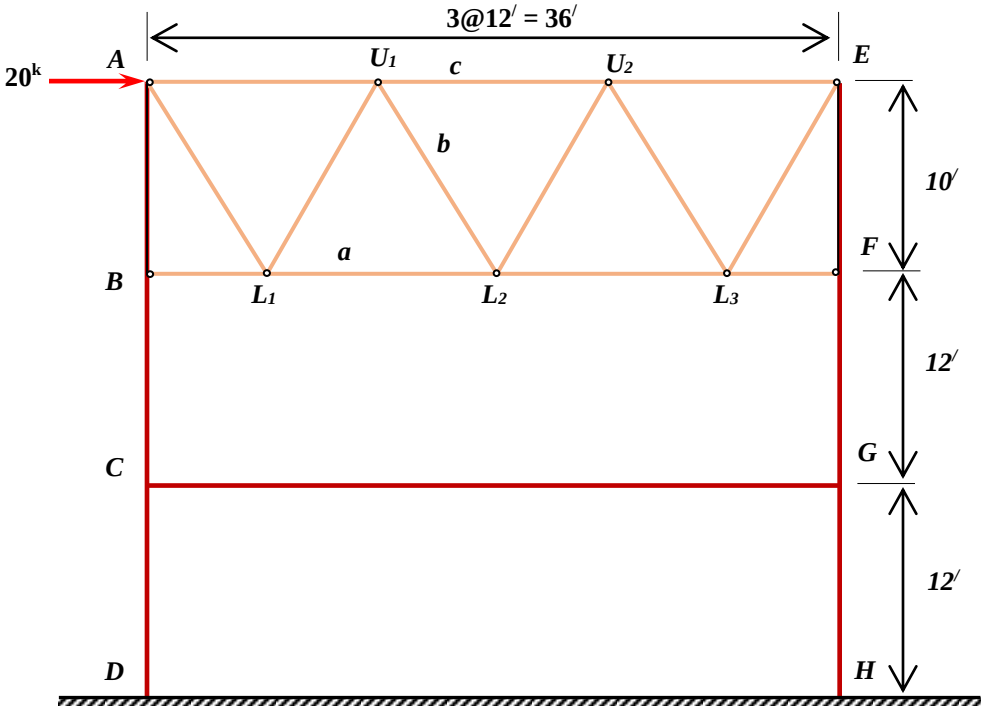
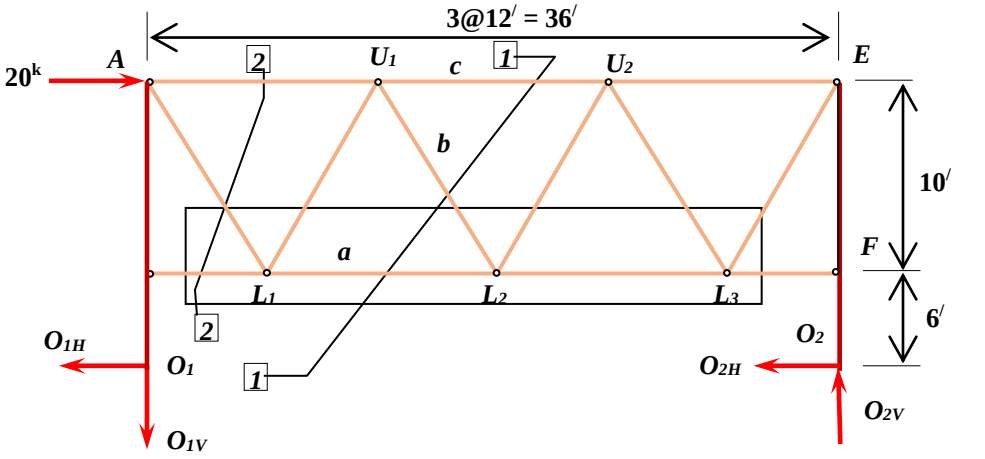
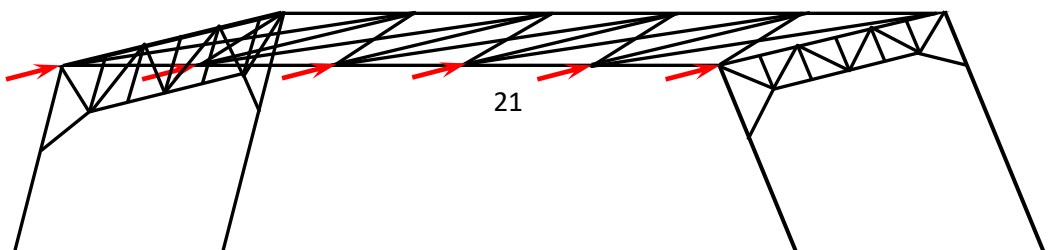
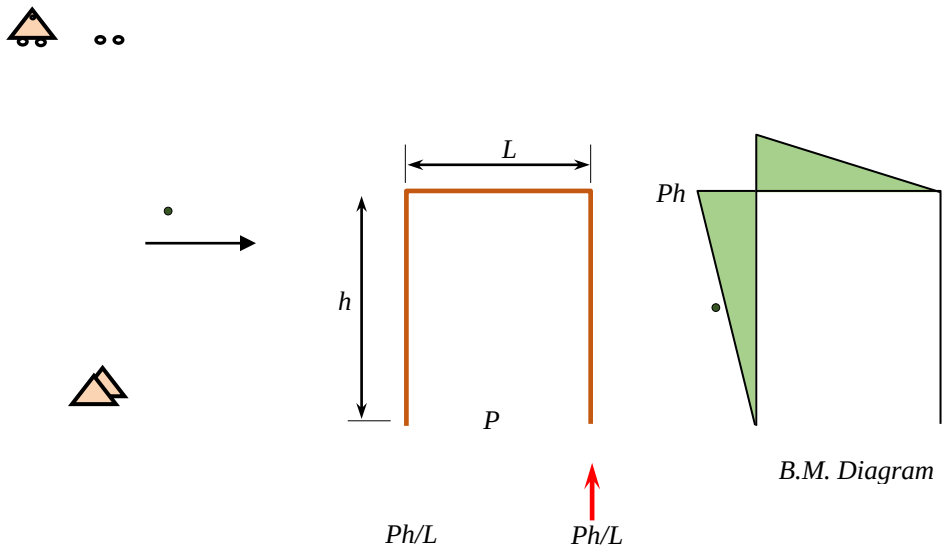


figure below. Also draw SF and BM diagram of vertical members.









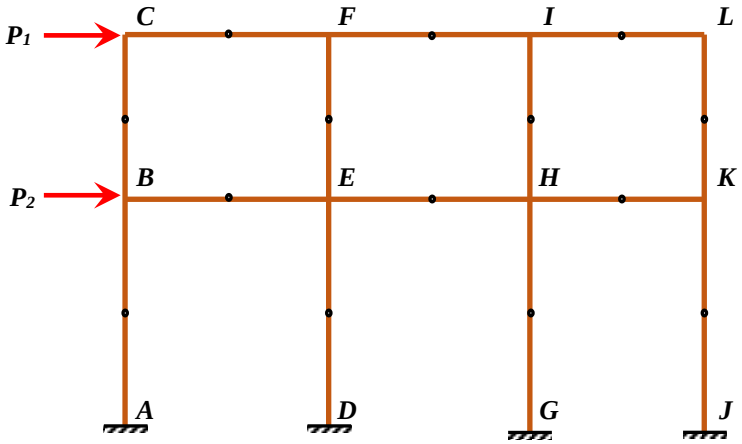
Approximate analysis of statically indeterminate structures

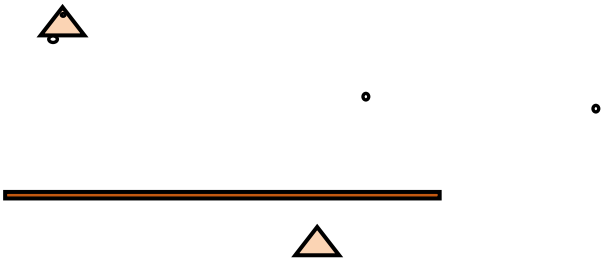
5. **Approximate analysis due to vertical load**
6. **Portal Method**
7. **Cantilever Method**
8. ~~**Factor Method**~~

The Portal Method

Assumptions

1. **There is a point of inflection at the center of each girder.**
2. **There is a point of inflection at the center of each column.**
3. **The total horizontal shear on each story is divided between the columns of that story in a manner such that each interior column carries twice as much shear as each exterior column.**





The approx. analysis of a statically determinate structure dose not depend on the elastic properties of its members. For

Approximate analysis due to vertical load

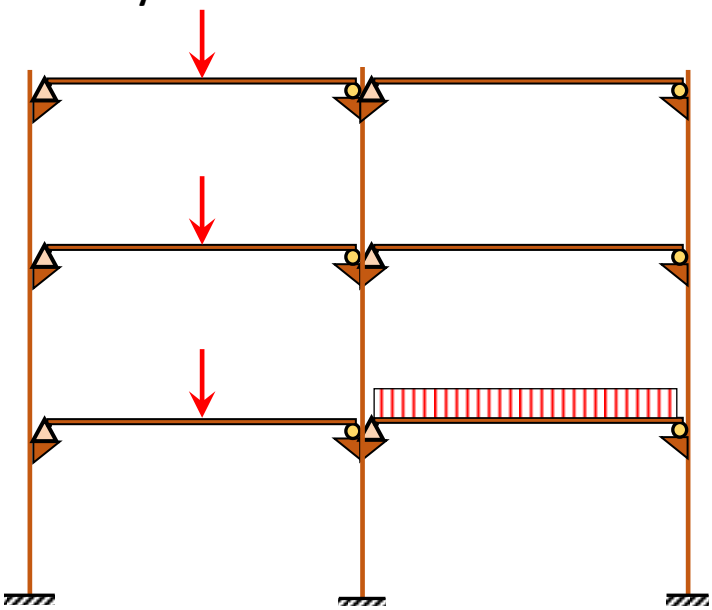
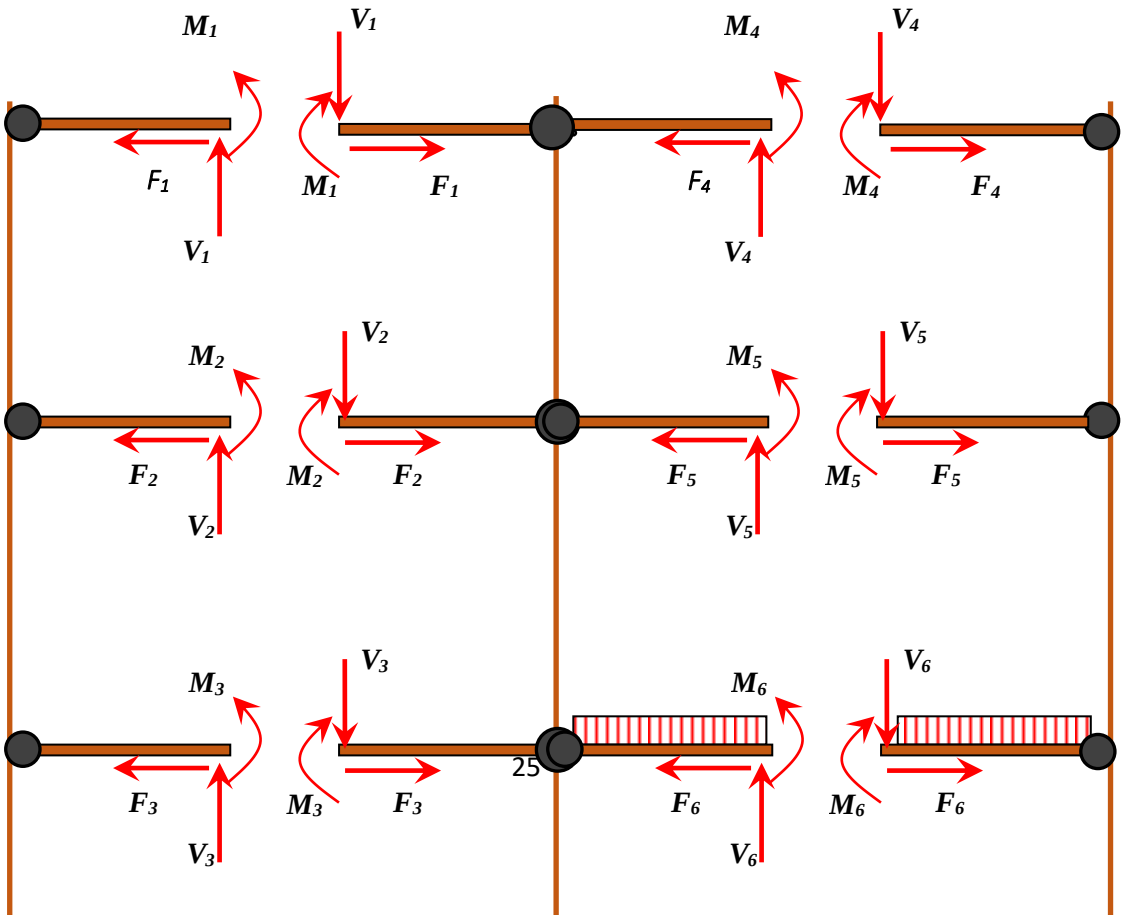


Fig. b

Rigid Frame in which the girders are rigidly connected to the columns so that all members can carry bending moment, shear force, and axial force.

DOI = (3M+R)-3j = (3*15+3*3)-3(12) = 18



Fully Clamped ***semi***

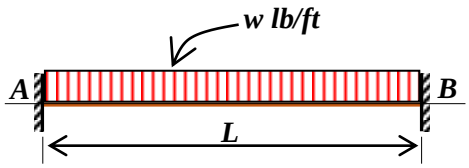
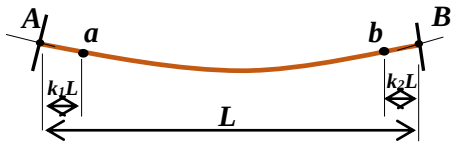
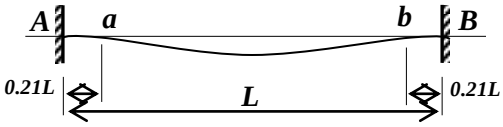
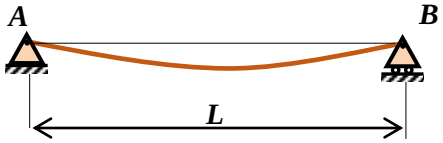


Fig. b



If the girder subjected to UDL *w* lb/ft, both the joints A and B will rotate as shown above.

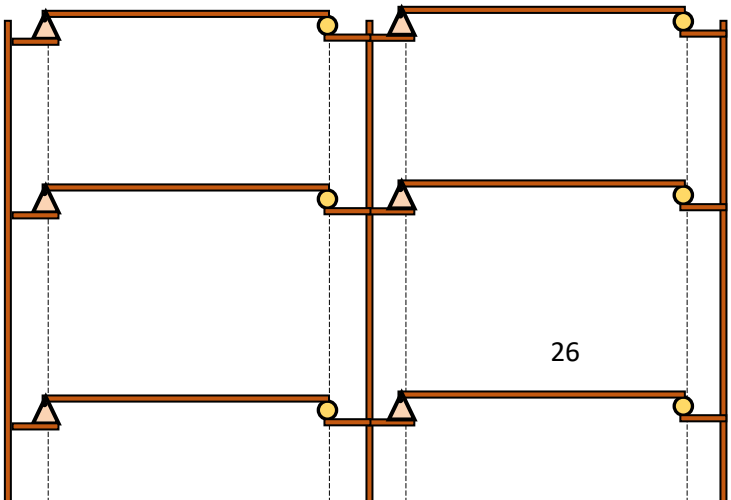


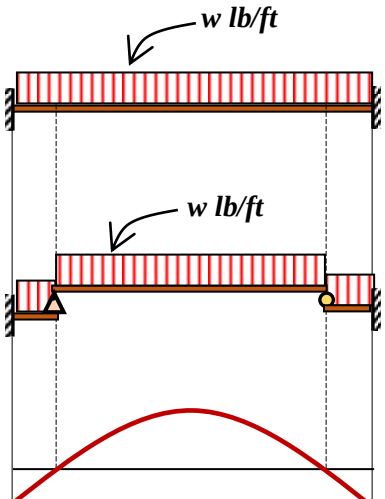


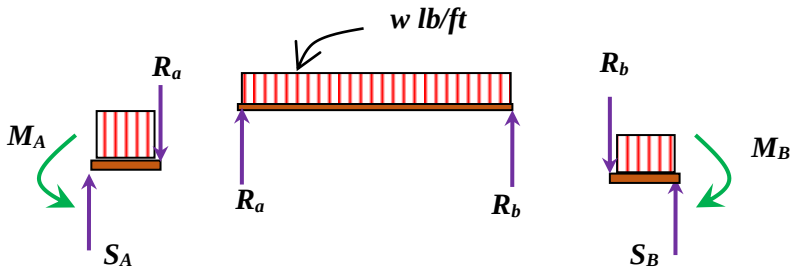
Points of inflection are at points *a* and *b*.

Assumptions

i. The axial force in the girder zero.
ii. A point of inflection occurs at the one-tenth point measure along the span from the left support.
iii. A point of inflection occurs at the one-tenth point measure along the span from the right support.






w lb/ft
R_a
M_A
S_A
R_a
R_b
R_b
M_B
S_B

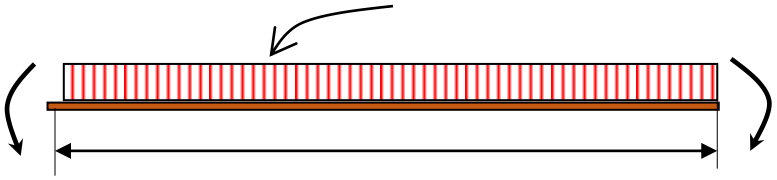
w lb/ft

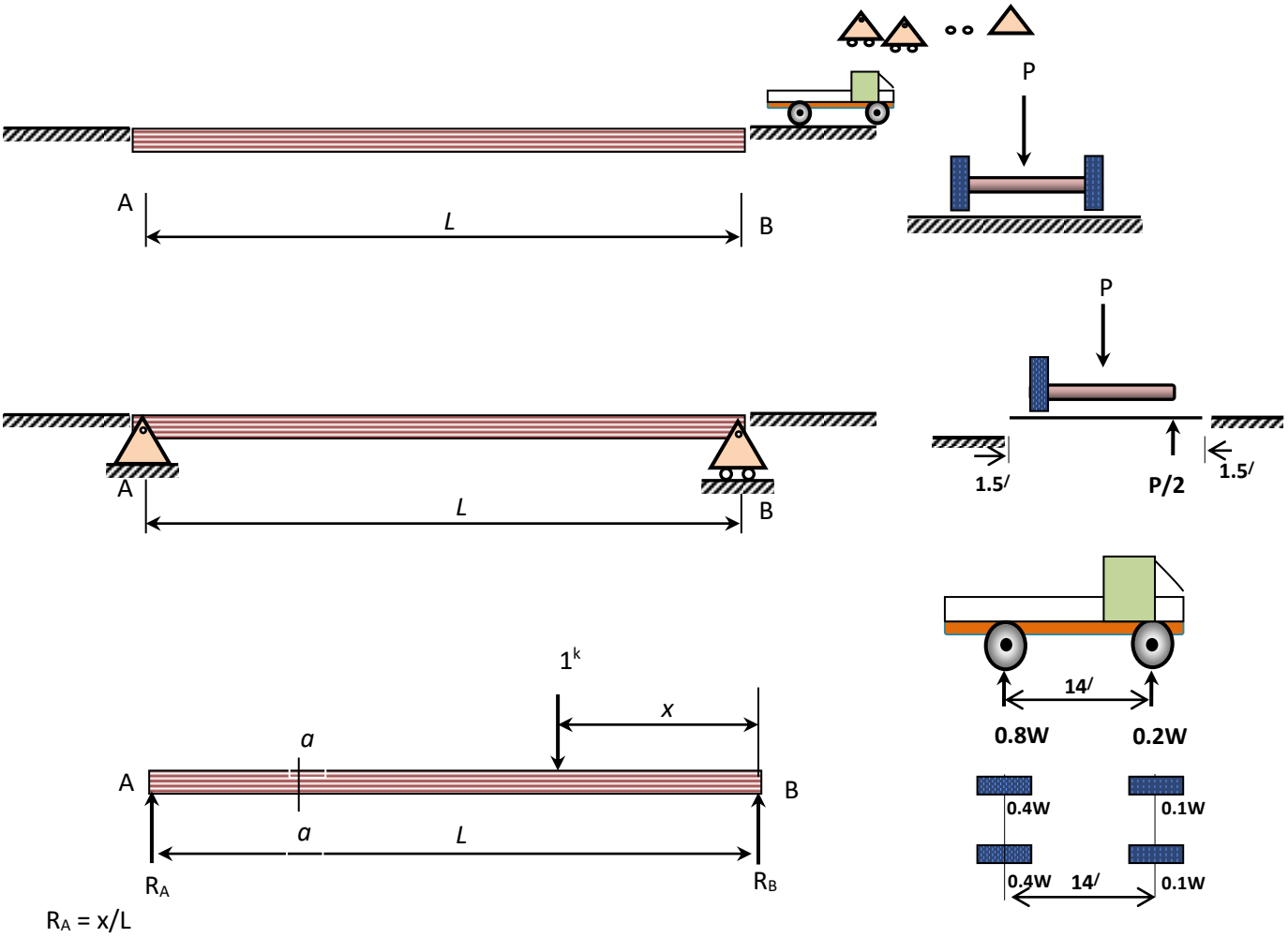
A ***B***

L

Determine points of inflection.

$M_{FEM} = wl^2/12$





$R_A = x/L$


6'
P/2