Note: Definitions in "Include Programs.sm" is highlighted in light blue

Includes the definitions from an external SMath file

include ("Include_Programs-R10.sm") = 43

appVersion (4) = "1.0.8348.30405"   appVersion (− 4) = "1.0.8348.30405"

Define

$kNm := kN\ m$

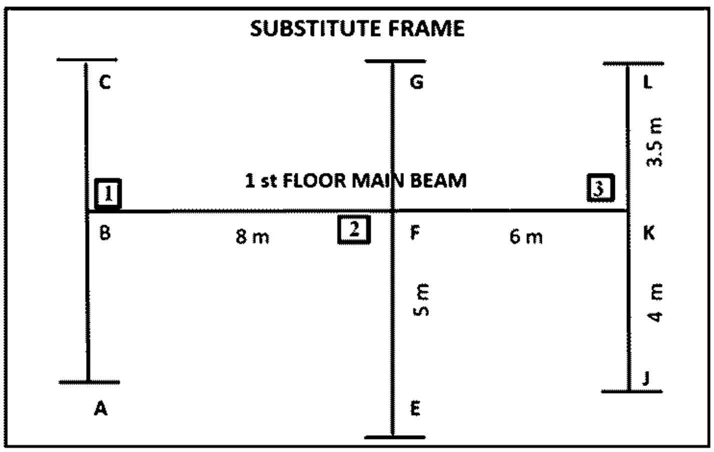
Assume

$E := 1\ MPa$

Assume Young's Modulus for RC: This is not really required, but used only for consistent units in intermediate calculations. We can use any numerical value. Ex **E = 1 MPa**

$t_0 := time(0)$

Desinged and Detailed (BS 8100: 1997) - Page 10 J.B. Higgins and B.R. Rogers (32 pages)
Published by: British Cement AssociationISBN 0 7210 154 1541 7 - Price Group E : British Cement Association 1988



For the first floor beams the columns above are assumed to be fixed and those below pinned at foundation level. The foundation will not provide rotational restraint.

Member Stiffness (ST)
cond = 0.75 when Pinned at base.
cond = 1 when fixed at both ends.
This program can handle both cases as shown below.

$$cond := \begin{bmatrix} \text{"Pinned"} & 0.75 \\ \text{"Fixed"} & 1 \end{bmatrix}$$

(●) Pinned   ( ) Fixed

FDN

$FDN = 0.75$

DATA
4 upper columns, 4 lower columns and 3 beams

Column

$$b_{UC} := \begin{bmatrix} 300 \\ 300 \\ 300 \end{bmatrix} mm$$
$$h_{UC} := \begin{bmatrix} 300 \\ 300 \\ 300 \end{bmatrix} mm$$
$$b_{LC} := \begin{bmatrix} 300 \\ 300 \\ 300 \end{bmatrix} mm$$
$$h_{LC} := \begin{bmatrix} 300 \\ 300 \\ 300 \end{bmatrix} mm$$
$$H_{UC} := \begin{bmatrix} 3.5 \\ 3.5 \\ 3.5 \end{bmatrix} m$$
$$H_{LC} := \begin{bmatrix} 4 \\ 5 \\ 4 \end{bmatrix} m$$

Beam

$$b_{beam} := \begin{bmatrix} 300 \\ 300 \end{bmatrix} mm$$
$$h_{beam} := \begin{bmatrix} 500 \\ 500 \end{bmatrix} mm$$
$$L := \begin{bmatrix} 8 \\ 6 \end{bmatrix} m$$

Define

$kNm := kN\ m$

Assume

$E := 1\ MPa$

Flanged Beams can be effective only in case of sagging as the concrete is able to take compression. In limit state design we neglect the tensile strength of concrete. As a result, at supports, continuous **'T' beams should be designed as a rectangular beam *(with width equal to the web width)*.**

Defie

$$Line_{zero} := \begin{bmatrix} 0 & 0 \\ \sum\left(\frac{L}{m}\right) & 0 \end{bmatrix}$$

Define

$$LL_{[1..rows(L)]} := 0 = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

Moment of Inertia

Upper Columna

$$I_{UC} := \overrightarrow{\frac{1}{12} \cdot b_{UC} \cdot \left(h_{UC}\right)^3} = \begin{bmatrix} 0.0007 \\ 0.0007 \\ 0.0007 \end{bmatrix} m^4$$

Lower Columna

$$I_{LC} := \overrightarrow{\frac{1}{12} \cdot b_{LC} \cdot \left(h_{LC}\right)^3} = \begin{bmatrix} 0.0007 \\ 0.0007 \\ 0.0007 \end{bmatrix} m^4$$

Beams

$$I_{beam} := \overrightarrow{\frac{1}{12} \cdot b_{beam} \cdot \left(h_{beam}\right)^3} = \begin{bmatrix} 0.0031 \\ 0.0031 \end{bmatrix} m^4$$

Foundation Columns Pinned at Base

Foundation Columns Pinned at Base

$FDN = 0.75$

Call Program 2 to find the Stiffness Matrix the Sustitute Frame

$$K1 := Find\_K\left(L, I_{UC}, I_{LC}, I_{beam}, H_{UC}, H_{LC}, FDN\right) = \begin{bmatrix} 2.8402 & 0.7812 & 0 \\ 0.7812 & 4.8223 & 1.0417 \\ 0 & 1.0417 & 3.361 \end{bmatrix} kNm$$

Frames are spaced at 5 m

$S_{frame} := 5\ m$

$L_{building} := 36\ m$

$\gamma_{cu} := 24\ \frac{kN}{m^3}$

$slab_{thick} := 175\ mm$

Loadings

$finishes_{floor} := 0.5\ \frac{kN}{m^2}$

$q_{k\_floor} := 4.0\ \frac{kN}{m^2}$

2A. Self weights, Dead loads

Self Weight of Beam

$$W_{beam} := \left(h_{beam_1} - slab_{thick}\right)\cdot b_{beam_1}\cdot \gamma_{cu} = 2.34\ \frac{kN}{m}$$

D/L from Slab

$$W_{slab} := slab_{thick}\cdot \gamma_{cu} + finishes_{floor} = 4.7\ \frac{kN}{m^2}$$

Floors D/L

$$g_{k\_floor} := W_{slab} = 4.7\ \frac{kN}{m^2}$$

2B. Design Loads on Beams

Dead load

$$G_{k\_floor} := g_{k\_floor}\cdot S_{frame} + W_{beam} = 25.84\ \frac{kN}{m}$$

Imposed loadd

$$Q_{k\_floor} := q_{k\_floor}\cdot S_{frame} = 20\ \frac{kN}{m}$$

Max Design Load

$$F1 := 1.4\cdot G_{k\_floor} + 1.6\cdot Q_{k\_floor} = 68.18\ \frac{kN}{m}$$

Min Design Load

$$F2 := 1.0\cdot G_{k\_floor} = 25.84\ \frac{kN}{m}$$

Define Load Patterns for All 4 Cases

Case I Case II Case III

$$FF := \begin{bmatrix} \begin{bmatrix} F1 \\ F1 \end{bmatrix} & \begin{bmatrix} F1 \\ F2 \end{bmatrix} & \begin{bmatrix} F2 \\ F1 \end{bmatrix} \end{bmatrix} = \begin{bmatrix} \begin{bmatrix} 68.18 \\ 68.18 \end{bmatrix} & \begin{bmatrix} 68.18 \\ 25.84 \end{bmatrix} & \begin{bmatrix} 25.84 \\ 68.18 \end{bmatrix} \end{bmatrix} \frac{kN}{m}$$

3 load cases **have been considered in this example**

Call Program 7 to find support moments, upper & lower column moments

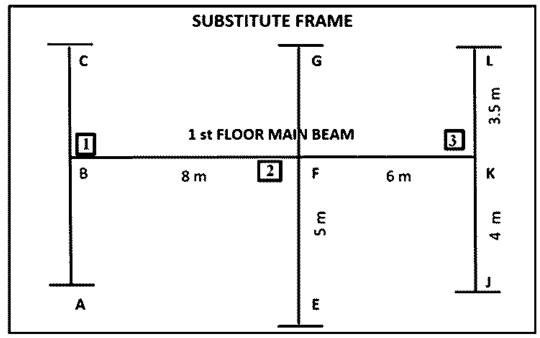
$$M_{all} := NEW\_BMM\left(FF, K1, H_{UC}, H_{LC}, I_{beam}, I_{UC}, I_{LC}, FDN, L\right)$$

$FDN = 0.75$

Upper Col | Lower Col

$$M_{all} = \begin{bmatrix} \begin{bmatrix} -179.6 & 402.1 \end{bmatrix} & \begin{bmatrix} -348.3 & 59.7 \end{bmatrix} & \begin{bmatrix} 108.5 \\ -35.2 \\ -36 \end{bmatrix} & \begin{bmatrix} 71.2 \\ -18.5 \\ -23.6 \end{bmatrix} \\ \begin{bmatrix} -193.3 & 349.7 \end{bmatrix} & \begin{bmatrix} -250.3 & -4 \end{bmatrix} & \begin{bmatrix} 116.7 \\ -65.2 \\ 2.4 \end{bmatrix} & \begin{bmatrix} 76.6 \\ -34.2 \\ 1.6 \end{bmatrix} \\ \begin{bmatrix} -54.4 & 204.7 \end{bmatrix} & \begin{bmatrix} -230 & 86.3 \end{bmatrix} & \begin{bmatrix} 32.9 \\ 16.6 \\ -52.1 \end{bmatrix} & \begin{bmatrix} 21.6 \\ 8.7 \\ -34.2 \end{bmatrix} \end{bmatrix} kNm$$

Foundation Columns Pinned at Base



Get Column Moments

$$M_{col} := M_{all}{}_{\left[1..rows\left(M_{all}\right)\right]\left[\left(cols\left(M_{all}\right)-1\right)..cols\left(M_{all}\right)\right]}$$

$$M_{col} = \begin{bmatrix} \begin{bmatrix} 108.45 \\ -35.24 \\ -36.02 \end{bmatrix} & \begin{bmatrix} 71.17 \\ -18.5 \\ -23.64 \end{bmatrix} \\ \begin{bmatrix} 116.69 \\ -65.19 \\ 2.41 \end{bmatrix} & \begin{bmatrix} 76.58 \\ -34.23 \\ 1.58 \end{bmatrix} \\ \begin{bmatrix} 32.87 \\ 16.6 \\ -52.09 \end{bmatrix} & \begin{bmatrix} 21.57 \\ 8.71 \\ -34.18 \end{bmatrix} \end{bmatrix} kNm$$

```
Call Program 9 : Sum of Upper & Lpwer Col Moments
```

$$Col\_Sum := Sum\_Col\_M\left(M_{col}\right) = \begin{bmatrix} \begin{bmatrix} 179.62 \\ 53.74 \\ 59.66 \end{bmatrix} \\ \begin{bmatrix} 193.27 \\ 99.42 \\ 4 \end{bmatrix} \\ \begin{bmatrix} 54.43 \\ 25.31 \\ 86.27 \end{bmatrix} \end{bmatrix} kNm$$

Case I

Case II

Case III

Beam1 | **Center Beam**

L R | L R

$$M_{sup} := M_{all}{}_{\left[1..rows\left(M_{all}\right)\right]\left[1..rows\left(L\right)\right]} = \begin{bmatrix} \begin{bmatrix} -179.6 & 402.1 \end{bmatrix} & \begin{bmatrix} -348.3 & 59.7 \end{bmatrix} \\ \begin{bmatrix} -193.3 & 349.7 \end{bmatrix} & \begin{bmatrix} -250.3 & -4 \end{bmatrix} \\ \begin{bmatrix} -54.4 & 204.7 \end{bmatrix} & \begin{bmatrix} -230 & 86.3 \end{bmatrix} \end{bmatrix} kNm$$

Case I
Case II
Case III

```
Convert the nested matrix to its absolute values
```

$$MM_{sup} := \overrightarrow{\left|M_{sup}\right|} = \begin{bmatrix} \begin{bmatrix} 180 & 402 \end{bmatrix} & \begin{bmatrix} 348 & 60 \end{bmatrix} \\ \begin{bmatrix} 193 & 350 \end{bmatrix} & \begin{bmatrix} 250 & 4 \end{bmatrix} \\ \begin{bmatrix} 54 & 205 \end{bmatrix} & \begin{bmatrix} 230 & 86 \end{bmatrix} \end{bmatrix} kNm$$

	SF1	SF2	Max Span M	X_Max
	kN	kN	kNm	m

`Call PROGRAMS 11 : Find SF, Max Span BM & X_max for ALL Loading Cases`

$$Res\_All := Find\_All\left(M_{all}, FF, L\right) = \begin{bmatrix} \begin{bmatrix} \begin{bmatrix} 2.45\cdot10^5 \frac{kg\,m}{s^2} \\ 2.53\cdot10^5 \frac{kg\,m}{s^2} \end{bmatrix} & \begin{bmatrix} -3.01\cdot10^5 \frac{kg\,m}{s^2} \\ -1.56\cdot10^5 \frac{kg\,m}{s^2} \end{bmatrix} & \begin{bmatrix} -2.6\cdot10^5 \frac{kg\,m^2}{s^2} \\ -1.2\cdot10^5 \frac{kg\,m^2}{s^2} \end{bmatrix} & \begin{bmatrix} 3.59\,m \\ 3.71\,m \end{bmatrix} \end{bmatrix} \\ \begin{bmatrix} \begin{bmatrix} 2.53\cdot10^5 \frac{kg\,m}{s^2} \\ 1.2\cdot10^5 \frac{kg\,m}{s^2} \end{bmatrix} & \begin{bmatrix} -2.92\cdot10^5 \frac{kg\,m}{s^2} \\ -35133.9 \frac{kg\,m}{s^2} \end{bmatrix} & \begin{bmatrix} -2.77\cdot10^5 \frac{kg\,m^2}{s^2} \\ -27880.36 \frac{kg\,m^2}{s^2} \end{bmatrix} & \begin{bmatrix} 3.71\,m \\ 4.64\,m \end{bmatrix} \end{bmatrix} \\ \begin{bmatrix} \begin{bmatrix} 84574.29 \frac{kg\,m}{s^2} \\ 2.28\cdot10^5 \frac{kg\,m}{s^2} \end{bmatrix} & \begin{bmatrix} -1.22\cdot10^5 \frac{kg\,m}{s^2} \\ -1.81\cdot10^5 \frac{kg\,m}{s^2} \end{bmatrix} & \begin{bmatrix} -83971.86 \frac{kg\,m^2}{s^2} \\ -1.53\cdot10^5 \frac{kg\,m^2}{s^2} \end{bmatrix} & \begin{bmatrix} 3.27\,m \\ 3.35\,m \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Case 1

Case 2

Case 3

Note: MATRIX VECTORIZE & TRANSPOSE .Extensively used to transform display of some outputs

`CALL PROGRAM 12 : Extract All SFF`

$$SFF := Calc\_SF\left(Res\_All\right) = \begin{bmatrix} \begin{bmatrix} 244.9 \\ 252.6 \end{bmatrix} & \begin{bmatrix} -300.5 \\ -156.4 \end{bmatrix} \\ \begin{bmatrix} 253.1 \\ 119.9 \end{bmatrix} & \begin{bmatrix} -292.3 \\ -35.1 \end{bmatrix} \\ \begin{bmatrix} 84.6 \\ 228.5 \end{bmatrix} & \begin{bmatrix} -122.1 \\ -180.6 \end{bmatrix} \end{bmatrix} kN$$

`Convert SFF to absolute values`

$$SFF_{ABS} := \overrightarrow{\left|SFF\right|} = \begin{bmatrix} \begin{bmatrix} 244.9 \\ 252.6 \end{bmatrix} & \begin{bmatrix} 300.5 \\ 156.4 \end{bmatrix} \\ \begin{bmatrix} 253.1 \\ 119.9 \end{bmatrix} & \begin{bmatrix} 292.3 \\ 35.1 \end{bmatrix} \\ \begin{bmatrix} 84.6 \\ 228.5 \end{bmatrix} & \begin{bmatrix} 122.1 \\ 180.6 \end{bmatrix} \end{bmatrix} kN$$

`Call Program 8`

$$SFF_{max} := Find\_Max\_Abs\left(SFF_{ABS}\right) = 300.51\ kN$$

Beam1 (L, R) **Beam 2** (L, R)

$$\overrightarrow{SFF}^T = \begin{bmatrix} \begin{bmatrix} 244.9 & -300.5 \\ 253.1 & -292.3 \\ 84.6 & -122.1 \end{bmatrix} & \begin{bmatrix} 252.6 & -156.4 \\ 119.9 & -35.1 \\ 228.5 & -180.6 \end{bmatrix} \end{bmatrix} kN$$

`CALL PROGRAM 14 : Extract All Span Moments`

$$M_{span} := Span\_M\left(Res\_All\right) = \begin{bmatrix} \begin{bmatrix} -260.2 \\ -119.8 \end{bmatrix} \\ \begin{bmatrix} -276.7 \\ -27.9 \end{bmatrix} \\ \begin{bmatrix} -84 \\ -152.8 \end{bmatrix} \end{bmatrix} kNm$$

MATRIX VECTORIZE & TRANSPOSE

Beam1 **Beam 2**

$$\overrightarrow{M_{span}}^T = \begin{bmatrix} \begin{bmatrix} -260.2 \\ -276.7 \\ -84 \end{bmatrix} & \begin{bmatrix} -119.8 \\ -27.9 \\ -152.8 \end{bmatrix} \end{bmatrix} kNm$$

`CALL PROGRAM 15 : Extract All X-max`

$$X_{max} := X\_Max\left(Res\_All\right) = \begin{bmatrix} \begin{bmatrix} 3.6 \\ 3.7 \end{bmatrix} \\ \begin{bmatrix} 3.7 \\ 4.6 \end{bmatrix} \\ \begin{bmatrix} 3.3 \\ 3.4 \end{bmatrix} \end{bmatrix} m$$

Case I

Case II

Case III

R

CALL Programs 18 : To Plot BMD for ALL Cases

$BMD\_All := BMD\_All\_Cases\left(M_{sup}, SFF, L, FF\right)$

$BMD\_All =$

0	179.6	0	348.3	0	193.3	0	250.3	0	54.4
0.2	132	0.2	299.2	0.2	144	0.2	226.9	0.2	38
0.4	87.1	0.4	252.7	0.4	97.5	0.4	204.4	0.4	22.7
0.6	45	0.6	209	0.6	53.7	0.6	183	0.6	8.3
0.8	5.5	0.8	168	0.8	12.6	0.8	162.7	0.8	−5
1	−31.2	1	129.8	1	−25.8	1	143.3	1	−17.2
1.2	−65.2	1.2	94.3	1.2	−61.4	1.2	125	1.2	−28.5
1.4	−96.4	1.4	61.4	1.4	−94.3	1.4	107.8	1.4	−38.6
1.6	−124.9	1.6	31.4	1.6	−124.5	1.6	91.5	1.6	−47.8
1.8	−150.7	1.8	4	1.8	−151.9	1.8	76.4	1.8	−55.9
2	−173.8	2	−20.6	2	−176.7	2	62.2	2	−63
2.2	−194.2	2.2	−42.5	2.2	−198.7	2.2	49.1	2.2	−69.1
2.4	−211.8	2.4	−61.7	2.4	−217.9	2.4	37	2.4	−74.1
2.6	−226.7	2.6	−78.1	2.6	−234.5	2.6	25.9	2.6	−78.1
2.8	−238.8	2.8	−91.8	2.8	−248.3	2.8	15.9	2.8	−81.1
3	−248.3	3	−102.8	3	−259.4	3	6.9	3	−83
3.2	−255	3.2	−111.1	3.2	−267.7	3.2	−1.1	3.2	−83.9
3.4	−259	3.4	−116.6	3.4	−273.4	3.4	−8	3.4	−83.8
3.6	−260.2	3.6	−119.4	3.6	−276.3	3.6	−13.9	3.6	−82.6
3.8	−258.8	3.8	−119.5	3.8	−276.5	3.8	−18.8	3.8	−80.4
4	−254.6	4	−116.8	4	−273.9	4	−22.6	4	−77.1
4.2	−247.6	4.2	−111.4	4.2	−268.6	4.2	−25.4	4.2	−72.9
4.4	−238	4.4	−103.3	4.4	−260.6	4.4	−27.1	4.4	−67.6
4.6	−225.6	4.6	−92.5	4.6	−249.9	4.6	−27.9	4.6	−61.2
4.8	−210.5	4.8	−79	4.8	−236.4	4.8	−27.6	4.8	−53.8
5	−192.7	5	−62.7	5	−220.3	5	−26.2	5	−45.4
5.2	−172.1	5.2	−43.7	5.2	−201.3	5.2	−23.8	5.2	−36
5.4	−148.8	5.4	−21.9	5.4	−179.7	5.4	−20.4	5.4	−25.5
5.6	−122.8	5.6	2.6	5.6	−155.3	5.6	−16	5.6	−14
5.8	−94.1	5.8	29.7	5.8	−128.3	5.8	−10.5	5.8	−1.5
6	−62.6	6	59.7	6	−98.4	6	−4	6	12.1
6.2	−28.4			6.2	−65.9			6.2	26.7
6.4	8.5			6.4	−30.6			6.4	42.4
6.6	48.2			6.6	7.4			6.6	59
6.8	90.5			6.8	48.1			6.8	76.7
7	135.6			7	91.6			7	95.5
7.2	183.5			7.2	137.7			7.2	115.3
7.4	234			7.4	186.7			7.4	136.1
7.6	287.3			7.6	238.3			7.6	157.9
7.8	343.3			7.8	292.7			7.8	180.8
8	402.1			8	349.7			8	204.7

...

CALL Program 21 : Cordinates of Max Span Moments

$Pts\_MSpan := Pts\_All\_Cases\left(X_{max}, M_{span}, L\right) = \begin{bmatrix} \begin{bmatrix} [3.6 \; -260.2] \\ [11.7 \; -119.8] \end{bmatrix} \\ \begin{bmatrix} [3.7 \; -276.7] \\ [12.6 \; -27.9] \end{bmatrix} \\ \begin{bmatrix} [3.3 \; -84] \\ [11.4 \; -152.8] \end{bmatrix} \end{bmatrix}$

$X_{max} = \begin{bmatrix} \begin{bmatrix} 3.6 \\ 3.7 \end{bmatrix} \\ \begin{bmatrix} 3.7 \\ 4.6 \end{bmatrix} \\ \begin{bmatrix} 3.3 \\ 3.4 \end{bmatrix} \end{bmatrix} m$ $\qquad M_{span} = \begin{bmatrix} \begin{bmatrix} -260.2 \\ -119.8 \end{bmatrix} \\ \begin{bmatrix} -276.7 \\ -27.9 \end{bmatrix} \\ \begin{bmatrix} -84 \\ -152.8 \end{bmatrix} \end{bmatrix} kNm$

Call Program 8

$M_{sup\_max} := Find\_Max\_Abs\left(MM_{sup}\right) = 402.1\ kNm$

Use Ceil2 function

$\left\lceil \frac{M_{sup\_max}}{kNm} \right\rceil_{50} = 450$

Use Ceil2 function

$\left\lceil \frac{SFF_{max}}{kN} \right\rceil_{50} = 350$

$MSpan_{ABS} := \overrightarrow{\left|M_{span}\right|}$

Call Program 8

$M\_Span_{max} := Find\_Max\_Abs\left(MSpan_{ABS}\right)$

$M\_Span_{max} = 276.7081\ kNm$

CALL Program 23 : X cordinates to plot support moments

$X\_Cord := Sup\_Xcord(L) = \begin{bmatrix} 0 \\ 8 \\ 8 \\ 14 \end{bmatrix} m$

CALL Program 24 : Get BMD Cases

$BMD := Find\_BMD\_Cases(BMD\_All, LL, FF)$

$rows(BMD) = 3$ $\qquad cols(BMD) = 1$ $\qquad rows\left(FF_1\right) = 2$

$BM\_Case := [1..cols(FF)] = \begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix}$

(●) 1 ( ) 2 ( ) 3

nn

$Y_{Sup\_Max} := \left\lceil \frac{M_{sup\_max}}{kNm} \right\rceil_{50} = 450$

$Y_{Span\_Min} := \left\lceil \frac{M\_Span_{max}}{kNm} \right\rceil_{400} = 400$

Case Number Selected $nn = 1$

$\frac{M\_Span_{max}}{kNm} = 276.7081$

X Y Plot Settings $PLT := \text{"XYPlot1"}$

$XYPlot_{XLimMin_1} := -1$ $\qquad XYPlot_{XLimMax_1} := \sum \frac{L}{m} + 1 = [15]$

$XYPlot_{YLimMin_1} := -Y_{Span\_Min} = [-400]$ $\qquad XYPlot_{YLimMax_1} := Y_{Sup\_Max} = [450]$

$XYPlot_{XTick_1} := 1$ $\qquad XYPlot_{YTick_1} := 50$

setprop("XYPlot1.XYLabel.XLabel", "Length (m)") = 1

setprop("XYPlot1.XYLabel.YLabel", "BM (kNm)") = 1

$XY_{labelFont}(font, pName) := \text{setprop}(\text{"{pName}.XYLabel.LabelFont"}, font)$

$XY_{labelFont}(\text{"Trebuchet MS,8pt"}, \text{"XYPlot1"}) = 1$

$Pts\_MSpan_{nn} = \begin{bmatrix} [3.6 \; -260.2] \\ [11.7 \; -119.8] \end{bmatrix}$

$\text{setprop}(\text{"XYPlot1.XYLabel.LabelFontColor"}, \text{"brown"}) = 1$

$nn = 1$

$MyTitle := \text{concat}(\text{"FIRST FLOOR BMD: Case "}, \text{num2str}(nn)) = \text{"FIRST FLOOR BMD: Case 1"}$

$\text{setprop}(\text{"XYPlot1.Title.Text"}, MyTitle) = 1$

$\text{setprop}(\text{"XYPlot1.Title.TitleFont"}, \text{"Trebuchet MS,8pt"}) = 1$

CALL Programs 25 : Plot BMD for a given CASE Number nn

CALL Program 27 : Arrange Support Moment values & X cordinates

$Plot\_BMD(nn)^T =$

0	179.62
0.2	132.01
0.4	87.12
0.6	44.96
0.8	5.52
1	−31.19
1.2	−65.17
1.4	−96.42
1.6	−124.95
1.8	−150.75
2	−173.82
2.2	−194.17
2.4	−211.79
2.6	−226.68
2.8	−238.84
3	−248.28
3.2	−254.99
3.4	−258.97
3.6	−260.23
3.8	−258.76
4	−254.56
4.2	−247.64
4.4	−237.99
4.6	−225.61
4.8	−210.5
5	−192.67
5.2	−172.11
5.4	−148.82
5.6	−122.81
5.8	−94.07
6	−62.6
6.2	−28.4
6.4	8.52
6.6	48.17
6.8	90.54
7	135.65
7.2	183.48
7.4	234.03
7.6	287.32
7.8	343.33
8	402.07

8	348.33
8.2	299.17
8.4	252.73
8.6	209.02
8.8	168.04
9	129.78
9.2	94.25
9.4	61.45
9.6	31.37
9.8	4.03
10	−20.6
10.2	−42.49
10.4	−61.66
10.6	−78.1
10.8	−91.81
11	−102.79
11.2	−111.05
11.4	−116.59
11.6	−119.39
11.8	−119.47
12	−116.82
12.2	−111.44
12.4	−103.34
12.6	−92.51
12.8	−78.95
13	−62.67
13.2	−43.65
13.4	−21.92
13.6	2.55
13.8	29.74
14	59.66

$Pts\_MSup := Arrange\_M\_Sup\_All\left(\frac{M_{sup}}{kNm}, \frac{X\_Cord}{m}\right) = \begin{bmatrix} \begin{bmatrix} [0 \; 179.6] \\ [8 \; 402.1] \\ [8 \; 348.3] \\ [14 \; 59.7] \end{bmatrix} \\ \begin{bmatrix} [0 \; 193.3] \\ [8 \; 349.7] \\ [8 \; 250.3] \\ [14 \; 4] \end{bmatrix} \\ \begin{bmatrix} [0 \; 54.4] \\ [8 \; 204.7] \\ [8 \; 230] \\ [14 \; 86.3] \end{bmatrix} \end{bmatrix}$

$M_{sup} = \begin{bmatrix} [-179.6 \; 402.1] & [-348.3 \; 59.7] \\ [-193.3 \; 349.7] & [-250.3 \; -4] \\ [-54.4 \; 204.7] & [-230 \; 86.3] \end{bmatrix} kNm$

$Pts\_MSup_{nn} = \begin{bmatrix} [0 \; 179.6] \\ [8 \; 402.1] \\ [8 \; 348.3] \\ [14 \; 59.7] \end{bmatrix}$

$nn = 1$

CALL Program 28 : Labels to plot

$Plot\_Labs(Pts\_MSup_{nn}) = \begin{bmatrix} 0 & 179.6 & \text{"179.6"} & 6 & \text{"red"} \\ 8 & 402.1 & \text{"402.1"} & 6 & \text{"red"} \\ 8 & 348.3 & \text{"348.3"} & 6 & \text{"red"} \\ 14 & 59.7 & \text{"59.7"} & 6 & \text{"red"} \end{bmatrix}$

CALL Program 28 : Labels to plot

$Plot\_Labs(Pts\_MSpan_{nn}) = \begin{bmatrix} 3.6 & -260.2 & \text{"-260.2"} & 6 & \text{"red"} \\ 11.7 & -119.8 & \text{"-119.8"} & 6 & \text{"red"} \end{bmatrix}$

$Line_{zero} = \begin{bmatrix} 0 & 0 \\ 14 & 0 \end{bmatrix}$

$\text{col}(MM_{sup}^T, nn) = \begin{bmatrix} [180 \; 402] \\ [348 \; 60] \end{bmatrix} kNm$

$M_{span_{nn}} = \begin{bmatrix} -260 \\ -120 \end{bmatrix} kNm$

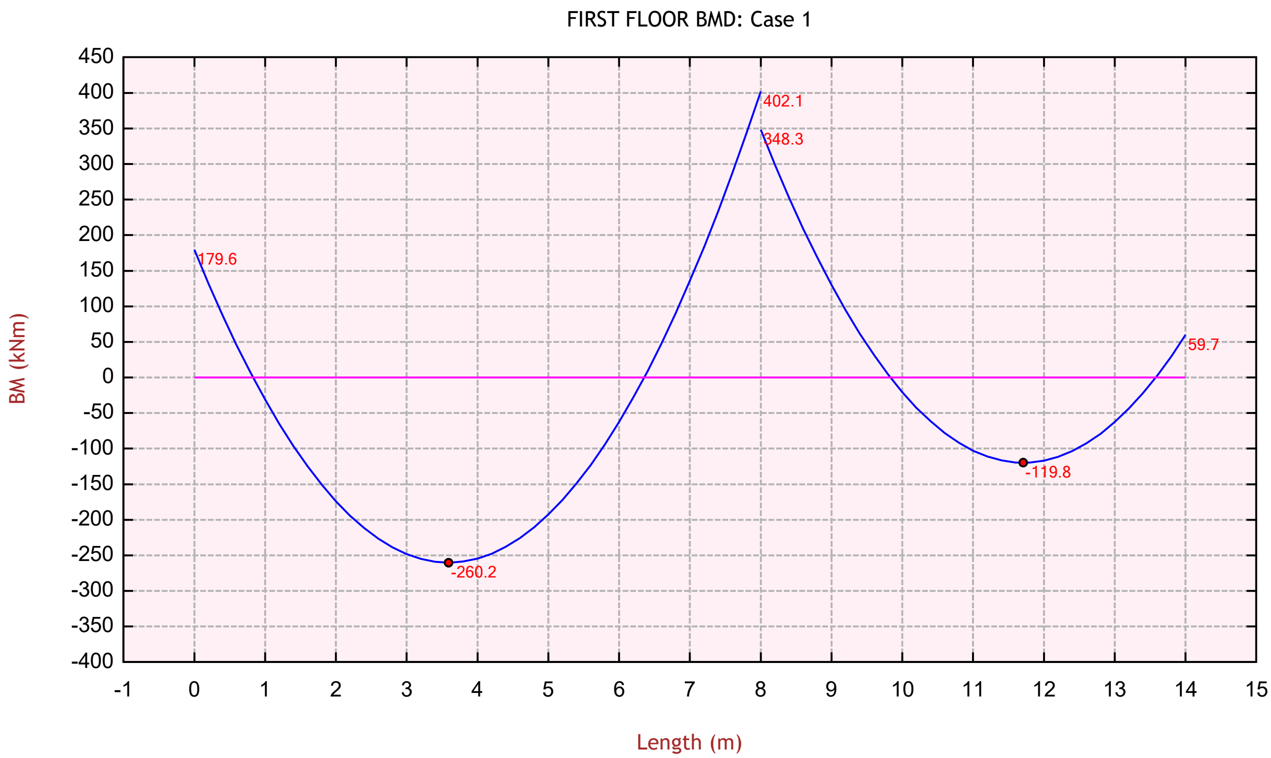
$M_{sup\_max} = 402.1 \; kNm$

$M\_Span_{max} = 276.7 \; kNm$

$X_{max_{nn}} = \begin{bmatrix} 3.6 \\ 3.7 \end{bmatrix} m$

$FF_{nn} = \begin{bmatrix} 68.176 \\ 68.176 \end{bmatrix} \frac{kN}{m}$

$L = \begin{bmatrix} 8 \\ 6 \end{bmatrix} m$



Results from EXCEL using Stiffness Method

CASE I SUMMARY		**Max**			**Max**		
CASE I	68.18				68.18		Case Loading ***KN/m***
-179.62	260.23		402.07	-348.33	119.77	59.66	Beam Moments ***KNm***
108.45			-35.24			-36.02	Upper Column ***kNm***
71.17			-18.50			-23.64	Lower Column ***kNm***
244.90			300.51	252.64		156.42	Shear ***kN***
CASE II SUMMARY		**Max**			**Min**		
CASE II	68.18				25.84		Case Loading ***KN/m***
-193.27	276.71		349.74	-250.32	27.88	-4.00	Beam Moments ***KNm***
116.69			-65.19			2.41	Upper Column ***kNm***
76.58			-34.23			1.58	Lower Column ***kNm***
253.15			292.26	119.91		35.13	Shear ***kN***
CASE III SUMMARY		**Min**			**Max**		
CASE III	25.84				68.18		Case Loading ***KN/m***
-54.43	83.97		204.72	-230.03	152.85	86.27	Beam Moments ***KNm***
32.87			16.60			-52.09	Upper Column ***kNm***
21.57			8.71			-34.18	Lower Column ***kNm***
84.57			122.15	228.49		180.57	Shear ***kN***

$\mathrm{time}(0) - t_0 = 0.5\ s$

Shear Force Diagram

CALL Program 29 : Arrange SF values to PLOT

$$Plot\_SF := Arrange\_SF(X\_Cord, SFF) = \begin{bmatrix} \begin{bmatrix} 0 & 244.9 \\ 8 & -300.5 \\ 8 & 252.6 \\ 14 & -156.4 \end{bmatrix} \\ \begin{bmatrix} 0 & 253.1 \\ 8 & -292.3 \\ 8 & 119.9 \\ 14 & -35.1 \end{bmatrix} \\ \begin{bmatrix} 0 & 84.6 \\ 8 & -122.1 \\ 8 & 228.5 \\ 14 & -180.6 \end{bmatrix} \end{bmatrix}$$

Define

$$SF\_Case := [1..cols(FF)] = \begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix}$$

(●) 1 ( ) 2 ( ) 3

nn2

$nn2 = 1$

CALL Program 19

$$\frac{Get\_L(L)}{m} = \begin{bmatrix} 0 \\ 8 \end{bmatrix}$$

Program 33

$$X_0 = [0 \ \ 0]$$

CALL Program 31: Labels to print SF zero x_cordinates on SFD

$$Labs\_ZeroSF(n\#) := Find\_Labs\_ZeroSF(X_{max}\ \ n\#\ \ 1)$$

$$Labs\_ZeroSF(nn2) = \begin{bmatrix} 3.59 & 0 & \text{"3.59"} & 6 & \text{"red"} \\ 11.71 & 0 & \text{"3.71"} & 6 & \text{"red"} \end{bmatrix}$$

$$X_L := \text{augment}\left(\sum\left(\frac{L}{m}\right), 0\right) = [14 \ \ 0]$$

$$Plot\_SF(nn2) := \text{stack}\left(X_0, Plot\_SF_{nn2}, X_L\right)$$

$$Plot\_SF(nn2) = \begin{bmatrix} 0 & 0 \\ 0 & 244.9 \\ 8 & -300.5 \\ 8 & 252.6 \\ 14 & -156.4 \\ 14 & 0 \end{bmatrix}$$

CALL Program 30 :Labels to print SF values on SFD

$$Plot\_Labs\_SF\left(Plot\_SF_{nn2}\right) = \begin{bmatrix} 0 & 244.9 & \text{"244.9"} & 6 & \text{"black"} \\ 8 & -300.51 & \text{"-300.5"} & 6 & \text{"black"} \\ 8 & 252.64 & \text{"252.6"} & 6 & \text{"black"} \\ 14 & -156.42 & \text{"-156.4"} & 6 & \text{"black"} \end{bmatrix}$$

X Y Plot Settings for SFD

$XYPlot_{XLimMin_2} := -1$ $\quad XYPlot_{XLimMax_2} := \dfrac{\sum L}{m} + 2 = \begin{bmatrix} 15 \\ 16 \end{bmatrix}$ $\quad Y_{SF\_Max} := \left\lceil \dfrac{SFF_{max}}{kN} \right\rceil_{100} = 400$

$XYPlot_{YLimMin_2} := -Y_{SF\_Max}$ $\quad XYPlot_{YLimMax_2} := Y_{SF\_Max}$

$XYPlot_{XTick_2} := 1$ $\quad XYPlot_{YTick_2} := 50$ $\quad LL = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$

setprop("XYPlot2.XYLabel.XLabel", "Length (m)") = 1

setprop("XYPlot2.XYLabel.YLabel", "SF (kN)") = 1 $\quad Line_{zero} = \begin{bmatrix} 0 & 0 \\ 14 & 0 \end{bmatrix}$

$XY_{labelFont}(font, pName) :=$ setprop("{pName}.XYLabel.LabelFont", $font$) $\quad nn2 = 1$

$XY_{labelFont}$("Trebuchet MS,8pt", "XYPlot2") = 1

setprop("XYPlot2.XYLabel.LabelFontColor", "brown") = 1

$MyTitle :=$ concat("FIRST FLOOR SFD: Case ", num2str($nn2$)) = "FIRST FLOOR SFD: Case 1"

setprop("XYPlot2.Title.Text", $MyTitle$) = 1

setprop("XYPlot2.Title.TitleFont", "Trebuchet MS,8pt") = 1 $\quad SFF_{max} = 300.5\ kN$

$Zero\_SF(nn2) := \text{augment}\left(\dfrac{Get\_L(L) + X_{max_{nn2}}}{m}, LL\right) = \begin{bmatrix} 3.59 & 0 \\ 11.71 & 0 \end{bmatrix}$ $\quad Get\_L(L) = \begin{bmatrix} 0 \\ 8 \end{bmatrix} m$ $\quad X_{max_{nn2}} = \begin{bmatrix} 3.59 \\ 3.71 \end{bmatrix} m$ $\quad LL = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$

$Labs\_ZeroSF(nn2) = \begin{bmatrix} 3.59 & 0 & \text{"3.59"} & 6 & \text{"red"} \\ 11.71 & 0 & \text{"3.71"} & 6 & \text{"red"} \end{bmatrix}$

$Plot\_SF(nn2) = \begin{bmatrix} 0 & 0 \\ 0 & 244.9 \\ 8 & -300.51 \\ 8 & 252.64 \\ 14 & -156.42 \\ 14 & 0 \end{bmatrix}$

$Plot\_Labs\_SF\left(Plot\_SF_{nn2}\right) = \begin{bmatrix} 0 & 244.9 & \text{"244.9"} & 6 & \text{"black"} \\ 8 & -300.5 & \text{"-300.5"} & 6 & \text{"black"} \\ 8 & 252.6 & \text{"252.6"} & 6 & \text{"black"} \\ 14 & -156.4 & \text{"-156.4"} & 6 & \text{"black"} \end{bmatrix}$

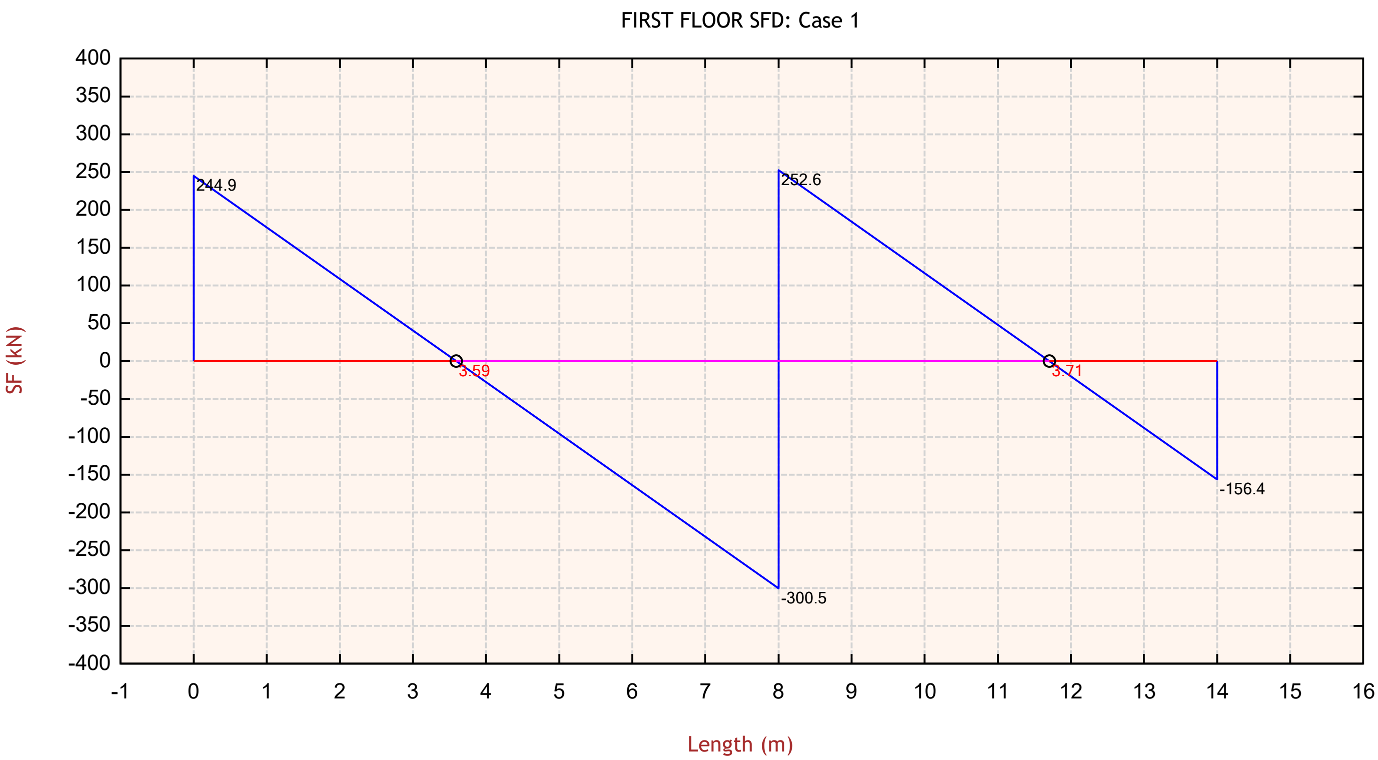
Results from EXCEL using Stiffness Method

CASE I SUMMARY		**Max**			**Max**		
CASE I		68.18			68.18		Case Loading ***KN/m***
-179.62	260.23		402.07	-348.33	119.77	59.66	Beam Moments ***KNm***
108.45			-35.24			-36.02	Upper Column ***kNm***
71.17			-18.50			-23.64	Lower Column ***kNm***
244.90			300.51	252.64		156.42	Shear ***kN***
CASE II SUMMARY		**Max**			**Min**		
CASE II		68.18			25.84		Case Loading ***KN/m***
-193.27	276.71		349.74	-250.32	27.88	-4.00	Beam Moments ***KNm***
116.69			-65.19			2.41	Upper Column ***kNm***
76.58			-34.23			1.58	Lower Column ***kNm***
253.15			292.26	119.91		35.13	Shear ***kN***
CASE III SUMMARY		**Min**			**Max**		
CASE III		25.84			68.18		Case Loading ***KN/m***
-54.43	83.97		204.72	-230.03	152.85	86.27	Beam Moments ***KNm***
32.87			16.60			-52.09	Upper Column ***kNm***
21.57			8.71			-34.18	Lower Column ***kNm***
84.57			122.15	228.49		180.57	Shear ***kN***

Beam Shear Forces

	Beam1		Beam 2		
	L	R	L	R	

$$\overrightarrow{SFF}^{T} = \left[\begin{bmatrix} 245 & -301 \\ 253 & -292 \\ 85 & -122 \end{bmatrix} \begin{bmatrix} 253 & -156 \\ 120 & -35 \\ 228 & -181 \end{bmatrix}\right] \text{kN} \quad \begin{matrix} \text{Case 1} \\ \text{Case 2} \\ \text{Case 3} \end{matrix}$$

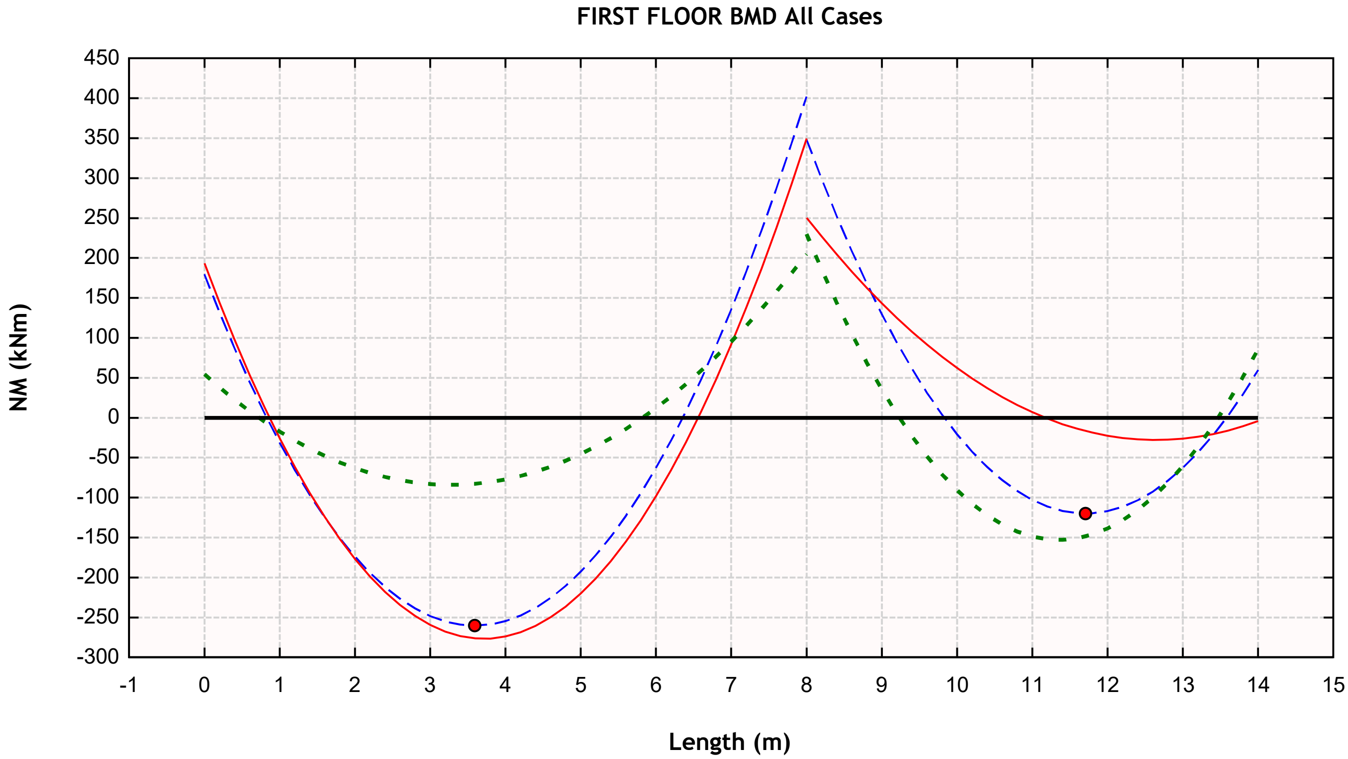


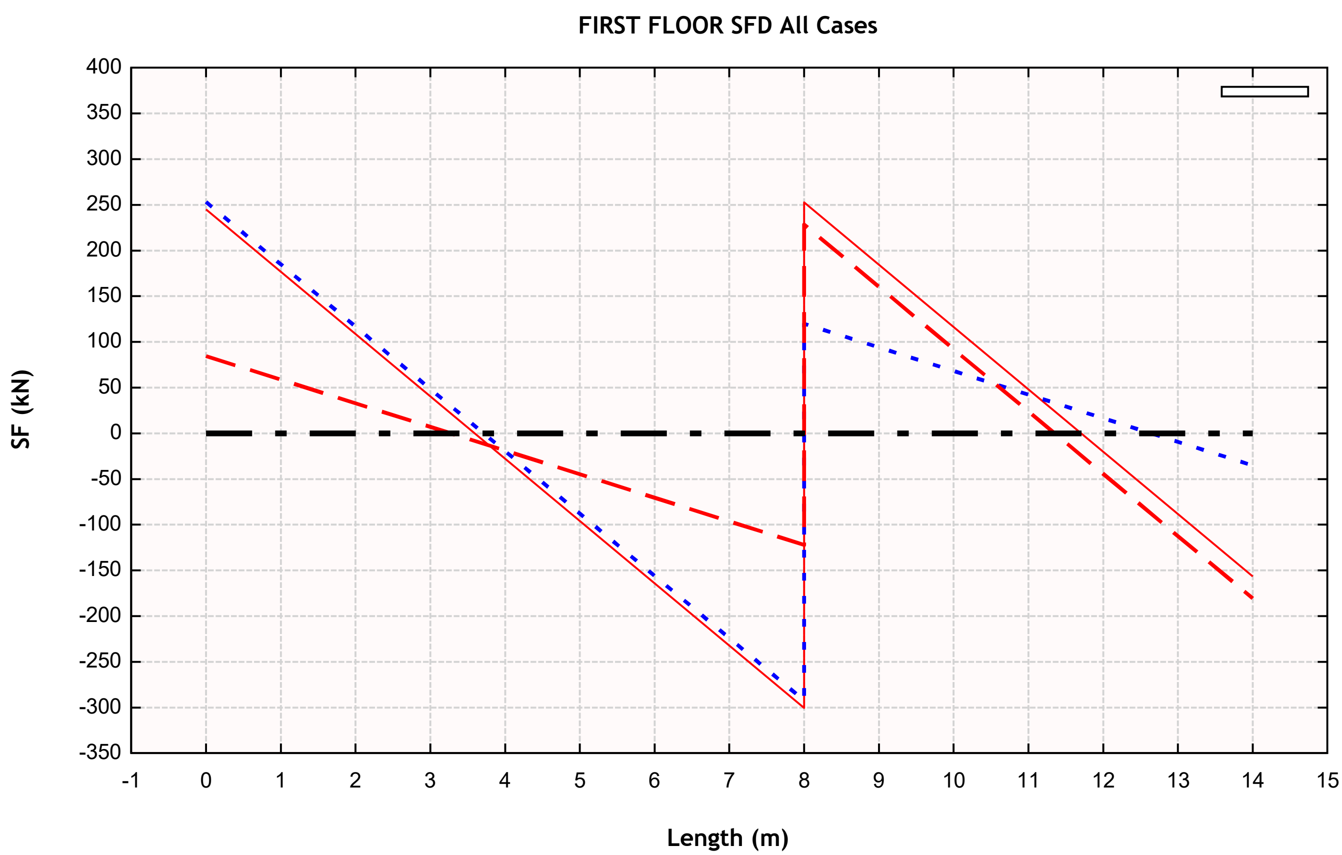
INTERNAL COLUMN (Foundation → Roof)
AXIAL LOADING and MOMENTS from ANALYSIS

	BEAM LOADS kN		COLUMN DESIGN LOADS kN				COL. MOMENTS kNm			
	TOTAL		IMPOSED		DEAD		TOP		BOTTOM	
LOAD CASE	1	2	1	2	1	2	1	2	1	2
LEVEL										
Roof	249	244	54	53	195	191	34	54		
	210	133	46		164	133			32	58
SW					9	9				
			100	53	368	333				
3rd Fl.	298	290	140	136	158	154	32	58		
	249	117	117		132	117			32	58
SW					9	9				
			357	189	667	613				
2nd Fl.	298	290	140	136	158	154	32	58		
	249	117	117		132	117			35	65
SW.					9	9				
			614	325	966	893				
1st Fl.	300	292	141	137	159	155	19	34		
	252	120	118		134	120			-	-
SW.					14	14				
Fdns.			873	462	1273	1182				

Internal Columns

$$\overrightarrow{SFF}^{T} = \left[\begin{bmatrix} 245 & -301 \\ 253 & -292 \\ 85 & -122 \end{bmatrix} \begin{bmatrix} 253 & -156 \\ 120 & -35 \\ 228 & -181 \end{bmatrix}\right] \text{kN}$$


FIRST FLOOR BMD All Cases
NM (kNm)
Length (m)


FIRST FLOOR SFD All Cases
SF (kN)
Length (m)

time$(0)-t_0=0.7$ s

Plotting Column Moments

Unlike BMD and SFD, plotting Column Moments is reatively difficult, The main reason is that both Column Moments and the Column locations have to be plotted on the X-azis. Hence, Column moment values are divided by total length of the horizontal beams. Then these values are converted to strings and plotted at the proper locations for both upper and lower columns.

Upper Lower

$$M_{col} = \begin{bmatrix} \begin{bmatrix} 108.5 \\ -35.2 \\ -36 \end{bmatrix} & \begin{bmatrix} 71.2 \\ -18.5 \\ -23.6 \end{bmatrix} \\ \begin{bmatrix} 116.7 \\ -65.2 \\ 2.4 \end{bmatrix} & \begin{bmatrix} 76.6 \\ -34.2 \\ 1.6 \end{bmatrix} \\ \begin{bmatrix} 32.9 \\ 16.6 \\ -52.1 \end{bmatrix} & \begin{bmatrix} 21.6 \\ 8.7 \\ -34.2 \end{bmatrix} \end{bmatrix} kNm$$

Define

$$Col\_Case := [1..\text{cols}(FF)] = \begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix}$$

Number of Columns

$$N_{cols} := \text{rows}(L) + 1 = 3$$

(●) 1 ( ) 2 ( ) 3

nn3

$nn3 = 1$

$$Max_{col\_top} := \text{Max}\left(Max\_Abs\left(\text{col}\left(M_{col}, 1\right)\right)\right) = 116.7\ kNm \qquad Min_{col\_top} := \text{Min}\left(Min\_Abs\left(\text{col}\left(M_{col}, 1\right)\right)\right) = 2.4\ kNm$$

$$Max_{col\_bot} := \text{Max}\left(Max\_Abs\left(\text{col}\left(M_{col}, 2\right)\right)\right) = 76.6\ kNm \qquad Min_{col\_bot} := \text{Min}\left(Min\_Abs\left(\text{col}\left(M_{col}, 2\right)\right)\right) = 1.6\ kNm$$

Scale to plot column moments

$$SC := \text{round}\left(\frac{Max_{col\_top}}{Max_{col\_bot}}, 0\right) = 2$$

Note: In CASES 1 & 2, the column moments at joint 1 are large compared to CASE 3. Hence. the plot will looks odd, and to avoid such a situation, a SCALE is arbitrarily introduced in PLOTTING the column moments

$nn3 = 1$ $FDN = 0.75$ Already defined at the start

Call Program 36: To Plot Upper Column Moments

$$MCol_{top} := Plot\_UP\_Col\_M\left(\text{col}\left(M_{col}, 1\right), L, nn3, H_{UC}, 1, SC\right)$$

Call Program 37: To Plot Lower Column Moments

$$MCol_{bot} := Plot\_LOW\_Col\_M\left(\text{col}\left(M_{col}, 2\right), L, nn3, H_{LC}, -1, FDN, SC\right)$$

CALL Program 38: Convert Top Col Moments to strings

$$MSTR_{top} := MStr2_{top}\left(nn3, M_{col}\right) = \begin{bmatrix} \text{"108"} \\ \text{"-35"} \\ \text{"-36"} \end{bmatrix}$$

CALL Program 38: Convert Bot Col Moments to strings

$$MSTR_{bot} := MStr2_{bot}\left(nn3, M_{col}\right) = \begin{bmatrix} \text{"71"} \\ \text{"-18"} \\ \text{"-24"} \end{bmatrix}$$

`Call Program 35: Stack Upper Col matrices`

$$Cords_{top} := STACK\left(MCol_{top}\left[1..N_{cols}\right]\right) = \begin{bmatrix} 3.9 & 0 \\ 6.7 & 0 \\ 12.7 & 0 \end{bmatrix}$$

`Call Program 35: Stack Bottom Col matrices`

$$Cords_{bot} := STACK\left(MCol_{bot}\left[1..\left(N_{cols}\right)\right]\right) = \begin{bmatrix} -2.5 & 0 \\ 8.7 & 0 \\ 14.8 & 0 \end{bmatrix}$$

Upper Column - Cordinates to plot moments

$$MCol_{top} = \begin{bmatrix} \begin{bmatrix} 0 & 0 \\ 3.9 & 0 \end{bmatrix} \\ \begin{bmatrix} 8 & 0 \\ 6.7 & 0 \end{bmatrix} \\ \begin{bmatrix} 14 & 0 \\ 12.7 & 0 \end{bmatrix} \\ \begin{bmatrix} 0 & 0 \\ 0 & 3.5 \end{bmatrix} \\ \begin{bmatrix} 8 & 0 \\ 8 & 3.5 \end{bmatrix} \\ \begin{bmatrix} 14 & 0 \\ 14 & 3.5 \end{bmatrix} \\ \begin{bmatrix} -1.9 & 3.5 \\ 0 & 3.5 \end{bmatrix} \\ \begin{bmatrix} 8.6 & 3.5 \\ 8 & 3.5 \end{bmatrix} \\ \begin{bmatrix} 14.6 & 3.5 \\ 14 & 3.5 \end{bmatrix} \\ \begin{bmatrix} -1.9 & 3.5 \\ 3.9 & 0 \end{bmatrix} \\ \begin{bmatrix} 8.6 & 3.5 \\ 6.7 & 0 \end{bmatrix} \\ \begin{bmatrix} 14.6 & 3.5 \\ 12.7 & 0 \end{bmatrix} \end{bmatrix}$$

Upper column (first four matrices)

Upper Vertical lines (next four matrices)

Far end of upper column. (last four matrices)

Bottom Column - Cordinates to plot moments

$$MCol_{bot} = \begin{bmatrix} \begin{bmatrix} 0 & 0 \\ -2.5 & 0 \end{bmatrix} \\ \begin{bmatrix} 8 & 0 \\ 8.7 & 0 \end{bmatrix} \\ \begin{bmatrix} 14 & 0 \\ 14.8 & 0 \end{bmatrix} \\ \begin{bmatrix} 0 & 0 \\ 0 & -4 \end{bmatrix} \\ \begin{bmatrix} 8 & 0 \\ 8 & -5 \end{bmatrix} \\ \begin{bmatrix} 14 & 0 \\ 14 & -4 \end{bmatrix} \\ \begin{bmatrix} 0 & -4 \\ 0 & -4 \end{bmatrix} \\ \begin{bmatrix} 8 & -5 \\ 8 & -5 \end{bmatrix} \\ \begin{bmatrix} 14 & -4 \\ 14 & -4 \end{bmatrix} \\ \begin{bmatrix} 0 & -4 \\ -2.5 & 0 \end{bmatrix} \\ \begin{bmatrix} 8 & -5 \\ 8.7 & 0 \end{bmatrix} \\ \begin{bmatrix} 14 & -4 \\ 14.8 & 0 \end{bmatrix} \end{bmatrix}$$

Bottom column (first four matrices)

Bottom Vertical lines (next four matrices)

Far end of bottom column. (last four matrices)

`Call Program 40: Plot UPPER column moment string values`

$$PTS_{top} := Plot\_Pts\left(nn3, Cords_{top}, MSTR_{top}\right)$$

$$PTS_{top} = \begin{bmatrix} 3.9 & 0 & \text{"108"} & 6 & \text{"black"} \\ 6.7 & 0 & \text{"-35"} & 6 & \text{"black"} \\ 12.7 & 0 & \text{"-36"} & 6 & \text{"black"} \end{bmatrix}$$

`Call Program 40: Plot BOTTOM column moment string values`

$$PTS_{bot} := Plot\_Pts\left(nn3, Cords_{bot}, MSTR_{bot}\right)$$

$$PTS_{bot} = \begin{bmatrix} -2.5 & 0 & \text{"71"} & 6 & \text{"black"} \\ 8.7 & 0 & \text{"-18"} & 6 & \text{"black"} \\ 14.8 & 0 & \text{"-24"} & 6 & \text{"black"} \end{bmatrix}$$

$FDN = 0.75$

$nn3 = 1$

XY Plot Settings for Column Moment Diagram **CASE** $nn3 = 1$

$$XYPlot_{XLimMin_5} := -6 \qquad XYPlot_{XLimMax_5} := \frac{\sum L}{m} + 4 \qquad Y_{Col\_Max} := \frac{\mathrm{Max}\left(H_{LC}, H_{UC}\right)}{m} + 1 = 6$$

$$XYPlot_{YLimMin_5} := -Y_{Col\_Max} \qquad XYPlot_{YLimMax_5} := Y_{Col\_Max}$$

$$XYPlot_{XTick_5} := 2 \qquad XYPlot_{YTick_5} := 1$$

$FDN_{cond} :=$ | $TXT := \begin{cases} \text{"Fixed Foundation"} & \text{if } FDN = 1 \\ \text{"Pinned Foundation"} & \text{otherwise} \end{cases}$

setprop("XYPlot5.XYLabel.XLabel", "Length (m)") = 1

FDN_{cond} = "Pinned Foundation"

setprop("XYPlot5.XYLabel.YLabel", "Height (m)") = 1

$XY_{labelFont}(font, pName)$:= setprop("{pName}.XYLabel.LabelFont", font)

$XY_{labelFont}$("Trebuchet MS,7pt", "XYPlot5") = 1

setprop("XYPlot5.XYLabel.LabelFontColor", "brown") = 1

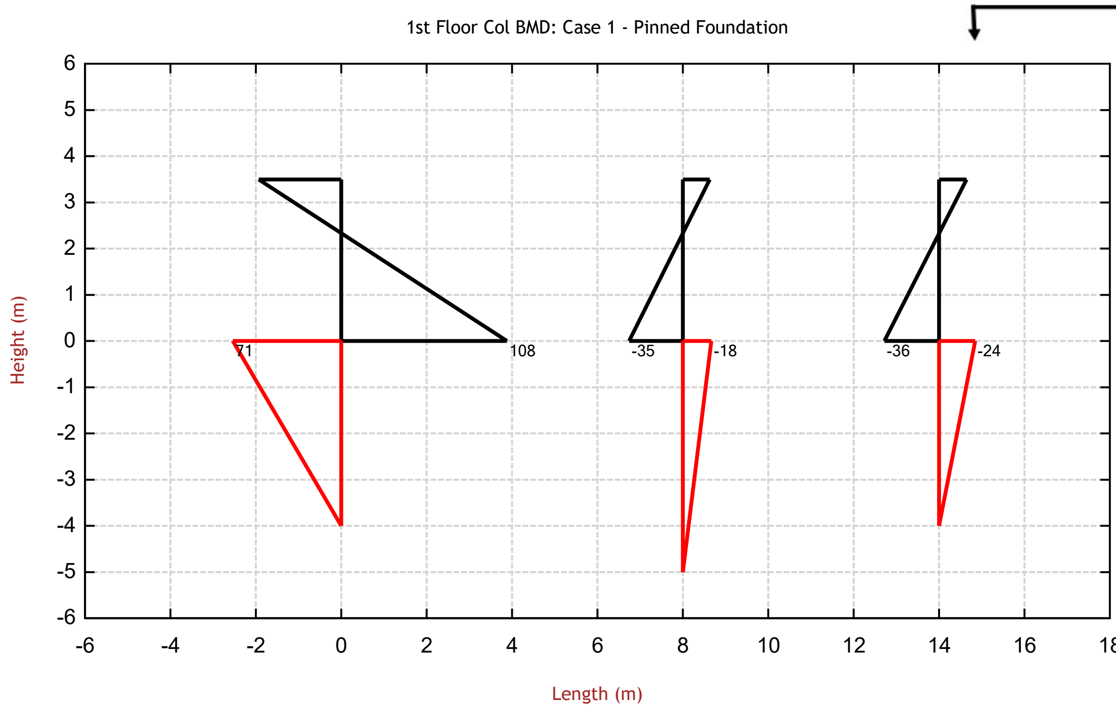
$MyTitle$:= concat("1st Floor Col BMD: Case ", num2str(nn3), " - ", FDN_{cond}) = "1st Floor Col BMD: Case 1 - Pinned Foundation"

setprop("XYPlot5.Title.Text", $MyTitle$) = 1

setprop("XYPlot5.Title.TitleFont", "Trebuchet MS,7pt") = 1

Case number $nn3 = 1$ $FDN = 0.75$

Foundation Columns Pinned at Base



Check with plot

Upper Column

$$M_{col\,nn3\,1} = \begin{bmatrix} 108 \\ -35 \\ -36 \end{bmatrix} kNm$$

Bottom Column

$$M_{col\,nn3\,2} = \begin{bmatrix} 71 \\ -18 \\ -24 \end{bmatrix} kNm$$

Upper Column

$$M_{col\,1\,1} = \begin{bmatrix} 108 \\ -35 \\ -36 \end{bmatrix} kNm$$

Bottom Column

$$M_{col\,1\,2} = \begin{bmatrix} 71 \\ -18 \\ -24 \end{bmatrix} kNm$$

Case 1

time(0) − t_0 = 0.7 s

Upper Column

$$M_{col\,2\,1} = \begin{bmatrix} 117 \\ -65 \\ 2 \end{bmatrix} kNm$$

Bottom Column

$$M_{col\,2\,2} = \begin{bmatrix} 77 \\ -34 \\ 2 \end{bmatrix} kNm$$

Case 2

Upper Column

$$M_{col\,3\,1} = \begin{bmatrix} 33 \\ 17 \\ -52 \end{bmatrix} kNm$$

Bottom Column

$$M_{col\,3\,2} = \begin{bmatrix} 22 \\ 9 \\ -34 \end{bmatrix} kNm$$

Case 3