# CHAPTER SIX

# 6. KANIS METHOD OR ROTATION CONTRIBUTION METHOD OF FRAME ANALYSIS

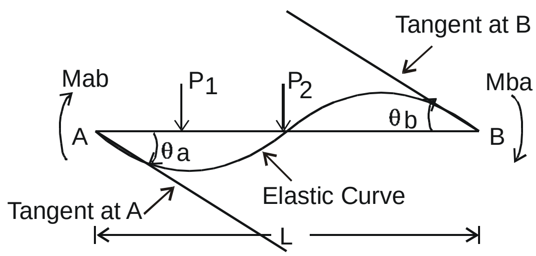
This method may be considered as a further simplification of moment distribution method wherein the problems involving sway were attempted in a tabular form thrice (for double story frames) and two shear co-efficients had to be determined which when inserted in end moments gave us the final end moments. All this effort can be cut short very considerably by using this method.

→ Frame analysis is carried out by solving the slope – deflection equations by successive approximations. Useful in case of side sway as well.

→ Operation is simple, as it is carried out in a specific direction. If some error is committed, it will be eliminated in subsequent cycles if the restraining moments and distribution factors have been determined correctly. Please note that the method does not give realistic results in cases of columns of unequal heights within a storey and for pin ended columns both of these cases are in fact extremely rare even in actual practice. Even codes suggest that RC columns framing into footings or members above may be considered more or less as fixed for analysis and design purposes.

**Case 1. No side sway and therefore no translation of joints derivation.**

Consider a typical member AB loaded as shown below:




A GENERAL BEAM ELEMENT UNDER END MOMENTS AND LOADS

**General Slope deflection equations are**.

$$Mab = MFab + \frac{2EI}{L}(-2\theta a - \theta b) \quad \rightarrow (1)$$

$$Mba = MFba + \frac{2EI}{L}(-\theta a - 2\theta b) \quad \rightarrow (2)$$

equation (1) can be re-written as

$$Mab = MFab + 2\,M'ab + M'ba \quad \rightarrow (3)$$

where MFab = fixed end moment at A due to applied loads.

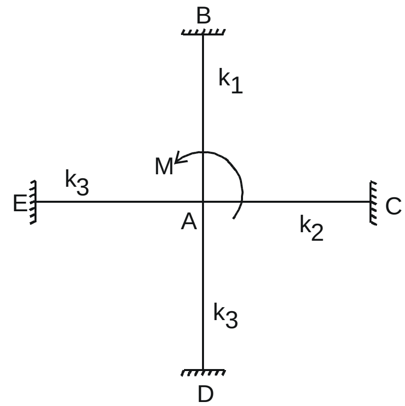
and $M'ab$ = rotation contribution of near end A of member AB $= -\frac{EI}{L}(2\theta a)$

$$= -\frac{2EI\,\theta a}{L} = -2E\,k_1\,\theta a \quad \rightarrow (4) \text{ where } \left[k_1 = \frac{I_1}{L_1}\right]$$

$M'ba$ = rotation contribution of for end B of member AB.

So $M'ba = -\frac{2\,EI\,\theta b}{L} = -2Ek_1\,\theta b \quad \rightarrow (5)$

Now consider a generalized joint A in a frame where members AB, AC, AD.........meet. It carries a moment M.




For equilibrium of joint A, $\sum Ma = 0$

or Mab + Mac + Mad + Mae.................= 0 Putting these end moments in form of eqn. (3)

or $\sum MF\,(ab, ac, ad) + 2\sum M'\,(ab, ac, ad) + \sum M'\,(ba, ca, da) = 0$

Let $\sum MF\,(ab, ac, ad) = MFa$ (net FEM at A)

So $MFa + 2\sum M'\,(ab, ac, ad) + \sum M'\,(ba, ca, da) = 0 \quad \rightarrow (6)$

From (6), $\sum M'\,(ab, ac, ad) = -\frac{1}{2}[(MFa + \sum M'\,(ba, ca, da)] \quad \rightarrow (7)$

From (4), $\sum M'\,(ab, ac, ad) = -2Ek_1\,\theta a - 2\,Ek_2\,\theta a - 2\,Ek_3\,\theta a + \ldots\ldots$

$= -2\,E\theta a\,(k_1 + k_2 + k_3)$

$= -2\,E\theta a\,(\sum k)$, ( sum of the member stiffnesses framing in at joint A)

or $\theta a = -\dfrac{\sum M'\,(ab, ac, ad)}{2E\,(\sum k)} \quad \rightarrow (8)$

From (4), $M'ab = -2\,Ek_1\,\theta a$. Put $\theta a$ from (8), we have

$$M'ab = -2E\,k_1\left[-\frac{\sum M'\,(ab, ac, ad)}{2E\,(\sum k)}\right] = \frac{k_1}{\sum k}[\sum M'\,(ab, ac, ad)]$$

From (7), Put $\sum M'\,(ab, ac, ad)$

So $M'ab = \dfrac{k_1}{\sum k}\left[-\frac{1}{2}(MFa + \sum M'\,(ba, ca, da))\right]$

or $\quad M'ab = -\frac{1}{2}\frac{k_1}{\sum k}[\ MFa\ + \sum M'\ (ba,\ ca,\ da)]$

on similar lines $\quad M'ac = -\frac{1}{2}\frac{k_2}{\sum k}[\ MFa\ + \sum M'\ (ba,\ ca,\ da)]$

and $\quad M'ad = -\frac{1}{2}\frac{k_3}{\sum k}[\ MFa\ + \sum M'\ (ba,\ ca,\ da)]$

rotation contribution of near end of member ad. $\qquad$ sum of the rotations contributions of far ends of members meeting at A.

Sum of rotation factors at near end of members ab, ac, ad is

$$-\frac{1}{2}\frac{k_1}{\sum k}-\frac{1}{2}\frac{k_2}{\sum k}-\frac{1}{2}\frac{k_3}{\sum k} = -\frac{1}{2}\left[\cancel{\frac{k_1+k_2+k_3+\ldots\ldots}{\sum k}}\right]$$

$$= -\frac{1}{2},\ \left[\text{sum of rotation factors of different members meeting at a joint is equal to } -\frac{1}{2}\right]$$

**Therefore, if net fixed end moment at any joint along with sum of the far end contribution of members meeting at that joint are known then near end moment contribution can be determined. If far end contributions are approximate, near end contributions will also be approximate. When Far end contributions are not known (as in the first cycle), they can be assumed to be zero.**

**6.1. RULES FOR CALCULATING ROTATION CONTRIBUTIONS :—** Case-1: Without sides way.

**Definition**: **"Restrained moment at a joint is the algebraic sum of FE.M's of different members meeting at that joint."**

**1.** Sum of the restrained moment of a joint and all rotation contributions of the far ends of members meeting at that joint is multiplied by respective rotation factors to get the required near end rotation contribution. For the first cycle when far end contributions are not known, they may be taken as zero (Ist approximation).

**2.** By repeated application of this calculation procedure and proceeding from joint to joint in an arbitrary sequence **but in a specific direction**, all rotation contributions are known. The process is usually stopped when end moment values converge. This normally happens after three or four cycles. But values after 2nd cycle may also be acceptable for academic.

**6.2. Case 2**:— **With side sway (joint translations)**

In this case in addition to rotation contribution, linear displacement contributions ( Sway contributions ) of columns of a particular storey are calculated after every cycle as follows:

**6.2.1. For the first cycle**.

**(A) →** **Linear Displacement Contribution** ( LDC) of a column = Linear displacement factor (LDF) of a particular column of a story multiplied by [storey moment + contributions at the ends of columns of that story]

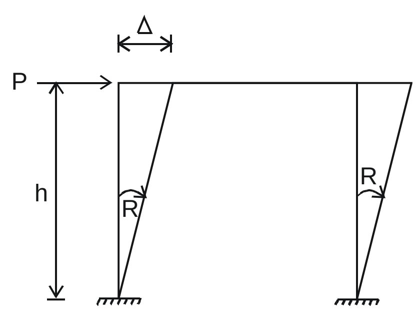
Linear displacement factor (LDF) for columns of a storey = $-\frac{3}{2}$

Linear displacement factor of a column = $-\frac{3}{2}\frac{k}{\sum k}$ Where k=stiffness of the column being considered and Σk is the sum of stiffness of all columns of that storey.

**6.2.2. (B) →** **Storey moment** = Storey shear x $\frac{1}{3}$ of storey height.

**6.2.3. (C) →** **Storey shear** : It may be considered as reaction of column at horizontal beam / slab levels due to lateral loads by considering the columns of each sotrey as simply supported beams in vertical direction. **"If applied load gives + R value (according to sign conversion of slope deflection method), storey shear is +ve or vice versa."**

Consider a general sway case.




**6.3. SIGN CONVENSION ON MOMENTS**:– Counter-clockwise moments are positive and clockwise rotations are positive.

## For first cycle with side sway.

**(D)** Near end contribution of various members meeting at that joint. = respective rotation contribution factor × [Restrained moment + far end contributions]

**Linear displacement contributions will be calculated after the end of each cycle for the columns only**.

**FOR 2ND AND SUBSEQUENT CYCLES.**

**(E) →** Near end contributions of various members meeting at a joint. = Respective rotation contribution factor × [Restrained moment + far end contributions + linear displacement contribution of columns of different storeys meeting at that joint].

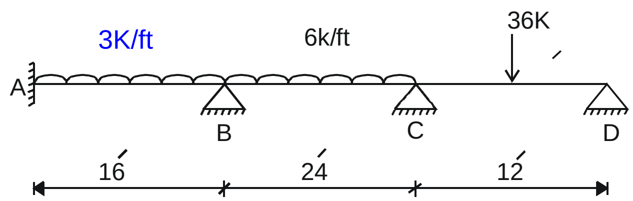
### 6.4. Rules for the Calculation of final end moments (sidesway cases)

**(F)** For beams, End moment = FEM + 2 near end contribution + Far end contributions.

**(G)** For columns, End moment. = FEM + 2 near end contribution + Far end contribution + linear displacement contribution of that column for the latest cycle.

### 6.5. APPLICATION OF ROTATION CONTRIBUTION METHOD (KANI'S METHOD) FOR THE ANALYSIS OF CONTINUOUS BEAMS

**Example No.1:** Analyze the following beam by rotation contribution method. EI is constant.




EI = constt.

***Note.*** Analysis assumes continuous ends with some fixity. Therefore, in case of extreme hinged supports in exterior spans, modify (reduce) the stiffness by 3/4 = (0.75).for a hinged end.

**Step No. 1**. **Relative Stiffness.**

| Span | I | L | $\frac{I}{L}$ | $K_{rel}$ | K modified. |
|---|---|---|---|---|---|
| AB | 1 | 16 | $\frac{1}{16} \times 48$ | 3 | 3 |
| BC | 1 | 24 | $\frac{1}{24}$ | 2 | 2 |
| CD | 1 | 12 | $\frac{1}{12}$ | 4 x (3/4) | 3 |

(exterior or discontinuous hinged end)

**Step No.2**. **Fixed end moments.**

$$Mfab = +\frac{wL^2}{12} = +\frac{3 \times 16^2}{12} = +64 \text{ K-ft.}$$

$$Mfba = -64$$

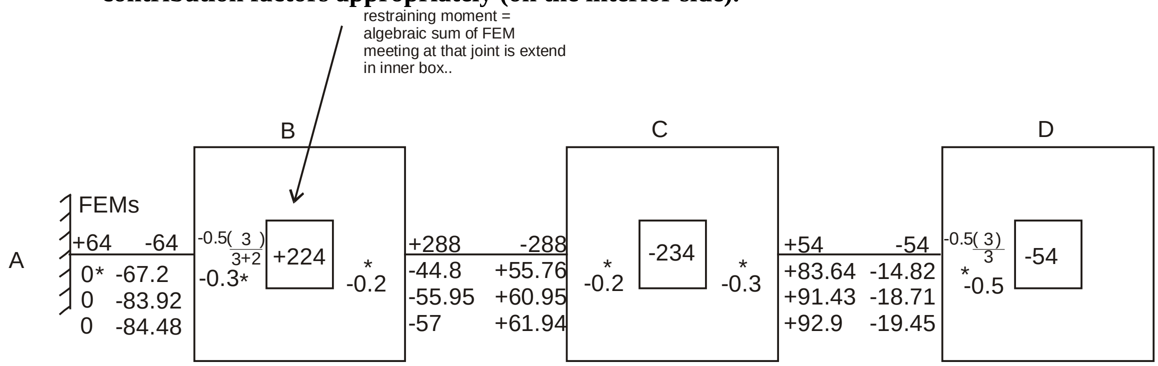
$$Mfbc = +\frac{6 \times 24^2}{12} = +288$$

$$Mfcb = -288$$

$$Mfcd = +\frac{Pa^2b}{L^2} = \frac{+36 \times 6^2 \times 6}{12^2} = +54$$

$$Mfdc = -54$$

**Step No.3. Draw Boxes, enter the values of FEMs near respective ends of exterior boxes and rotation contribution factors appropriately (on the interior side).**




* = Distribution factors.

A C( Far end contribution) B D( Far end contributions)

**FIRST CYCLE** ↓ ↓ ↓ ↓

Joint B: – 0.3 (+224 + 0 + 0) = – 67.2 (Span BA) Joint C: – 0.2(– 234 – 44.8 + 0) = +55.76 (Span CB)
and – 0.2 ( 224 + 0 + 0) = – 44.8 (Span BC) and – 0.3(– 234 – 44.8 + 0) = +83.64 (Span CD)

Joint D: – 0.5(– 54 +83.64) = – 14.82 (Span DC)

**2nd cycle**:

A C ( Far end contributions) B D (far end contributions)
↓ ↓ ↓ ↓

Joint B. – 0.3 (+ 224+0 +55.76) = – 83.92 Joint C: – 0.2 (– 234 – 55.95 – 14.82) = 60.95
– 0.2 (+224+0 +55.76) = – 55.85 – 0.3 (– 234 – 55.95 – 14.82) = 91.43

Joint D. – 0.5 ( – 54 + 91.43) = – 18.715

**3rd cycle**: Singular to second cycle procedure. We stop usually after 3 cycles and the answers can be further refined by having another couple of cycles. (Preferably go up to six cycles till difference in moment value is 0.1 or less). The last line gives near and far end contribution.

**Step No. 4. FINAL END MOMENTS**

**For beams**. End moment = FEM + 2near end cont. + Far end contribution.

Mab = + 64 + 2 x 0 – 84.48 = – 20.48 k – ft.

Mba = – 64 – 2 x 84.48 + 0 = – 232.96 k – ft.

Mbc = + 288– 2 x 57 + 61.94 = +235.9 k – ft.

Mcb = – 288 + 2 x 61.94 – 57 = – 221.12

Mcd = + 54 + 2 x 92.9 – 19.45 = + 220.35

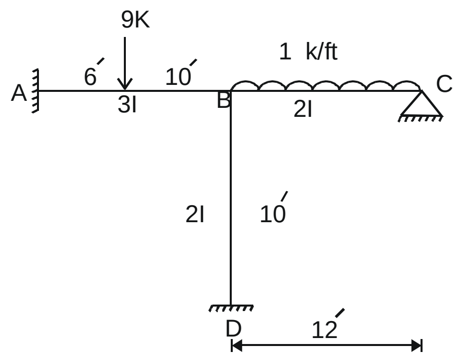
Mdc = – 54 – 2 x 19.45 + 92.9 = zero

The beam has been analyzed and we can draw shear force and bending moment diagrams as usual.

## 6.6. Rotation Contribution Method: Application to frames without side sway.

**Example No 2:**

Analyze the following frame by Kanis method ( rotation Contribution Method )




**Step No. 1** **Relative Stiffness.**

| Span | I | L | $\frac{I}{L}$ | $K_{rel}$ | K modified. |
|---|---|---|---|---|---|
| AB | 3 | 16 | $\frac{3}{16} \times 240$ | 45 | 45 |
| BC | 2 | 12 | $\frac{2}{12} \times 240$ | $40\left(\frac{3}{4}\right)$ | 30 (Exterior hinged end) |
| BD | 2 | 10 | $\frac{2}{10} \times 240$ | 48 | 48 |
| | | | | | $\sum 103$ |

**Step No.2.** **FEM's**

$$Mfab = \frac{9 \times 6 \times 10^2}{16^2} = +21.1 \text{ K-ft}$$

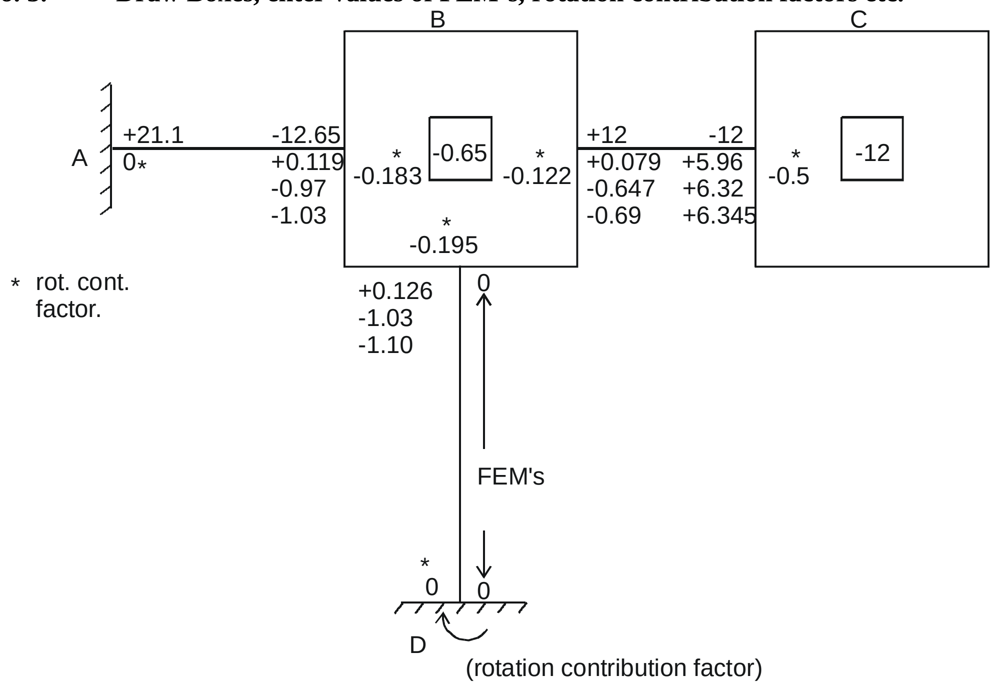
$$Mfba = \frac{9 \times 10 \times 6^2}{16^2} = -12.65$$

$$Mfbc = \frac{1 \times 12^2}{12} = +12$$

$$Mfcb = -12$$

Mfbd = Mfdb = 0 ( No load within span BD)

**Step No. 3.** **Draw Boxes, enter values of FEM's, rotation contribution factors etc.**




Apply all relevant rules in three cycles. Final end moments may now be calculated.

**For beams**. End moment = FEM + 2 x near end contribution. + Far end contribution

**For Columns** : End moment = FEM + 2 x near end contribution + Far end contribution + Linear displacement contribution of that column. To be taken in sway cases only.

Mab = 21.1 + 2x0 –1.03 = + 20.07 K–ft

Mba = –12.65 –2 x 1.03 + 0 = –14.71

Mbc = +12 –2 x 0.69 + 6.345 = 16.965

Mbd = 0 – 2x1.1 +0 = –2.2

Mcb = –12 + 2x 6.345 –0.69 = 0

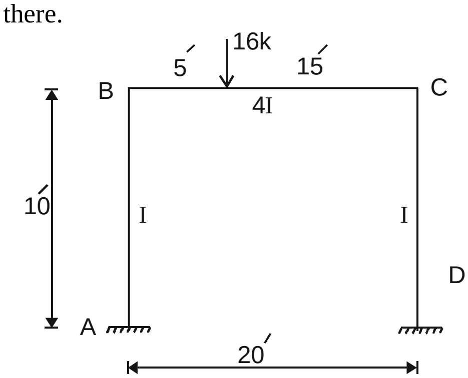
Mdb = 0 + 2x0–1.10 = –1.10

Equilibrium checks are satisfied. End moment values are OK. Now SFD and BMD can be drawn as usual.

**Example No. 3:** Analyse the following frame by rotation Contribution Method.

**SOLUTION:-**

It can be seen that sway case is there.



**Step No. 1.** **Relative Stiffness.**

| Member. | I | L | $\frac{I}{L}$ | $K_{rel}$ |
|---|---|---|---|---|
| AB | 1 | 10 | $\frac{1}{10} \times 10$ | 1 |
| BC | 4 | 20 | $\frac{4}{20} \times 10$ | 2 |
| CD | 1 | 10 | $\frac{1}{10} \times 10$ | 1 |

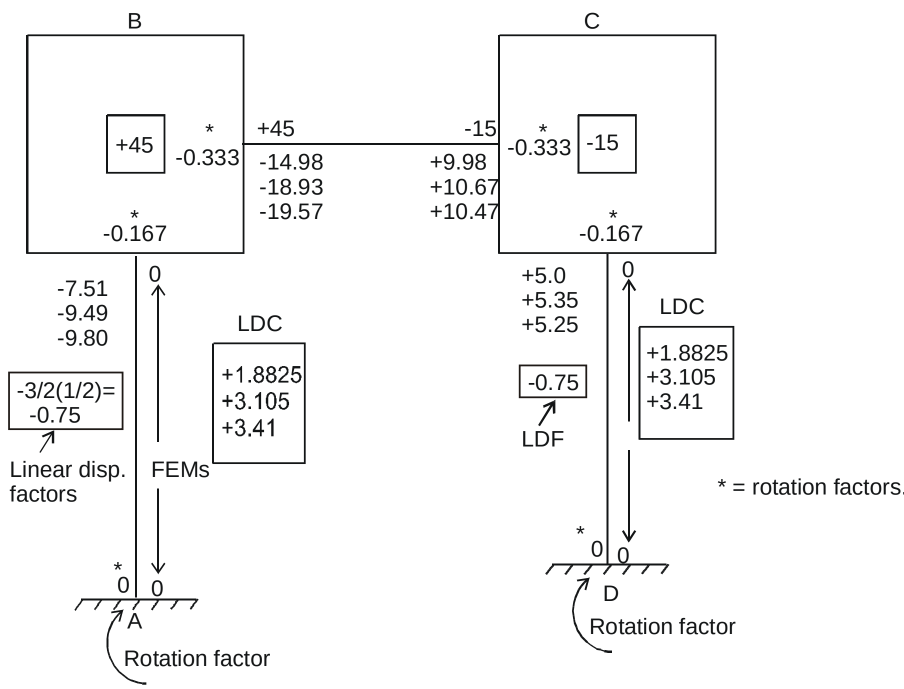
**Step No. 2.** **FEM's**

$$Mf_{BC} = \frac{+16 \times 5 \times 15^2}{20^2} = +45$$

$$Mf_{CB} = \frac{-16 \times 5^2 \times 15}{20^2} = -15$$

All other fixing moments are zero.

**Step No.3** **Draw Boxes, enter FEM's and rotation Contribution factors etc. Apply three cycles.**




See explanation of calculations on next page.

**Note:** After applying the first cycle as usual, calculate linear displacement contribution for columns of all storeys. Repeat this calculation after every cycle.

Linear displacement contribution (LDC) of a column=Linear displacement factor [ story moment + contribution of column ends of that storey)

Storey moment is zero because no horizontal load acts in column and there is no storey shear.

↓

**After 1st cycle: Linear Disp. Cont =** $-0.75\,[0 + 5.0 - 7.5 + 0 + 0] = +1.8825$

→ **For 2nd cycle onwards to calculate rotation contribution, apply following Rule**:–

Rotation contribution = rotation contribution factor [restrained moment + far end contributions + linear displacement contribution of columns. of different. storeys meeting at that joint.]

**2nd cycle**.

A     C( Far ends)
↓     ↓

Joint B.    – 0.167 [ +45 + 0 + 9.98 + 1.8825 ] = – 9.49    (Span BA)

and    – 0.333 [ ––––––– do –––––––– ] = – 18.93    (Span BC)

Joint C.    – 0.333 [ – 15 – 18.93 + 0 + 1.8825 ] = + 10.67    (Span CB)

and    – 0.167 [ –––––––– do –––––––– ] = + 5.35    (Span CD)

**After 2nd cycle**. Linear displacement contribution is equall to

storey moment.
↓
= – 0.75 [ 0 – 9.49 + 0 + 5.35 + 0 ] = + 3.105

**After 3rd cycle.**

After 3rd cycle , linear displacement. contribution of columns is equall to
storey moment.
↓

= – 0.75 [ 0 – 9.80 + 5.25 + 0 + 0 ] = 3.41

**Calculate end moments after 3rd cycle**.

For beams: End moment = FEM + 2 near end contribution. + Far end contribution.

For columns. End moment = FEM + 2 near end contribution + Far end contribution.
+ linear displacement. contribution of that column.

Applying these rules

Mab = 0 + 0 – 9.80 + 3.41 = – 6.3875 k.ft.

Mba = + 0 – 2 × 9.80 + 0 + 3.41 = + 16.19

Mbc = + 45 – 2 × 19.57 + 10.47 = + 16.33

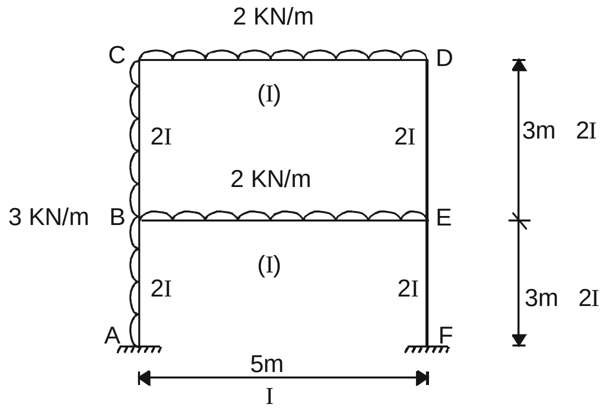
Mcb = – 15 + 2 × 10.47 – 19.57 = 13.63

Mcd = 0 + 2 × 5.25 + 0 + 3.41 = 13.91

Mdc = 0 + 2 × 0 + 5.25 + 3.41 = 8.66

By increasing number of cycles the accuracy is increased.

**Example No 4** : Solve the following double story frame carrying gravity and lateral loads by rotation contribution method.




**SOLUTION :–**

If this is analyzed by slope-deflection or Moment distribution method, it becomes very lengthy and laborious. This becomes easier if solved by rotation contribution method.

Step 1: **F.E.Ms.**

$$\text{Mfab} = \frac{+3 \times 3^2}{12} = +2.25 \text{ KN–m}$$

Mfba = – 2.25 KN–m

Mfbc = + 2.25 KN–m

Mfcb = – 2.25 KN–m

$$\text{Mfcd} = \frac{2 \times 5^2}{12} = +4.17 \text{ KN–m}$$

Mfdc = – 4.17 KN–m

Mfbe = + 4.17 KN–m

Mfeb = – 4.17 KN–m.

Mfde = Mfed = 0

Mfef = Mffe = 0

Step 2: **RELATIVE STIFFNESS :–**

| Span | I | L | $\frac{I}{L}$ | K |
|---|---|---|---|---|
| AB | 2 | 3 | $\frac{2}{3} \times 15$ | 10 |
| BC | 2 | 3 | $\frac{2}{3} \times 15$ | 10 |

| | | | | |
|---|---|---|---|---|
| BE | 1 | 5 | $\frac{1}{5} \times 15$ | 3 |
| CD | 1 | 5 | $\frac{1}{5} \times 15$ | 3 |
| DF | 2 | 3 | $\frac{2}{3} \times 15$ | 10 |
| EF | 2 | 3 | $\frac{2}{3} \times 15$ | 10 |

LINEAR DISPLACEMENT FACTOR = L.D.F. of a column of a particular storey.

$$\text{L.D.F.} = -\frac{3}{2}\frac{K}{\sum K}$$

Where K is the stiffness of that column & $\sum K$ is the stiffness of columns of that storey. Assuming columns of equal sizes in a story. ( EI same)

$$\text{L.D.F}_1 = -\frac{3}{2} \times \frac{10}{(10+10)} = -0.75 \qquad \text{(For story No. 1)}$$

$$\text{L.D.F}_2 = -\frac{3}{2} \times \frac{10}{(10+10)} = -0.75 \qquad \text{(For story No. 2)}$$

**Storey Shear :–**

This is, in fact, reaction at the slab or beam level due to horizontal forces. If storey shear causes a (–ve) value of R, it will be (–ve) & vice versa.

For determining storey shear the columns can be treated as simply supported vertical beams.

(1) Storey shear = – 9 KN ( For lower or ground story. At the slab level of ground story)
(2) Storey shear = – 4.5 ( For upper story ). At the slab level of upper story root)

**Storey Moment ( S.M) :–**

S.M. = Storey shear + h/3 where h is the height of that storey.

$$SM_1 = -9 \times \frac{3}{3} = -9 \qquad \text{( lower story )}$$

$$S.M_2 = -4.5 \times \frac{3}{3} = -4.5 \qquad \text{( Upper story )}$$

**Rotation Factors**

The sum of rotation factors at a joint is – ½. The rotation factors are obtained by dividing the value – ½ between different members meeting at a joint in proportion to their K values.

$$\mu ab = -\frac{1}{2}\,\frac{k_1}{\sum k}$$

$$\mu ac = -\frac{1}{2}\,\frac{k_2}{\sum k}\ \text{etc.}$$

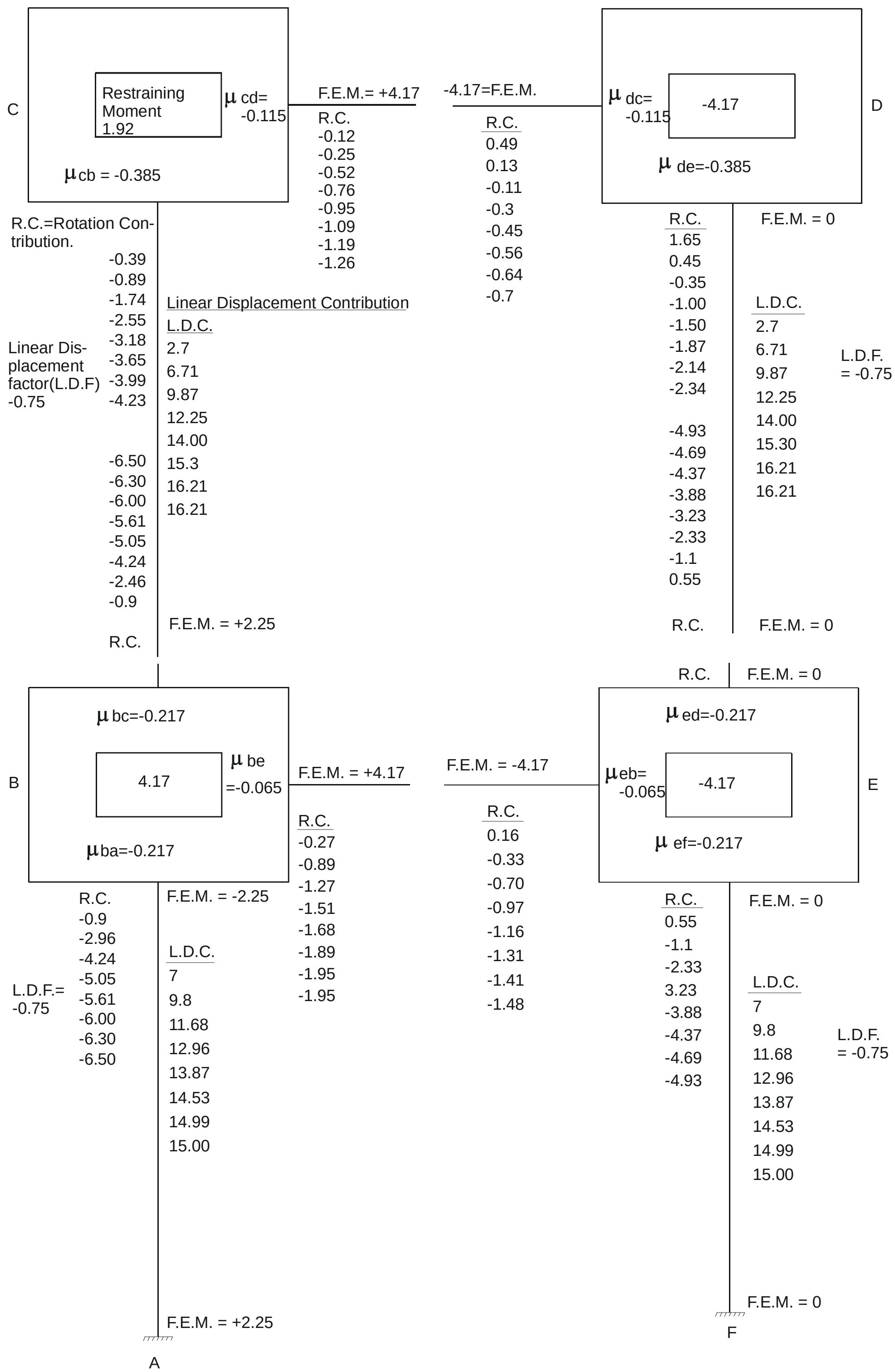
**Rotation Contributions:–**

The rule for calculating rotation contribution is as follows.

**Sum the restrained moments of a point and all rotation contribution of the far ends of the members meeting at a joint. Multiply this sum by respective rotation factors to get the required rotation contribution. For the first cycle far end contribution can be taken as zero**.

| Span | K | Rotation factor. |
|---|---|---|
| AB | 10 | 0 (Being fixed end) |
| BC | 10 | $-\frac{1}{2}\left(\frac{10}{23}\right) = -0.217$ |
| BE | 3 | $-0.5\left(\frac{3}{23}\right) = -0.065$ |
| BA | 10 | $-0.5\left(\frac{10}{23}\right) = -0.217$ |
| CB | 10 | – 0.385 |
| CD | 3 | – 0.115 |
| DC | 3 | – 0.115 |
| DE | 10 | – 0.385 |
| ED | 10 | – 0.217 |
| EB | 3 | – 0.065 |
| EF | 10 | – 0.217 |
| FE | 10 | 0 (Being fixed end) |

Now draw boxes, enter FEMs values, rotation factors etc. As it is a two storeyed frame, calculations on a single A4 size paper may not be possible. A reduced page showing calculation is annexed.




Double – storey frame carrying gravity and lateral loads – Analysed by Rotation Contribution Method.

**First Cycle** :–

Near end contribution = Rotation factor of respective member (Restrained moment + far end contributions).

Joint B = R.F. ( 4.17 )

C = R.F. ( 1.92 – 0.9 )

D = R.F. (– 4.17 – 0.12)

E = R.F. (– 4.17 + 1.65)

**After First Cycle** :–

Linear Displacement Contribution :–= L.D.F.[Storey moment + Rotation contribution at the end of columns of that storey].

$L.D.C_1 = -0.75\,(-9 - 0.9 + 0.55) = 7$

$L.D.C_2 = -0.75\,(4.5 - 0.9 - 0.39 + 0.55 + 1.65) = 2.7$

**For 2nd Cycle And Onwards** :–

Near end contribution = R.F.[Restrained moment + Far end contribution + Linear displacement contributions of columns of different storeys meeting at that joint]

Joint B= R.F. (4.17 + 0.16 – 0.39 + 7 + 2.7 )

C= ″ (1.92 + 0.49 – 2.96 + 2.7)

D= ″ (– 4.17 – 0.25 + 0.55 + 2.7)

E= ″ (– 4.17 + 0.45 – 0.89 + 2.7 + 7 ).

**After 2nd Cycle :–**

$L.D.C_1 = -0.75\,(-9 - 2.96 - 1.1) = 9.8$

$L.D.C_2 = -0.75\,(-4.5 - 2.96 - 0.83 - 1.1 + 0.45) = 6.71$

**3rd Cycle :–**

Joint B= R.F. ( 4.17 – 0.33 – 0.83 + 9.8 + 6.71)

C= ″ ( 1.92 + 0.13 – 4.24 + 6.71 )

D= ″ (– 4.17 – 1.1 – 0.52 + 6.71)

E= ″ (– 4.17 – 1.27 – 0.35 + 9.8 + 6.71)

**After 3rd Cycle :–**

$L.D.C_1 = -0.75 (-9 - 4.24 - 2.33) = 11.68$

$L.D.C_2 = -0.75 (-4.5 - 1.74 - 4.24 - 0.35 - 2.33) = 9.87$

**4th Cycle** :–

Joint B= R.F. $(4.17 - 0.70 - 1.74 + 11.68 + 9.87)$

C= ″ $(1.92 - 0.11 - 5.05 + 9.87)$

D= ″ $(-4.17 - 0.76 - 2.33 + 9.87)$

E= ″ $(-4.17 - 1 - 1.51 + 9.87 + 11.68)$.

**After 4th Cycle** :–

$L.D.C_1 = -0.75 (-9 - 5.05 - 3.23) = 12.96$

$L.D.C_2 = -0.75 (-4.5 - 5.05 - 2.55 - 1.00 - 3.23) = 12.25$

**5th Cycle :–**

Joint B= R.F. $(4.17 - 0.97 - 2.55 + 12.25 + 12.96)$

C= ″ $(1.92 - 0.3 - 5.61 + 12.25)$

D= ″ $(-4.17 - 0.95 - 3.23 + 12.25)$

E= ″ $(-4.17 - 1.5 - 1.68 + 12.25 + 12.96)$

**After 5th Cycle** :–

$L.D.C_1 = -0.75 (-9 - 5.61 - 3.88) = 13.87$ (ground storey)

$L.D.C_2 = -0.75 (-4.5 - 5.61 - 3.18 - 1.5 - 3.88) = 14$ (First Floor)

**6th Cycle** :–

Joint B = R.F. $(4.17 - 1.16 - 3.18 + 14 + 13.87)$

C = ″ $(1.92 - 0.05 - 6 + 14)$

D = ″ $(-4.17 - 3.88 - 1.09 + 14)$

E = ″ $(-4.17 - 1.87 - 1.68 + 14 + 13.87)$

**After 6th Cycle** :–

$L.D.C_1 = -0.75\ (-9 - 6 - 4.37) = 14.53$

$L.D.C_2 = -0.75\ (-4.5 - 6 - 3.65 - 1.87 - 4.37) = 15.3$

**7th Cycle** :–

| | | | |
|---|---|---|---|
| Joint | B | = | R.F. (4.17 – 1.31 – 3.65 + 15.3 + 14.53) |
| | C | = | ″ (1.92 – 0.56 – 6.30 + 15.3) |
| | D | = | ″ (– 4.17 – 1.19 – 4.37 + 15.3) |
| | E | = | ″ (– 4.17 – 1.89 – 2.14 + 15.3 + 14.53) |

**After 7th Cycle :–**

$L.D.C_1 = -0.75\ (-9 - 6.30 - 4.69) = 14.99$

$L.D.C_2 = -0.75\ (-4.5 - 6.3 - 3.99 - 2.14 - 4.69) = 16.21$

**8th Cycle** :–

| | | | |
|---|---|---|---|
| Joint | B | = | R.F. (4.17 – 1.41 – 3.99 + 16.21 + 14.99) |
| | C | = | ″ (1.92 – 6.5 – 0.64 + 16.21) |
| | D | = | ″ (– 4.17 – 4.69 – 1.26 + 16.21) |
| | E | = | ″ (– 4.17 – 2.34 – 1.95 + 16.21 + 14.99) |

**After 8th Cycle :–**

$L.D.C_1 = -0.75\ (-9 - 6.5 - 4.93) \cong 15$

$L.D.C_2 = -0.75\ (-4.5 - 6.5 - 4.23 - 4.93 - 2.34). \cong 16.21$

**FINAL END MOMENTS :–**

(1) **Beams or Slabs :–**

= F.E.M + 2 (near end contribution) + far end contribution of that particular beam or slab.

(2) **For Columns :–**

= F.E.M + 2 (near end contribution) + far end contribution of that particular column + L.D.C. of that column. Applying these rules we get the following end moments.

**END MOMENTS :–**

| | | | |
|---|---|---|---|
| Mab | = 2.25 + 2 × 0 – 6.5 + 15 | = | + 10.75 KN–m |
| Mba | = – 2.25 – 2 (6.5) – 1 + 15 | = | – 0.25 ″ |
| Mbc | = 2.25 – 2 × 6.5 – 4.23 + 16.21 | = | + 1.23 ″ |
| Mbe | = 4.17 – 2 (1.95) – 1.48 | = | – 1.21 ″ |
| Mcb | = – 2.25 – 2 × 4.23 – 6.5 + 16.21 | = | – 1 ″ |
| Mcd | = 4.17 – 2 × 1.26 – 0.7 | = | + 0.95≅+1 ″ |
| Mdc | = – 4.17 – 2 × 0.7 – 1.26 | = | – 6.83 ″ |
| Mde | = 0 – 2 × 2.34 – 4.93 + 16.21 | = | + 6.60 ″ |
| Med | = 0 – 2 × 4.93 – 2.34 + 16.21 | = | + 4.01 ″ |
| Meb | = – 4.17 – 2 × 1.48 – 1.95 | = | – 9.08 KN–m |
| Mef | = 0 – 2 × 4.93 + 15 | = | + 5.14 ″ |
| Mfe | = 0 – 2 × 0 – 4.93 + 15 | = | + 10.07 ″ |

**Now frame is statically determinate and contains all end moments. It can be designed now**.

**Space for notes:**