ANALYSIS OF STEEL GABLE FRAME BY THE STIFFNESS MATRIX METHOD

A Dissertation Report

Submitted in the Partial fulfillment of the

Requirement for Award of the Degree

of

MASTER OF THECHNOLOGY

In STRUCTURAL ENGINEERING

By

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DECLARATION

I hereby declare that the dissertation entitled, "**Analysis of Steel Gable Frame by Stiffness Matrix Method"** submitted for the M.Tech degree is entirely my original work and all ideas and references have been duly acknowledge. It does not contain any work for the award of any other degree or diploma.

Date: Prabhdeep Singh

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CERTIFICATE

Certified that this project report entitled "**Analysis of Steel Gable Frame by Stiffness Matrix Method"** submitted independent by student of School of Civil Engineering, Lovely Professional University, Phagwara are carrying out the work under the direction of me for the Award of Degree. The report has not been submitted to a university or institution for the award of any degree.

Signature of Supervisor

Mr. Manoharan Rajalingam

Asso. Professor (Head of Structural Engineering Discipline)

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Any accomplishment requires the efforts of people and, this is not different. So it has been also complete with cooperation of many persons. I am thankful to my guide **"Mr. Manoharan Rajalingam"** who gave me the golden opportunity to do this wonderful research on the topic **"Analysis of Steel Gable Frame by Stiffness Matrix Method"**, which also helped me in doing a lot of Research and I came to know about so many new things.

Secondly I would also like to thank my parents and friends who helped me a lot in finishing this project within the limited time.

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Table of Contents

ABSTRACT

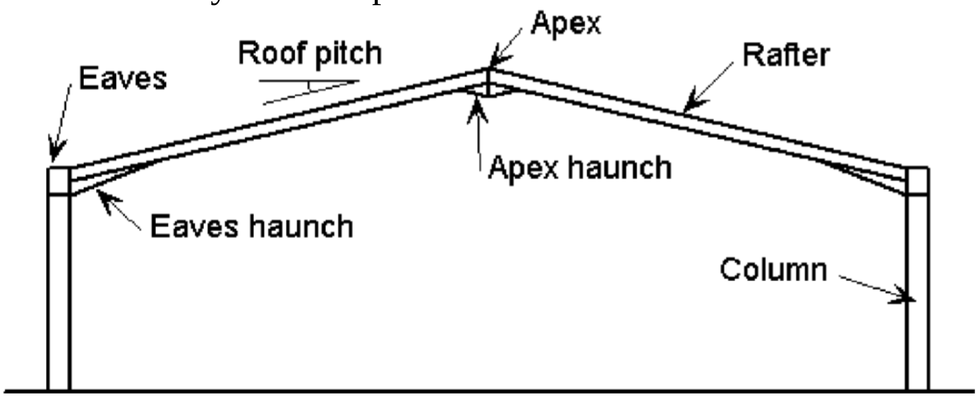
Gable frame are type of steel portal frame with one basic difference that is it has inclined sides and high. Gabel frame are used in single storey steel industrial building when large span is required. In this paper the single bay gable frame with 8m span and 2m rise are analyzed by the use of stiffness matrix that is also known as direct stiffness matrix. UDL load is applied on rise of gable frame and one nodal load is also applied on column. Local and global stiffness matrix all the member is formed. By the relation of stiffness matrix and force matrix all displacement are calculated. By the use of this displacement member reaction like shear force and bending moment are calculated.

Introduction

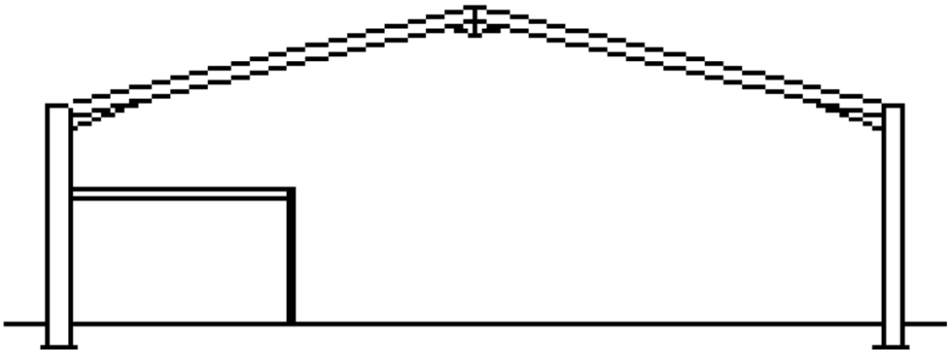
Steel portal frames were developed during Second World War. Portal frames are developed to achieve the low cost steel building. Steel portal frame and gable frames are now using commonly for single storey building. Portal frame are constructed by the hot rolled section. I section and H section are most commonly use in gable frame. Fixed support and pinned support are generally used in gable frame. The portal frame bases may be pinned or fixed, depending upon rotational restraint provided by the foundation and the connection detail between the stanchion and foundations. The foundation restraint depends on the type of foundation and modulus of the subgrade. Frames with pinned bases are heavier than those having fixity at the bases. However, frames with fixed base may require a more expensive foundation. For the design of portal frames, plastic methods of analysis are mainly used, which allows the engineer to analyze frames easily and design it economically

Types of portal frame

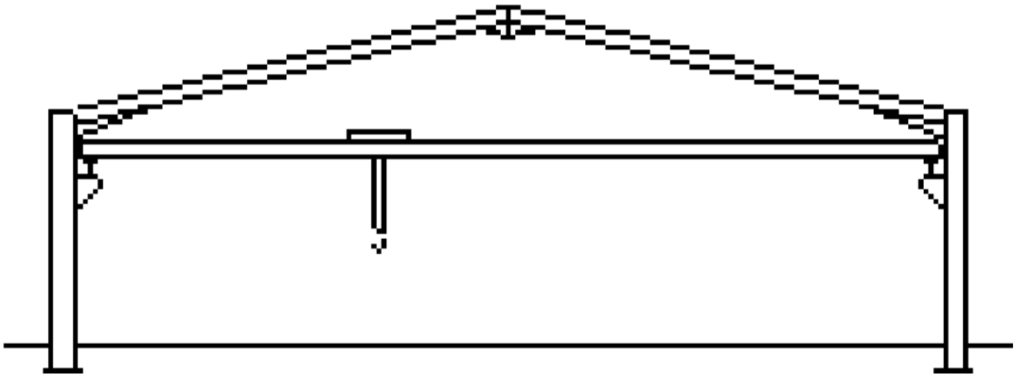
- Pitched roof symmetric portal frame



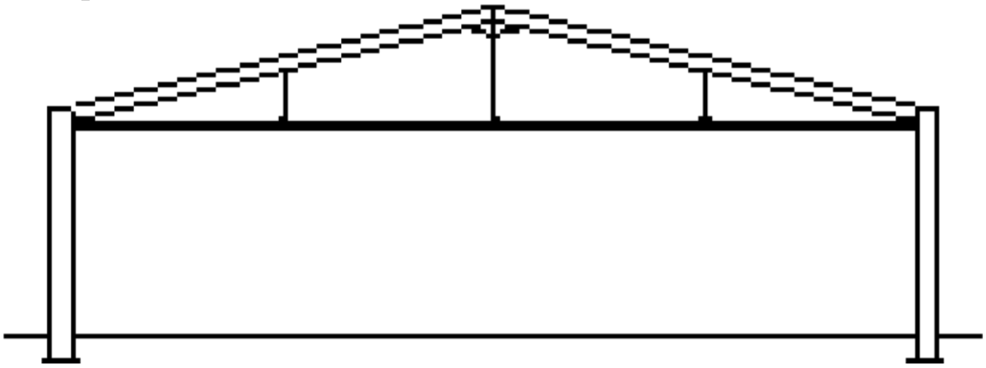
- Portal frame with internal mezzanine floor



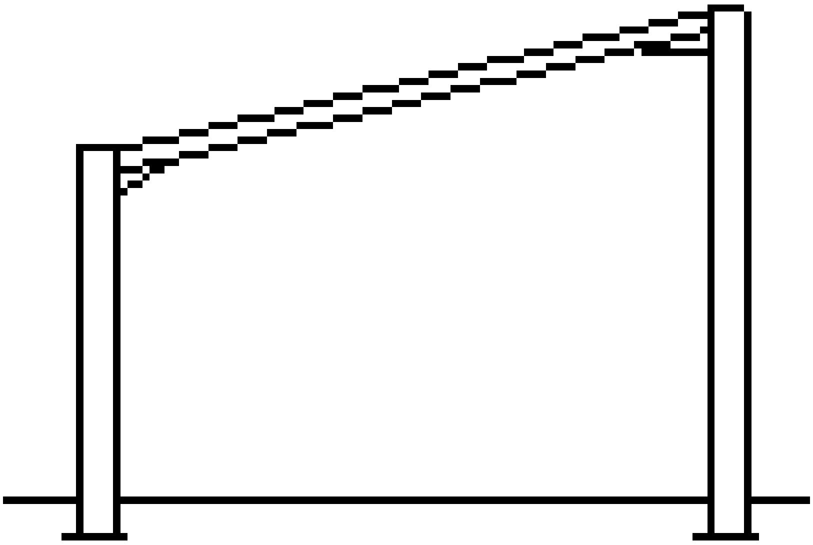
- Crane portal frame with column bracket



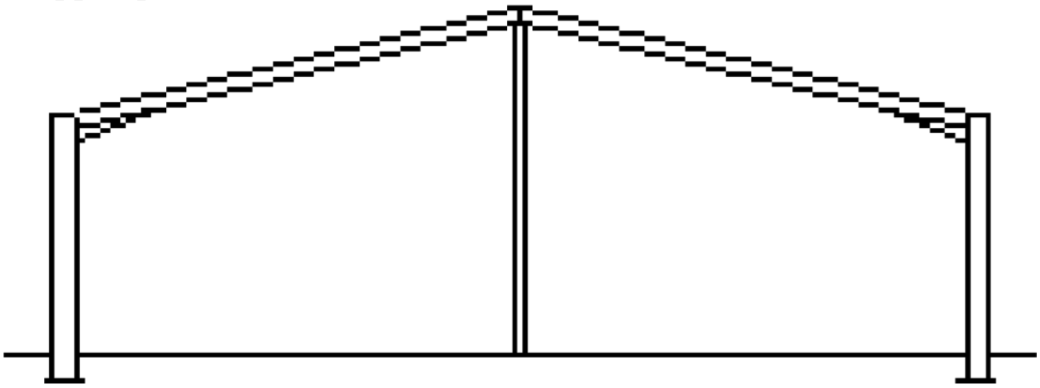
- Tied portal frame



- Mono pitiched portal frame



- Propped portal frame



Objective of the Study

Steel is the major material that is used in industrial buildings. The main objective of the study is that make the optimum design of the steel portal frames and gable frame. Frame is analyzed by direct stiffness matrix method. And formulae are get from the direct stiffness matrix and that is used for the formulation of excel sheet for the analysis of steel portal frame. Till now there is no availability of this kind of sheet.

Literature Review:

Simitses.G.J and Mohamed.S.E. (1989), has presented the concept of analyzing the gable frame with flexible joint connections and with elastic rotational restraints at the supports under static and dynamic loads by non-linear analysis. Symmetric gabled bends were found to buckle in either symmetric snap through mode or in a side sway mode. Critical loads are also obtained for the sudden application of the cause and they are 15-30 % lower than the corresponding static critical loads. In which established that the effect of column slenderness ratio λ, load parameter was negligibly small for both static and dynamic application of loads. These studies lead to the analysis of a model which accurately represents the behavior of real world gabled frames.

Nikhil Agrawal (2009) compared the design wind pressures for different zones of a building are made by the different International design wind codes. The loading is deducted has been utilized to compare its effect on the design of a column and roof truss structure for a gable frame. The selected structure is analyzed for various load combinations. Wind forces are obtained from different countries codes but the design of members is carried out as per Indian codes. An attempt has also been made in the present work to compare the design variables of a few International wind codes of Asia Pacific region

ArunlfoL uevanos Rojas (2013) analyzed the statically indeterminate structures considering the shear deformations are proposed. This paper considers the flexural and shear deformation but in traditional way. Comparison is done between the traditional method and proposed method. Equations are solved by approximation trickery in moment distribution method, as presented in Mohr and Maxwell method. The shear deformations will not be a recommended solution without usual practice. This is a logical situation since the rigidities are lower when considering shear deformations, because the elements are linear and have higher rotation and displacement when the load is applied. The method used for considering shear deformations and also it is more attached with the real conditions.

Methodology

Stiffness matrix method – Stiffness matrix method is also unknown as direct stiffness method. Stiffness is defines as the force required for unit displacement of member. With the help of stiffness matrix method steel and concrete structure can be analyzed.

Process of analysis a structure by stiffness matrix method is as follow

Fixed end moment for member will calculate.

Local stiffness matrix for the member is formed.

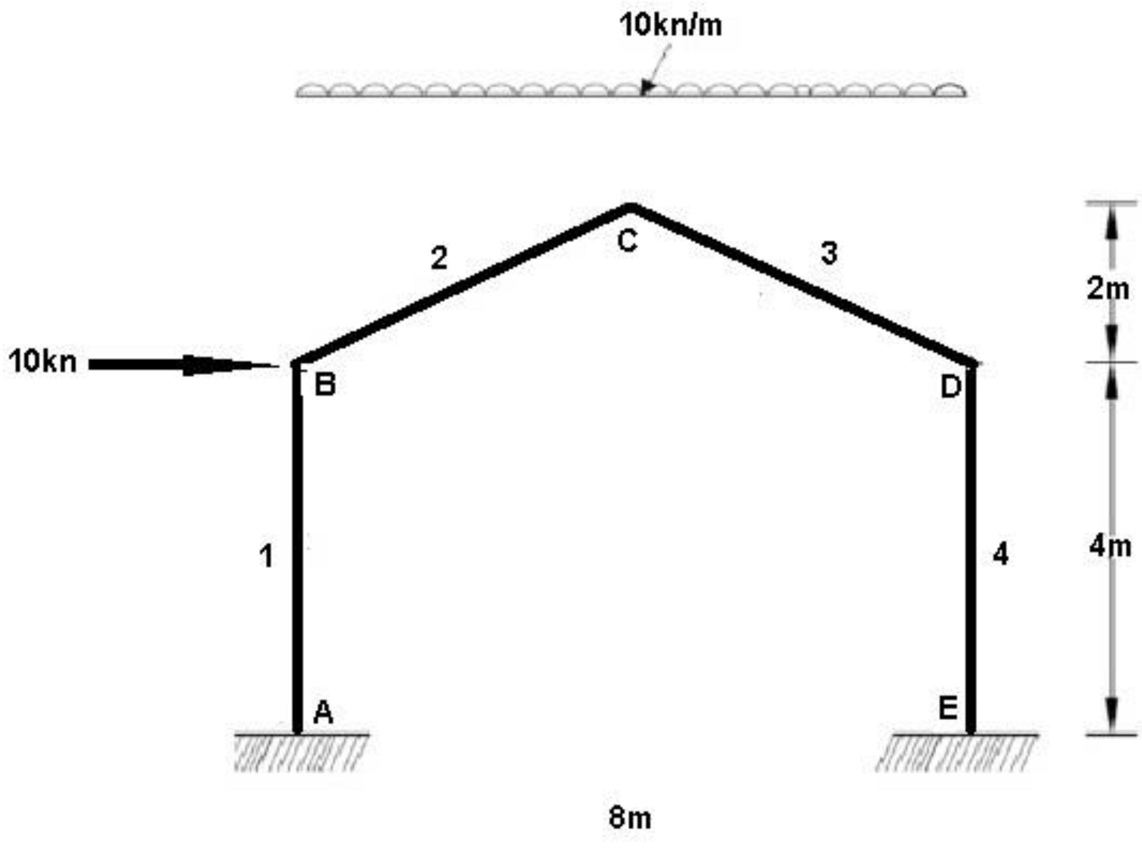
Transformation matrix is formed for members

Global stiffness matrix is made after the formation of local matrix for all members.

Following relation is followed for the calculation of member force and reactions.

[Force] = [stiffness][displacement]

INVESIGATION PROCESS



MEMBER	FIXED END MOMENT
M_{FAB}	0
M_{FBA}	0
M_{FBC}	-16.67kn-m
M_{FCB}	16.67kn-m
M_{FCD}	-16.67kn-m
M_{FDC}	-16.67kn-m
M_{FDE}	0
M_{FED}	0

Member 1 length L =4m, $\theta=90^0$ $\cos\theta= l= 0$, $\sin\theta =m=1$

$$[k']=\begin{bmatrix} \frac{AE}{L} & 0 & 0 & -\frac{AE}{L} & 0 & 0 \\ 0 & \frac{12EI_z}{L^3} & \frac{6EI_z}{L^2} & 0 & -\frac{12EI_z}{L^3} & \frac{6EI_z}{L^2} \\ 0 & \frac{6EI_z}{L^2} & \frac{4EI_z}{L} & 0 & -\frac{6EI_z}{L^2} & \frac{2EI_z}{L} \\ -\frac{AE}{L} & 0 & 0 & \frac{AE}{L} & 0 & 0 \\ 0 & -\frac{12EI_z}{L^3} & -\frac{6EI_z}{L^2} & 0 & \frac{12EI_z}{L^3} & -\frac{6EI_z}{L^2} \\ 0 & \frac{6EI_z}{L^2} & \frac{2EI_z}{L} & 0 & -\frac{6EI_z}{L^2} & \frac{4EI_z}{L} \end{bmatrix}$$

$[K^1] = [T]^T[k'][T]$

Here [T] is transformation matrix and it value is as follow

$[T]^T$ is the transpose of [T] matrix

$$[T] = \left[\begin{array}{ccc|ccc} l & m & 0 & 0 & 0 & 0 \\ -m & l & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & l & m & 0 \\ 0 & 0 & 0 & -m & l & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{array}\right]$$

$12EI/L^3 = 5\times10^2$kn/m

$AE/L = 5\times10^5$kn/m

$6EI/L^2 = 9.9\times102$

$4EI/L = 2.65\times10^3$

$2EI/L = 1.33\times10^3$

Transformation matrix for member 1

$$[T] = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

$[k^1]$

	1	2	3	4	5	6
1	5e2	0	-1e3	-5e2	0	-1e3
2	0	5e5	0	0	-5e5	0
3	-1e3	0	2.6e3	1e3	0	1.33e3
4	-5e2	0	1e3	5e2	0	1e3
5	0	-5e5	0	0	5e5	0
6	-1e3	0	1.3e3	0	0	2.6e3

Force matrix '[f]' for member 1

$[F^1]$ =

1	0
2	0
3	0
4	20
5	0
6	0

Member 2 L=4.7, ϴ=26.56 ,sinϴ = m = 0.45 , cosϴ = l = .90

$12EI/L^3 = 3.07\times10^2$kn/m

$AE/L = 4.3\times10^5$kn/m

$6EI/L^2 = 7.22\times102$

$4EI/L = 2.26\times10^3$

$2EI/L = 1.13\times10^3$

TRANSFORMATION MARTRIX FOR MEMBER 2

$$[T] = \begin{bmatrix} 0.9 & 0.45 & 0 & 0 & 0 & 0 \\ -0.45 & 0.9 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.9 & 0.45 & 0 \\ 0 & 0 & 0 & -0.45 & 0.9 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$[K^2] = [T]^T[k'][T]$

	4	5	6	7	8	9
4	87323.67	-174025.67	649.80	-87323.67	174025.67	649.80
5	-174025.67	348362.17	324.90	174025.67	-348362.17	324.90
6	649.80	324.90	2260.00	-649.80	-324.90	, 1130.00
7	-87323.67	174025.67	-649.80	87323.67	-174025.67	-649.80
8	174025.67	-348362.17	-324.90	-174025.67	348362.17	-324.90
9	649.80	324.90	1130.00	324.90	-649.80	2260.00

Force matrix for member 2 will be

$$F^2] = \begin{matrix} 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \end{matrix} \begin{bmatrix} -23.5 \\ 0 \\ -16.67 \\ -23.5 \\ 0 \\ 16.67 \end{bmatrix}$$

Similarly for member 3 , L=4.7 ɵ=116.56 , cosɵ=l= -.45 ,sinɵ=m=.90

$12EI/L^3 = 3.07\times10^2$kn/m

$AE/L = 4.3\times10^5$kn/m

$6EI/L^2 = 7.22\times102$

$4EI/L = 2.26\times10^3$

$2EI/L = 1.13\times10^3$

Transformation matrix for member 3 will be

[T] =

-0.45	0.90	0	0	0	0
-0.90	-0.45	0	0	0	0
0	0	1	0	0	0
0	0	0	-0.45	0.90	0
0	0	0	-.09	-.045	0
0	0	0	0	0	1

$[K^3]=[T]^T[k'][T]$

	7	8	9	10	11	12
7	348362.17	174025.67	-324.90	-348362.17	-174025.67	-324.908
8	174025.67	87323.67	649.80	-174025.67	-87323.67	649.80
9	-324.90	649.80	2260.00	324.90	-649.80	1130.00
10	-348362.17	-174025.67	324.903	48362.17	174025.67	324.90
11	-174025.67	-87323.67	-649.80	174025.67	87323.67	-649.80
12	-324.90	649.80	1130.00	324.90	-649.80	2260.0

Force matrix for member is

$$[F^3] = \begin{matrix} 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \end{matrix} \begin{bmatrix} -23.5 \\ 0 \\ -16.67 \\ -23.5 \\ 0 \\ 16.67 \end{bmatrix}$$

Member :3 L=4, ɵ=270^o , cosɵ=l=0 ,sinɵ = m = -1

$12EI/L^3 = 5\times10^2$kn/m

$AE/L = 5\times10^5$kn/m

$6EI/L^2 = 9.9\times102$

$4EI/L = 2.65\times10^3$

$2EI/L = 1.33\times10^3$

Transformation matrix for member 4

$$[T] = \begin{bmatrix} 0 & -1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$[K^4] = [T]^T[k'][T]$

	11	12	13	14	15	16
11	5×10^2	0	10×10^2	-5×10^2	0	10×10^2
12	0	5×10^5	0	0	-5×10^5	0
13	10×10^2	0	26.6×10^2	-10×10^2	0	13.3×10^2
14	-5×10^2	0	-10×10^2	5×10^2	0	-10×10^2
15	0	-5×10^5	0	0	5×10^5	0
16	10×10^2	0	13.3×10^2	-10×10^2	0	26.6×10^2

Now global force matrix for all the member is made

Global force matrix will be 15x1 order

$[F]_{global}$ =

	1
1	0
2	0
3	0
4	-3.5
5	0
6	-16.67
7	-47
8	0
9	0
10	-23.5
11	0
12	16.67
13	0
14	0
15	0

Global stiffness matrix $[K]_{global}$ =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	5×10^2	0	-1×10^3	5×10^2	0	-1×10^3	0	0	0	0	0	0	0	0	0
2	0	5×10^3	0	0	-5×10^3	0	0	0	0	0	0	0	0	0	0
3	-1×10^3	0	2.66×10^3	1×10^3	0	-1.33×10^3	0	0	0	0	0	0	0	0	0
4	5×10^2	0	1×10^3	8.78×10^4	-17.4×10^4	16.49×10^2	-8.7×10^4	17.4×10^4	649.98	0	0	0	0	0	0
5	0	-5×10^3	0	-17.4×10^4	84.83×10^4	324.90	-17.40×10^4	-34.83×10^4	324.8	0	0	0	0	0	0
6	-1×10^3	0	-1.33×10^3	16.49×10^2	324.90	4860	-649.80	-324.90	1130	0	0	0	0	0	0
7	0	0	0	-8.7×10^4	-17.40×10^4	-649.80	43.36×10^4	0	-974.7	-34.83×10^4	-17.04×10^4	-324.90	0	0	0
8	0	0	0	17.4×10^4	-34.83×10^4	-324.90	0	43.5×10^4	324.9	-17.04×10^4	-87.32×10^3	649.80	0	0	0
9	0	0	0	649.98	324.8	1130	-974.7	324.9	4520	324.90	-649.80	1130	0	0	0
10	0	0	0	0	0	0	-34.83×10^4	-17.04×10^4	324.90	48.86×10^3	17.40×10^4	49.36×10^3	-5×10^2	0	1000
11	0	0	0	0	0	0	-17.04×10^4	-87.32×10^3	-649.80	17.40×10^4	58.73×10^4	-649.80	0	-5×10^5	0
12	0	0	0	0	0	0	-324.90	649.80	1130	49.36×10^3	-649.80	4920	-1000	0	13.3×10^2
13	0	0	0	0	0	0	0	0	0	-5×10^2	0	-1000	500	0	-1000
14	0	0	0	0	0	0	0	0	0	0	-5×10^3	0	0	5×10^3	0
15	0	0	0	0	0	0	0	0	0	1000	0	13.3×10^2	-1000	0	26.6×10^2

From the stiffness and force matrix relationship

[F]=[K][D]

Here [D] is displacement matrix

Applying boundary conditions d1, d_2, d_3, d_{13}, d_{14}, d_{15} will be zero because of support conditions.

$$\begin{matrix} 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \end{matrix}\begin{bmatrix} \\ \\ \\ \\ F \\ \\ \\ \\ \\ \end{bmatrix} = \begin{matrix} \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \end{matrix}\begin{matrix} 4 \quad 5 \quad 6 \quad 7 \quad 8 \quad 9 \quad 10 \quad 11 \quad 12 \\ \begin{bmatrix} \\ \\ \\ \\ K \\ \\ \\ \\ \\ \end{bmatrix} \end{matrix}\begin{pmatrix} \\ \\ \\ \\ D \\ \\ \\ \\ \\ \end{pmatrix}$$

$$\begin{matrix} 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \end{matrix}\begin{bmatrix} d4 \\ d5 \\ d6 \\ d7 \\ d8 \\ d9 \\ d10 \\ d11 \\ d12 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

there is no deflection is come because load is too small

Reaction is calculated from the relation as stated below

[R] = [K][D]+[F]

Deflection is zero hence reactions are as follow.

R4 = -3.5KN

R5 = 0

R6 = -16.67KN-M

R7 = -47KN

R8 = 0

R9 = 0

R10 = -23.5 KN

R11= 0

R12=16.67KN-M

Conclusion – By the stiffness matrix method all the deflection and reaction of the member can be calculated and we can use the method for the formulation of excel sheet form the stiffness matrix for the analysis of steel portal frame

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