

Analysis of Multistorey Frame for Various Loadings

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ABSTRACT

We know multistorey structure portal frames are most common in all countries. All metropolitan cities and upcoming cities and major industries use multistorey frames in their structural systems. A Frame of G+3, one bay with point load and G+5, one bay has been taken for study, manually the point loads and uniformly distributed load of horizontal elements have been done. Manually analysis has been done using Stiffness Matrix Method of Deflection, Reaction, Bending Moments and Shear Forces. The Multistorey same frames also create in STAAD Pro, and out-put such as Deflection, Reaction, Bending Moments and Shear Forces have been calculated and a comparison between Manual Calculation and STAAD Pro. Software Calculations has been made.

Keywords: Stiffness matrix method, Deflection, Reaction, Bending Moments and Shear Forces

I. INTRODUCTION

The Multistorey Frame Analysis as we know it today, evolved over several years in this world. During this time many countries devolved but “India” is still one of devolving countries. The main aim of manually calculation and comparison with STAAD Pro is to provide a sustainable cost as compared to STAAD Pro. The Excel sheet which is based on manually calculation it will be easy to operate for most common portal frames. Also this paper will present of comparison and deference of results.

This comparison will be helpful to create and examples of multistory frames with manually calculation. The studies on stiffness matrix method for portal frames up to G + 3, one bay and G + 5 one bay for more research works of frames Deflection of elements, Reactions on foundation, bending moment, shear force of elements.

II. STIFFNESS MATRIX METHOD

The stiffness matrix is a matrix method and a method of analysis to find the member forces and displacements of joints in structure. Under the influence of loads, and support movement, this method can be used to find the displacements and internal forces.

The analysis of both skeletal structures and non-skeletal structures can be done by this method. Beams, plane and space frames and trusses, and grids are skeletal structure. Plates, shells, and 3-D solids are non-skeletal structure.

The stiffness matrix method has a sequential procedure which contains following six steps:

III.MODELING

- 1.1) First of all model the structure with members and joints
- 1.2) Specify the members and joints of the structure
- 1.3) Recognize all the components of join displacement which are unknown

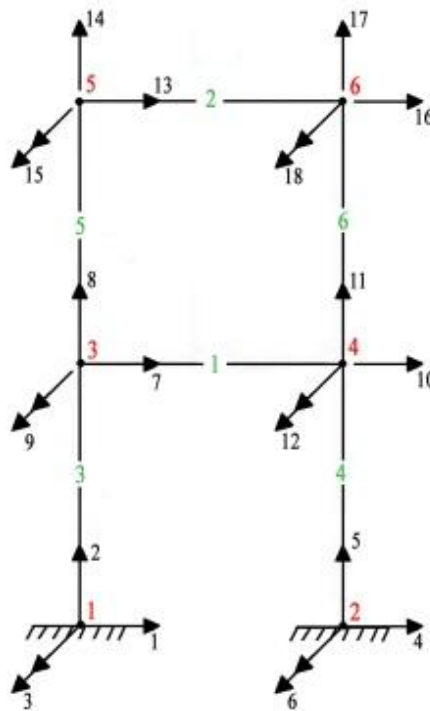


Fig. 1 Members and Nodes Numbers

1. **Load Vector** - Find out the load vector (member fixed end forces) for each member , for this example member length 4 m.

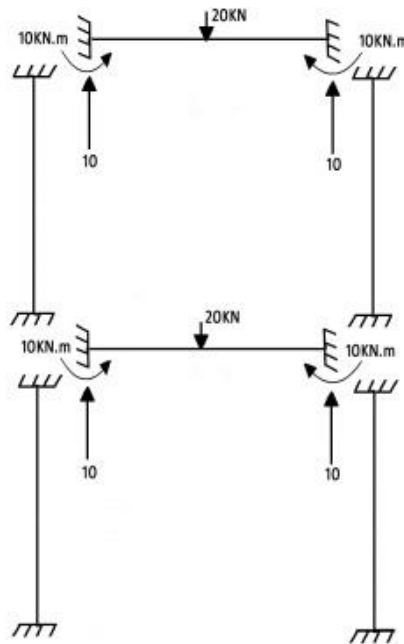


Fig.2 Fixed end action due to external load

2. **Stiffness matrix** - Determine the load vector due to joint displacements (i.e. member stiffness equations) for each member.

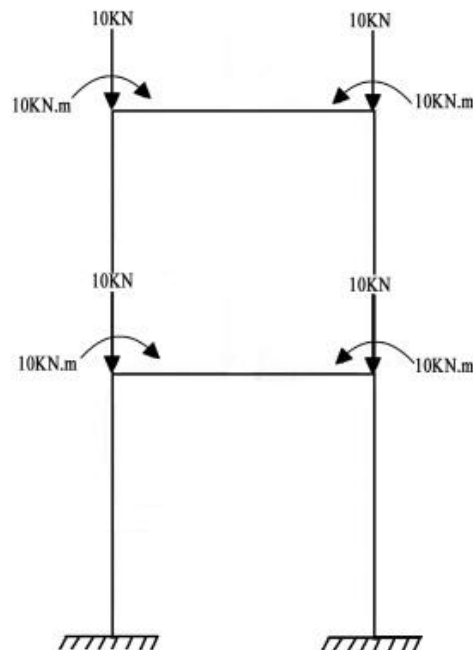


Fig.3 Equivalent joint loads

3. **Equilibrium equation** - Under the influences of forces in previous two steps and joint loads, write the equations of equilibrium of all joints.
4. **Solving equilibrium equation** - Solve equilibrium equation to find the joint displacements.

$$[P] = [K] [\Delta]$$

5. **Internal forces** - By using the resulting joint displacements, determine the total member end forces.

IV.DESCRPTION OF THE PROBLEM

Example 1: Analyse the Multistorey rigit frame of G+3, one bay with point load 50 KN on all horizontal elements, shown in Fig.4 by stiffness matrix method. Assume $E=200 \text{ Gpa}$; $I=1.33 \times 10^{-5} \text{ m}^4$ and $A=0.01 \text{ m}^2$. The flexural rigidity EI and axial rigidity EA are the same for all beams.

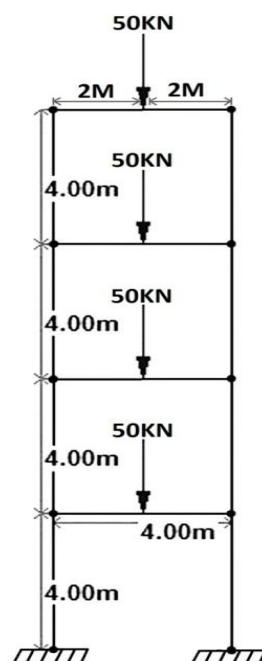


Fig. 4 Multistorey Frame, G+4 one bay with point loads

The plane frame is divided in to twelve beam elements as shown in Fig. 4 the numbering of joints and members are also shown in Fig. 5 and Fig. 6 the possible degrees of freedom at nodes are also shown in the figure. The origin of the global co- ordinate system is taken at node no. 1.

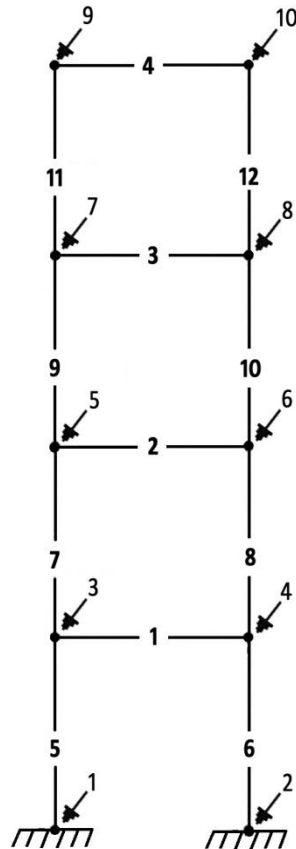


Fig. 5 Node and Member no.

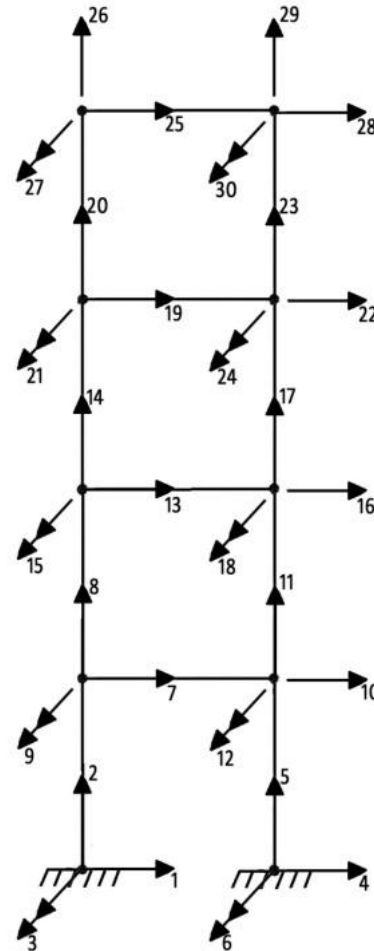


Fig. 6 Degree of freedom on each node.

Table – 1

Nodes Deflection Values of G+3

Node no.	Degree of freedom	Degree of freedom no.	Manual Calculation	STAAD Pro. Calculation	Difference	Units
3	X	7	-8.22×10^{-4}	-0.003	0.002	mm
	Y	8	-0.200	-0.200	0	mm
	Mz	9	-0.003	-0.003	0	Rad
	X	10	0.0045	0.003	0.001	mm

4	Y	11	-0.2221	-0.200	0.022	mm
	Mz	12	0.003	0.003	0	Rad
5	X	13	0.0215	0.001	0.02	mm
	Y	14	-0.350	-0.350	0	mm
	Mz	15	-0.0027	-0.003	0.001	Rad
6	X	16	0.0193	-0.001	0.018	mm
	Y	17	-0.394	-0.350	0.044	mm
	Mz	18	0.0026	0.003	0.0004	Rad
7	X	19	0.053	-0.003	0.05	mm
	Y	20	-0.450	-0.450	0	mm
	Mz	21	-0.002	-0.002	0	Rad
8	X	22	0.058	0.003	0.055	mm
	Y	23	-0.516	-0.450	0.066	mm
	Mz	24	0.002	0.002	0	Rad
9	X	25	0.080	0.008	0.072	mm
	Y	26	-0.500	-0.500	0	mm
	Mz	27	-0.005	-0.005	0	Rad
10	X	28	0.077	-0.008	0.069	mm
	Y	29	-0.588	-0.500	0.088	mm
	Mz	30	0.005	0.006	0.001	Rad

Table – 2

Reaction Values of Foundation Nodes of G+3

Node no.	Degree of freedom	Reaction no.	Manual Calculation	STAAD Pro. Calculation	Deference	Units
1	X	R ₁	3.200	3.211	0.011	KN
	Y	R ₂	100.050	100.000	0.050	KN
	Mz	R ₃	-4.256	-4.276	0.020	KNm
2	X	R ₄	-3.202	-3.211	0.090	KN
	Y	R ₅	100.000	100.000	0	KN
	Mz	R ₆	4.260	4.276	0.016	KNm

Table – 3

Element End Banding Moments of G+3

Element no.	Node no.	Degree of freedom	Manual (KNm)	STAAD Pro. (KNm)	Deference
1	N ₃	Mz	20.74	20.70	0.04
	N ₄	Mz	-20.74	-20.70	0.04
2	N ₅	Mz	21.42	21.40	0.02
	N ₆	Mz	-21.40	-21.40	0
3	N ₇	Mz	22.21	22.18	0.03
	N ₈	Mz	-22.17	-22.18	0.02
4	N ₉	Mz	17.67	17.58	0.09
	N ₁₀	Mz	-17.52	-17.58	0.06
5	N ₁	Mz	-4.256	-4.276	
	N ₃	Mz	-8.512	-8.569	0.02
6	N ₂	Mz	4.256	4.276	0
	N ₄	Mz	8.512	8.569	0.02
7	N ₃	Mz	-12.103	-12.138	0
	N ₅	Mz	-11.438	-11.436	0.02
8	N ₄	Mz	12.103	12.138	0
	N ₆	Mz	11.438	11.436	0.02
9	N ₅	Mz	-9.87	-9.973	0
	N ₇	Mz	-9.07	-9.197	0.02
10	N ₆	Mz	10.075	9.973	0
	N ₈	Mz	9.277	9.197	0.02
11	N ₇	Mz	-13.034	-12.988	0
	N ₉	Mz	-17.68	-17.586	0.02
12	N ₈	Mz	13.034	12.988	0
	N ₁₀	Mz	17.68	17.586	0.02

Table – 4

Element End Shear Forces of G+3

Element no.	Node no.	Degree of freedom	Manual (KN)	STAAD Pro. (KN)	Deference
1	N ₃	Y	25	25	0
	N ₄	Y	25	25	0
2	N ₅	Y	25.005	25	0.005
	N ₆	Y	24.995	25	0.005
3	N ₇	Y	25.01	25	0.03
	N ₈	Y	24.98	25	0.02
4	N ₉	Y	25.03	25	0.09
	N ₁₀	Y	24.96	25	0.06
5	N ₁	Y	-3.200	-3.211	0.011
	N ₃	Y	3.2	3.211	0.011
6	N ₂	Y	3.200	3.211	0.011
	N ₄	Y	-3.2	-3.211	0.011
7	N ₃	Y	-5.90	-5.893	0.007
	N ₅	Y	5.9	5.893	0.007
8	N ₄	Y	5.90	5.893	0.007
	N ₆	Y	-5.9	-5.893	0.007
9	N ₅	Y	-4.75	-4.792	0.043
	N ₇	Y	4.75	4.792	0.042
10	N ₆	Y	4.75	4.792	0.042
	N ₈	Y	-4.85	-4.792	0.058
11	N ₇	Y	-7.70	-7.643	0.057
	N ₉	Y	7.70	7.643	0.057
12	N ₈	Y	7.70	7.643	0.057
	N ₁₀	Y	-7.70	-7.643	0.057

Example 2: Analyse the Multistorey rigid frame of G+5, one bay with point load 40 KN and UDL 20KN/m on all horizontal elements, shown in Fig.7 by stiffness matrix method. Assume $E=200 \text{ Gpa}$; $I=1.33 \times 10^{-5} \text{ m}^4$ and $A=0.01 \text{ m}^2$. The flexural rigidity EI and axial rigidity EA are the same for all beams.

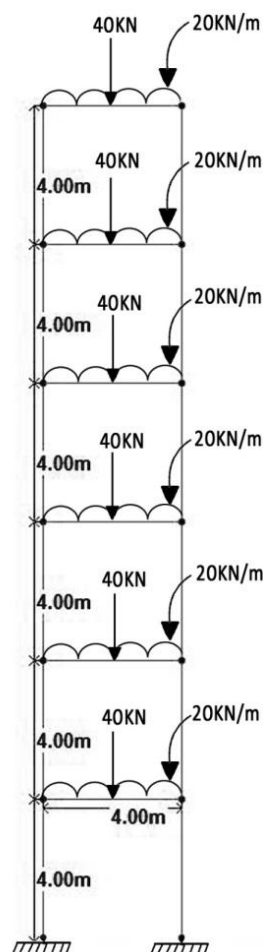


Fig.7 Multistorey Frame G+5 One bay with point load & U.D.L.

Table – 5

Nodes Deflection Values of G+5

Node no.	Degree of freedom	Deflection no.	Manual	STAAD Pro. Calculation	Difference	Units
3	X	u_7	-0.0048	-0.005	0.0002	mm
	Y	u_8	-0.720	-0.702	0.018	mm
	Mz	u_9	-0.006	-0.006	0	Rad
4	X	u_{10}	0.0048	0.005	0.0002	mm
	Y	u_{11}	-0.720	-0.702	0.018	mm
	Mz	u_{12}	0.006	0.006	0	Rad
	X	u_{13}	0.001	0.001	0	mm



5	Y	u_{14}	-1.320	-1.288	0.032	mm
	Mz	u_{15}	-0.0048	-0.005	0.0002	Rad
6	X	u_{16}	-0.001	-0.001	0	mm
	Y	u_{17}	-1.320	-1.288	0.032	mm
	Mz	u_{18}	0.0048	0.005	0.0002	Rad
7	X	u_{19}	-0.0004	-0.000	0.0004	mm
	Y	u_{20}	-1.800	-1.756	0.044	mm
	Mz	u_{21}	-0.005	-0.005	0	Rad
8	X	u_{22}	0.0004	0.000	0.0004	mm
	Y	u_{23}	-1.800	-1.756	0.044	mm
	Mz	u_{24}	0.005	0.005	0	Rad
9	X	u_{25}	0.001	0.001	0	mm
	Y	u_{26}	-2.160	-2.107	0.053	mm
	Mz	u_{27}	-0.005	-0.005	0	Rad
10	X	u_{28}	-0.001	-0.001	0	mm
	Y	u_{29}	-2.160	-2.107	0.053	mm
	Mz	u_{30}	0.005	0.005	0	Rad
11	X	u_{31}	-0.005	-0.005	0	mm
	Y	u_{32}	-2.400	-2.341	0.059	mm
	Mz	u_{33}	-0.0039	-0.004	0.0001	Rad
12	X	u_{34}	0.005	0.005	0	mm
	Y	u_{35}	-2.400	-2.341	0.059	mm
	Mz	u_{36}	0.0039	0.004	0.0001	Rad
13	X	u_{37}	0.014	0.014	0	mm
	Y	u_{38}	-2.520	-2.459	0.061	mm
	Mz	u_{39}	-0.01	-0.01	0	Rad
14	X	u_{40}	-0.014	-0.014	0	mm
	Y	u_{41}	-2.520	-2.459	0.061	mm
	Mz	u_{42}	0.010	0.010	0	Rad

Table – 6

Reaction Values of Foundation Nodes of G+5

Node no.	Degree of freedom	Reaction no.	Manual Calculation	STAAD Pro. Calculation	Difference	Units
1	X	R ₁	6.059	6.038	0.021	KN
	Y	R ₂	360	360	0	KN
	Mz	R ₃	-8.060	-8.040	0.020	KNm
2	X	R ₄	-6.0591	-6.038	0.021	KN
	Y	R ₅	360	360	0	KN
	Mz	R ₆	8.0602	8.040	0.02	KNm

Table – 7

Element End Banding Moments of G+5

Element no.	Node no.	Degree of freedom	Manual Calculation (KNm)	STAAD Pro. Calculation (KNm)	Difference
1	N ₃	Mz	38.6113	38.594	0.017
	N ₄	Mz	-38.6113	-38.594	0.017
2	N ₅	Mz	40.276	40.258	0.018
	N ₆	Mz	-40.276	-40.258	0.018
3	N ₇	Mz	40.0044	39.987	0.017
	N ₈	Mz	-40.0044	-39.987	0.017
4	N ₉	Mz	39.7019	39.686	0.015
	N ₁₀	Mz	-39.7019	-39.686	0.015
5	N ₁₁	Mz	-41.491	-41.470	0.021
	N ₁₂	Mz	-41.491	-41.470	0.021
6	N ₁₃	Mz	32.8298	32.808	0.021
	N ₁₄	Mz	-32.8298	-32.808	0.021
7	N ₁	Mz	-8.0602	-8.040	0.020
	N ₃	Mz	-16.1156	-16.113	0.002
8	N ₂	Mz	8.0602	8.040	0.020
	N ₄	Mz	16.1156	16.113	0.002
9	N ₃	Mz	-22.4956	-22.482	0.013
	N ₅	Mz	-20.8309	-20.818	0.012
10	N ₄	Mz	22.4956	22.482	0.013

	N ₆	Mz	20.8309	20.818	0.012
11	N ₅	Mz	-19.4451	-19.439	0.006
	N ₇	Mz	-19.7167	-19.710	0.006
12	N ₆	Mz	19.4450	19.439	0.006
	N ₈	Mz	19.7167	19.710	0.006
13	N ₇	Mz	-20.2878	-20.277	0.010
	N ₉	Mz	-20.5903	-20.577	0.013
14	N ₈	Mz	20.2878	20.277	0.010
	N ₁₀	Mz	20.5903	20.577	0.013
15	N ₉	Mz	-19.1115	-19.109	0.002
	N ₁₁	Mz	-17.3224	-17.324	0.001
16	N ₁₀	Mz	19.1115	19.109	0.002
	N ₁₂	Mz	17.3224	17.324	0.002
17	N ₁₁	Mz	-24.1687	-24.146	0.022
	N ₁₃	Mz	-32.8298	-32.808	0.021
18	N ₁₂	Mz	24.1687	24.146	0.022
	N ₁₄	Mz	32.8298	32.808	0.021

Table – 8

Element End Shear Forces of G+5

Element no.	Node no.	Degree of freedom	Manual Calculation (KN)	STAAD Pro. Calculation (KN)	Difference
1	N ₃	Y	60	60	0
	N ₄	Y	60	60	0
2	N ₅	Y	60	60	0
	N ₆	Y	60	60	0
3	N ₇	Y	60	60	0
	N ₈	Y	60	60	0
4	N ₉	Y	60	60	0
	N ₁₀	Y	60	60	0
5	N ₁₁	Y	60	60	0
	N ₁₂	Y	60	60	0
6	N ₁₃	Y	60	60	0
	N ₁₄	Y	60	60	0

7	N ₁	Y	-6.0591	-6.038	0.021
	N ₃	Y	6.0591	6.038	0.021
8	N ₂	Y	6.0591	6.038	0.021
	N ₄	Y	-6.0591	-6.038	0.021
9	N ₃	Y	-10.8588	-10.825	0.033
	N ₅	Y	10.8588	10.825	0.033
10	N ₄	Y	10.8588	10.825	0.033
	N ₆	Y	-10.8588	-10.825	0.033
11	N ₅	Y	-9.8150	-9.787	0.028
	N ₇	Y	9.8150	9.787	0.028
12	N ₆	Y	9.8150	9.787	0.028
	N ₈	Y	-9.8150	-9.787	0.028
13	N ₇	Y	-10.2451	-10.213	0.032
	N ₉	Y	10.2451	10.213	0.032
14	N ₈	Y	10.2451	10.213	0.032
	N ₁₀	Y	-10.2451	-10.213	0.032
15	N ₉	Y	-9.1313	-9.108	0.023
	N ₁₁	Y	9.1313	9.108	0.023
16	N ₁₀	Y	9.1313	9.108	0.023
	N ₁₂	Y	-9.1313	-9.108	0.023
17	N ₁₁	Y	-14.2854	-14.238	0.047
	N ₁₃	Y	14.2854	14.238	0.047
18	N ₁₂	Y	14.2854	14.238	0.047
	N ₁₄	Y	-14.2854	-14.238	0.047

IV.RESULTS AND DISCUSSIONS

The first part of the work is completing of manual analysis using Stiffness Matrix Method and Second part is analysis in STAAD Pro software mostly used for analysis and design, and third part is comparison the results of both analysis. The same frame which is chosen for the research in model in STAAD Pro with applied the loading which is calculated by manual means. The compare final results of vertical and horizontal elements of stiffness matrix method with STAAD Pro results then only maximum deference is 0.09 in results.

V.CONCLUSION

The manual analysis by stiffness matrix method and STAAD Pro analysis, the following conclusion can be listed follows:

1. Stiffness matrix method is easy and full with lots off number as a degree of freedom in matrix of 30×30 for G+3 and 42×42 for G+5 subjected to vertical loadings of point load and U.D.L.
2. The comparison of manual and software's results, the results are quite same.
3. STAAD Pro is a great software for analysis and design, the only high skilled parson can use but we are creating Excel Sheets on base of this manual calculation, it will helps to every medal class constructors for saving time and money as we know STAAD Pro software and its License is costly in market.
4. The Excel sheets can be recommended for analysis of standard and mostly used for construction portal frames Etc.

REFERENCES

1. Kulkarni et al.(2013). Analysis of Multi-storey Building Frames Subjected to Gravity and Seismic Loads with Varying Inertia. International Journal of Engineering and Innovative Technology, 2, 132-138.
2. John & Glenn. (1975). Analysis of Flexibly connected steel frames. Canadian Journal of Civil Engineering, 2, 280-291.
3. Jones et al. (1983).The Analysis of frames with Semi-Rigid Connection – A State-of-the-Art Report.Journal of Constructional Steel Research, 3, 2-13.
4. Lei. (2001). Second-order analysis for semirigid steel framedesign. Canadian Journal of Civil Engineering, 28, 59-76.
5. Miodrag&Ratko. (2001). Nonlinear Analysis of frames with flexible connections. Computers and structures, 79, 1097-1107.
6. Miodrag et al. (2002). Dynamic analysis of steel frames with frames with flexible connections. Computers and Structures, 80, 935-955.