Study of Seismic Performance Assessment of Multistoried Reinforced Concrete Buildings With Mass Irregularity

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Abstract- *Irregular buildings make a large portion of the urban infrastructure in recent days. The presence of the irregularities is due to architectural, functional and economic constraints. The main aim of this research is to improving the performance of the seismic behaviour of the building structure with vertical irregularities in which mainly mass irregularity is considered. This is done by quantifying the effects of vertical irregularities in mass. The seismic demands which are investigated are base shear, storey shear, storey drift, deflection in X-direction, maximum deflection in X and Y directions etc.*

The effect of irregularities in the distributions of mass is considered. The seismic response of irregular is calculated by, equivalent lateral force method. A base structure is developed and cases that represent the irregular structures are defined by modifying the vertical distribution of mass of the storeys of base case.

The modelling of the whole building is carried out using the computer program named STAAD.Pro V8i.

The parametric study on the displacement, inter storey drift and storey shear have been calculated using equivalent static analysis to investigate the influence of the parameter on the behaviour of the building with mass irregularity. The selected building is analyzed through numerical models with modifying the loads such as dead load, live load, wind load etc

Keywords- Mass Irregularity, Response Spectrum Analysis, Storey Drift, Storey Shear, Base shear, Joint displacement.

I. INTRODUCTION

Buildings facilities have functional, aesthetic and economic objects. The different individuals involved in the process of constructing these facilities impose the objective. These individuals include owner, architect, structural engineer, contractor planner and society in general. The role of structural engineer is to provide a solution that meets the structural performance goals throughout the expected life of the structure, and at the same time, addresses the constraints imposed by other individuals involved in the process.
The main objective of this study is to improve the understanding the effects of vertical irregularities on the response of building structures to develop a way to estimate the seismic demands with the structures with the mass irregularity in building structures. This study consists of effects of mass irregularity in building structures. The torsional effects are beyond the scope of this study.

The effects of mass irregularity in buildings are considered and are done by performing parametric analyses in which irregularities in only one of the quantities are considered. The seismic response of irregular structures is calculated by means of elastic and inelastic dynamic analyses.

In this study, a base case structure is utilised and case that represents the irregular structures are defined by changing the distribution of mass of the different storeys in base case. The building structures are represented by simple analytical models in order to gain insight into the dynamic behaviour of the structure. The seismic demands of the cases are evaluated in a statistical manner. The base structure and the irregular structures are subjected to a ground motion records, and the seismic can be calculated the mean value of coefficients of variation.

Irregularities in buildings:

As per IS 1893-2002, there are two types of irregularities in the structures. They are:
1. Plan irregularity
2. Vertical irregularity

Plan irregularity:

The plan irregularity is categorized into five types. They are:

I. Torsional Irregularity:

It is one of the irregularities which is occurred when the floor diaphragms are fixed in their own axis related to vertical structural elements that resists the lateral forces

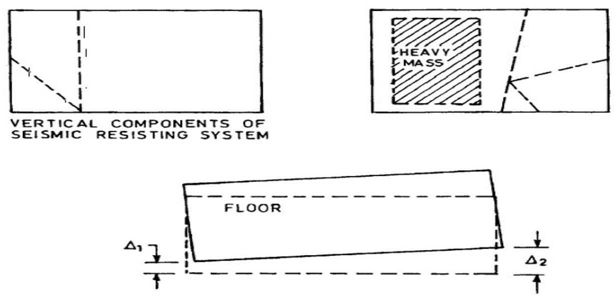

Figure 1.

II. Re-entrant Corners:

The plan configurations of a structure and its lateral forces resisting system which contains the re-entrant corners, where consider both the projections of the structure beyond the re-entrant corner are greater than the 15 percent of its plan dimensions in the given direction.

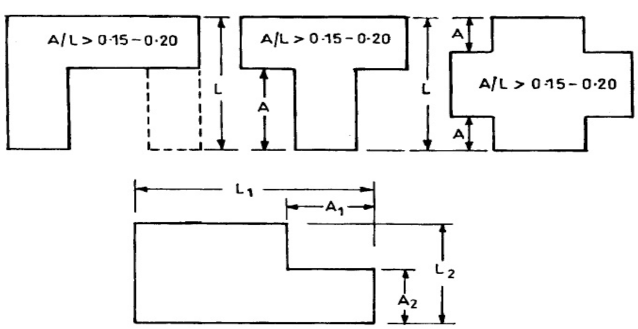

Figure 2

III. Diaphragm Discontinuity:

The diaphragms with discontinuities or modifications in the stiffness, including those which contain the cut-out or open areas greater than 50% of the gross enclosed diaphragm area, or changes in the effective diaphragm stiffness of more than 50% from one storey to the next storey.

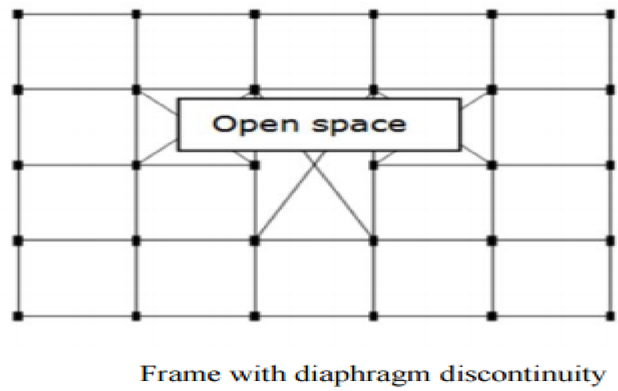

Figure 3.

IV. Out-of-Plane Offsets:

The discontinuities in a lateral force resistance path namely out-of –plane offsets of vertical elements are as shown below

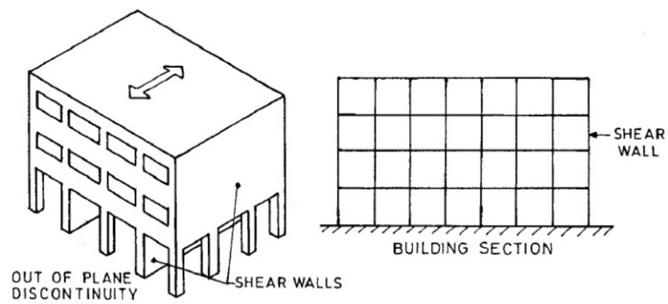

Figure 4.

V. Non Systems: parallel

The vertical elements which is resisting the lateral force are not parallel to it or symmetric to it about the major orthogonal axes or the lateral force elements.

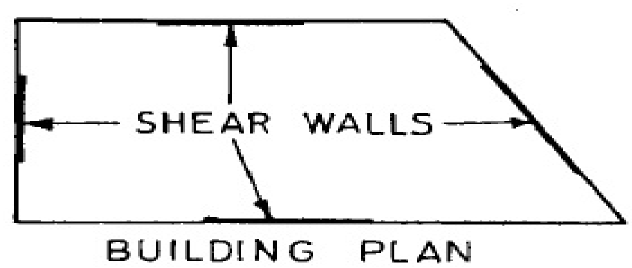

Figure 5.

Vertical irregularities in buildings:

i. Stiffness Irregularity:

a) Stiffness irregularity-Soft Storey: A soft storey is considered in a storey in which the lateral stiffness is less than 70 percent of the stiffness in the storey above of it or 80 percent of the average lateral stiffness of the three storey's above of it
b) Stiffness Irregularity-Extreme Soft Storey: An extreme soft storey is considered in which the lateral stiffness of any storey is less than 60 percent of the stiffness in the storey above from it or less than 70 percent of the average stiffness of the three storey's above from it. For example, buildings on STILTS fall under this category of stiffness irregularity

ii. Mass irregularity

Mass irregularity is to be considered where the seismic weight of any storey is more than 200% of that of its adjacent storey's above of it . The irregularity need not to be considered in case of roofs.

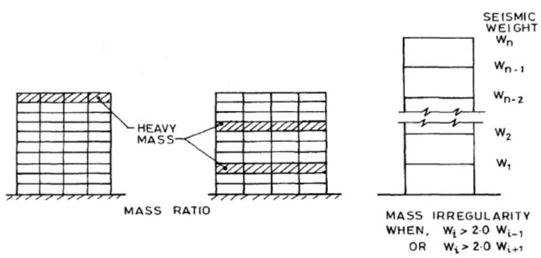

Figure 6.

iii. Vertical Geometric Irregularity:

Vertical geometric irregularity is to be considered where the dimensions in horizontal direction of the lateral forces resisting system in any storey is more than 150% of which in its adjacent storey which is above to it.

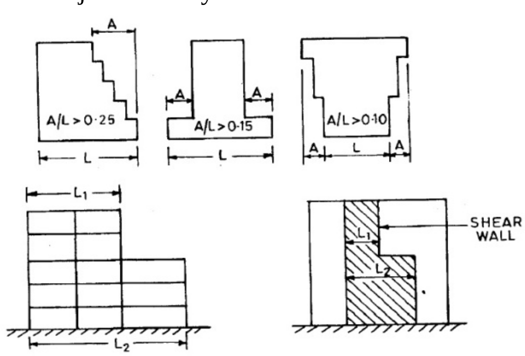

Figure 7.

II. LITERATURE REVIEW

Al-Ali & Krawinkler (1998) [4] concludes that the seismic response of the buildings is more sensitive to the stiffness irregularities than to the mass irregularities of similar magnitude. Effect of stiffness irregularity on inelastic behaviour of the buildings are appreciable than the effects of mass irregularity for same amount of stiffness's & masses. In case of the stiffness irregularity storey drift demand increase in the soft storey and decrease in most of other stories. Ductility & hysteretic energy is the demand decrease in soft storey & increase in other storey.

Poonam et al. (2012) [5] The Results of the numerical analysis are showed that any storey, especially the first storey must not be softer/weaker than the storeys above or below of it . The Irregularity in mass distribution also contributes the increased response of the buildings. The irregularities, if required to be provided, need to be provided by an appropriate and an extensive analysis and design processes.

Sarkar et al. (2010) [7] proposed a new method of quantifying irregularity in vertically irregular building frames, accounting for dynamic characteristics (mass and stiffness). The conclusions of the above research is as given.

A measure of vertical irregularity, suitable for the stepped buildings, is called 'regularity index', which is proposed, and accounting for the changes in mass and stiffness along the height of the building.

III. METHOD OF ANALYSIS

Method of Analysis: Equivalent Lateral Force Method

Determination of Design Base Shear -

Design base Shear is calculated by the formula.

$$V_B = A_h \text{ X } W$$

Where,

V_B = Base Shear

A_h = Design horizontal seismic coefficient for a structure

W = Seismic weight of building.

A_h is defined by the following formula

$$A_h = \frac{Z}{2} * \frac{I}{R} * \frac{S_a}{g}$$

Where,

Z = Zone factor for the maximum considered Earthquake (MCE)

I = Importance factor

R = Response reduction factor

S_a/g = Average response acceleration coefficient for rock or soil sites the approximate fundamental natural period of vibration (T_a) in seconds calculated by

$$T_a = 0.075\ h^{0.75} \quad \text{for RC frame building}$$

Where,

h = Height of building, in m

Lateral distribution of base shear – The design base is distributed along the height of the building by using this formula.

$$Q_i = V_B * \frac{W_i h_i^2}{\sum_{i=1}^{n} W_i h_i^2}$$

Where,

Q_i = Design Lateral force at floor ith floor

W_i = Seismic weight of floor ith floor

h_i = Height of floor measured from base.

n = Numbers of stories in the building

Therefore,

a = 0.24m (The required value)

IV. MATERIALS AND METHODS

The parameters considered in the performance evaluation are as under

Description of building

Type of structure	:	SMRF
Number of stories	:	G+10
Height of each Storey	:	3.5 m
Height of foundation	:	2.5m
Type of soil	:	Medium soil
Earthquake zone	:	Zone-IV
Materials		
Grade of Concrete	:	M25
Density of Concrete	:	25 KN/m3
Modulus of Elasticity	:	5000√fck
Fck	:	20 KN/mm2

Member dimensions

Beam Size	:	300mm x 500mm
Column Size up to basement	:	600mm x 600mm
Column Size	:	500mm x 500mm
Slab Thickness	:	150mm
Wall Thickness	:	230mm

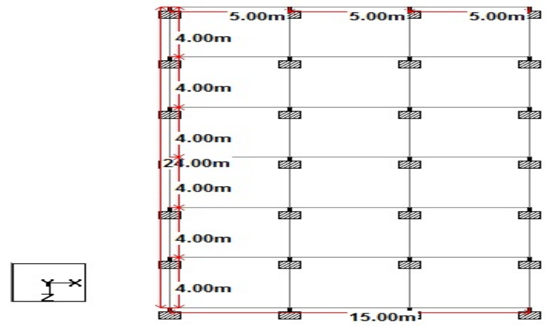

Figure 1.

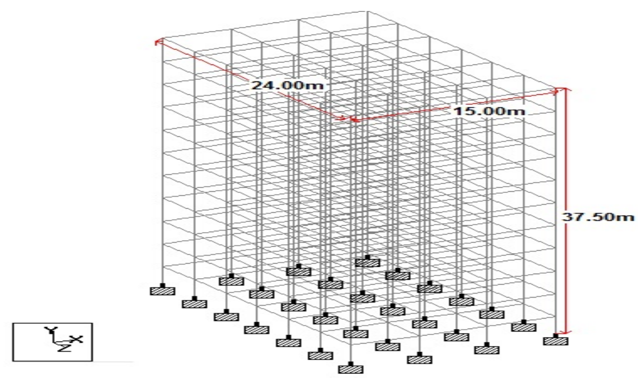

Figure 2. Plan and 3D view of G+10irregular building

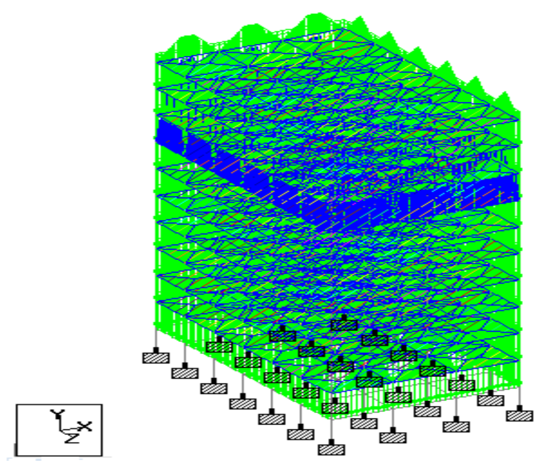

Figure 3. showing the load assignment in Equivalent lateral force method

V. RESULTS AND DISCUSSIONS

Peak storey shear:

The results of Base Shear for Buildings with different modes of stiffness irregularities. Comparison of their Peak Storey shear listed in table and plots the graph

Table 1. Peak Storey Shear (KN)

	Peak Storey Shear (KN)									
Storey	no MI	MI at 2nd	MI at 3rd	MI at 4th	MI at 5th	MI at 6th	MI at 7th	MI at 8th	MI at 9th	MI at 10th
10	309.36	343.66	317.43	308.3	296.38	304.14	318.63	316.15	291.17	277.31
9	633.12	697.92	653.99	640.96	617.16	627.23	650.31	642.31	596.3	979.87
8	886.04	970.11	924.35	916.64	884.17	889.71	908.1	890.55	1175.43	1195.57
7	1062.72	1151.61	1118.73	1125.84	1088.76	1083.85	1085.37	1310.13	1335.66	1335.87
6	1183.05	1262.62	1247.95	1275.32	1237.84	1221.41	1412.14	1431.6	1435.39	1429.13
5	1284.52	1347.07	1341.24	1386.5	1352.01	1534.69	1542.25	1529.9	1518.42	1516.8
4	1399	1448.93	1432.76	1485.94	1654.99	1674.07	1668.96	1638.72	1622.44	1627.89
3	1528.63	1580.12	1540.33	1793.54	1788.52	1799.82	1791.74	1763.32	1750.88	1758.68
2	1646.1	1712.57	1856.81	1917.44	1892.31	1897.46	1893.13	1878.06	1872.41	1877.68
1	1717.46	1944.19	1948.28	1988.75	1950.29	1952.14	1952.09	1948.56	1947.67	1949.77
Ground floor	1726.75	1957.85	1960.12	1997.79	1957.58	1959.05	1959.66	1957.78	1957.53	1959.12
Foundation	1726.75	1957.85	1960.12	1997.79	1957.58	1959.05	1959.66	1957.78	1957.53	1959.12

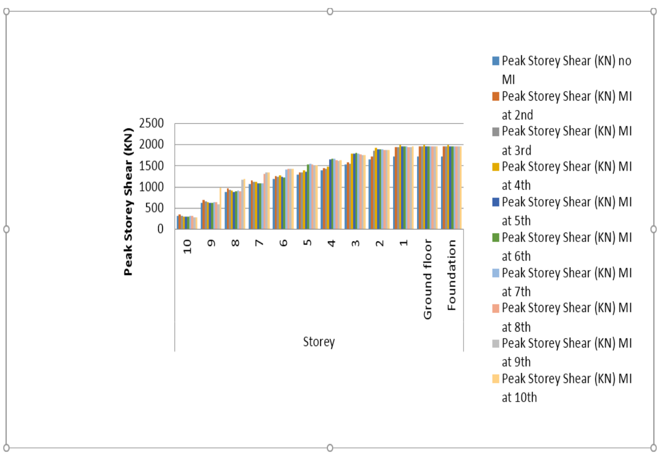

Figure 4.

Joint displacement in X-direction

Table 2. Joint displacement in X-direction

	JOINT DISPLACEMENT IN X-DIRECTION (cm)									
Node	No MI	MI at 2nd	MI at 3rd	MI at 4th	MI at 5th	MI at 6th	MI at 7th	MI at 8th	MI at 9th	MI at 10th
145	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
149	0.0419	0.0414	0.0481	0.0473	0.0474	0.0474	0.0474	0.0474	0.0474	0.0474
153	0.2223	0.2503	0.2453	0.2516	0.2509	0.2510	0.2510	0.2509	0.2509	0.2510
157	0.4442	0.5033	0.4994	0.4956	0.5021	0.5015	0.5016	0.5016	0.5018	0.5021
161	0.6699	0.7494	0.7545	0.7533	0.7508	0.7577	0.7573	0.7577	0.7582	0.7591
165	0.8917	0.9978	0.9930	1.0006	1.0035	1.0027	1.0105	1.0108	1.0122	1.0140
169	1.1035	1.2341	1.2270	1.2237	1.2357	1.2444	1.2464	1.2558	1.2578	1.2613
173	1.2993	1.4527	1.4426	1.4360	1.4367	1.4555	1.4718	1.4780	1.4903	1.4955
177	1.4723	1.6459	1.6332	1.6229	1.6619	1.6275	1.6558	1.6822	1.6943	1.7116
181	1.6152	1.8053	1.7906	1.7773	1.7705	1.7748	1.7927	1.8337	1.8729	1.8936
185	1.7190	1.9213	1.9049	1.8895	1.8801	1.8811	1.8966	1.9288	1.9862	2.0424
189	1.7865	1.9965	1.9575	1.9630	1.9522	1.9518	1.9657	1.9975	2.0488	2.1264

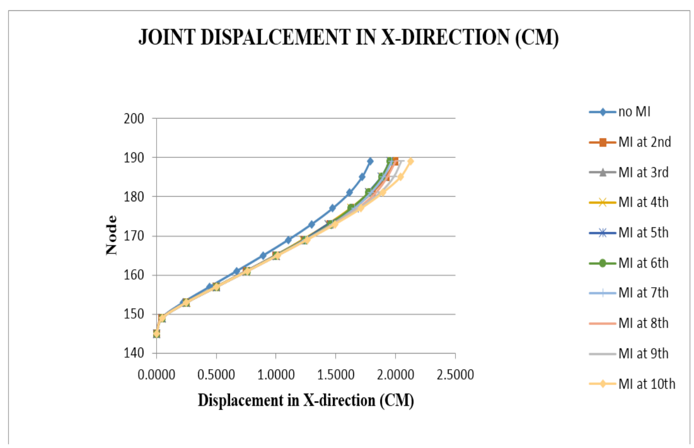

Figure 5.

Storey Drift

Table 3.

	Comparison of Storey drift in X-direction (cm)									
Height (m)	No MI	MI at 6.0m	MI at 9.5m	MI at 13m	MI at 16.5m	MI at 20m	MI at 23.5m	MI at 27m	MI at 31.5m	MI a 34m
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000
2.5	0.0432	0.0486	0.0486	0.0486	0.0486	0.0486	0.0486	0.0486	0.0487	0.048
6	0.1799	0.2021	0.2024	0.2025	0.2025	0.2026	0.2026	0.2027	0.2028	0.202
9.5	0.2200	0.2460	0.2465	0.2473	0.2476	0.2478	0.2480	0.2482	0.2484	0.248
13	0.2253	0.2516	0.2495	0.2515	0.2533	0.2540	0.2544	0.2549	0.2554	0.256
16.5	0.2211	0.2468	0.2438	0.2414	0.2460	0.2491	0.2504	0.2513	0.2522	0.253
20	0.2109	0.2355	0.2324	0.2286	0.2265	0.2345	0.2394	0.2416	0.2433	0.245
23.5	0.1947	0.2174	0.2145	0.2107	0.2065	0.2054	0.2178	0.2250	0.2284	0.231
27	0.1716	0.1916	0.1891	0.1857	0.1816	0.1776	0.1782	0.1959	0.2059	0.211
30.5	0.1409	0.1573	0.1553	0.1525	0.1491	0.1453	0.1422	0.1454	0.1692	0.182
34	0.1026	0.1146	0.1131	0.1111	0.1087	0.1059	0.1033	0.1018	0.1081	0.138
37.5	0.0619	0.0691	0.0682	0.0670	0.0656	0.0641	0.0627	0.0616	0.0622	0.072

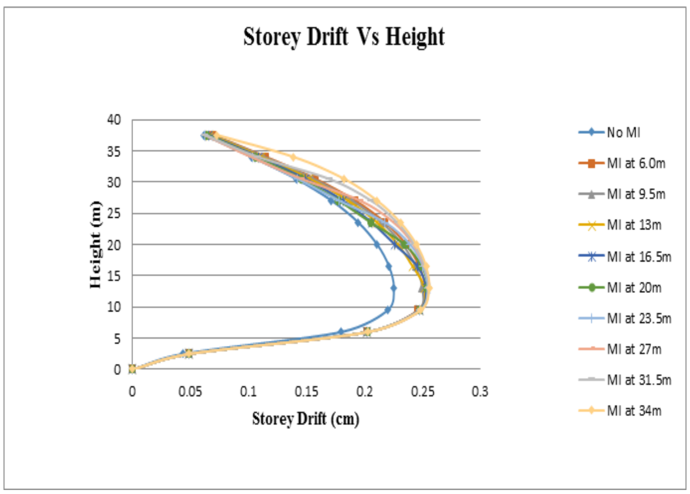

Figure 5.

Maximum Joint Displacement

The results of Maximum Joint Displacement for Buildings with different modes of mass irregularities

Maximum Joint Displacement in X Direction

Table 4. Comparison of maximum joint displacement in X-direction

	Comparison of maximum displacement in X-direction (cm)									
NODE	No MI	MI at 6m	MI at 9.5m	MI at 13m	MI at 16.5m	MI at 20m	MI at 23.5m	MI at 27m	MI at 31.5m	MI at 34m
189	1.7865	1.9965	1.9575	1.9630	1.9522	1.9518	1.9657	1.9975	2.0488	2.1264

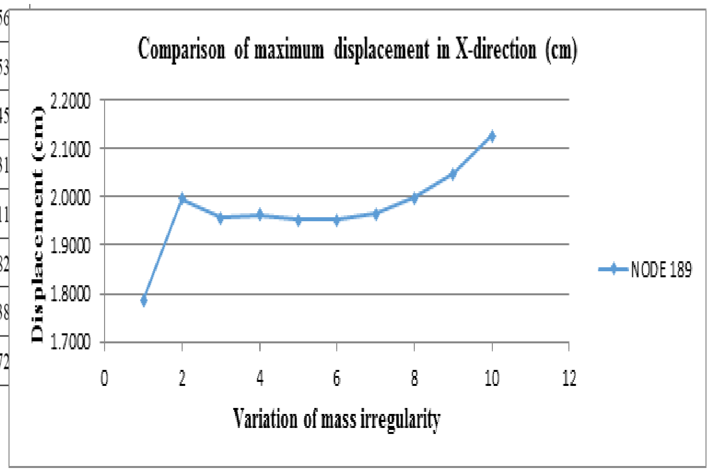

Figure 7.

Maximum Displacement In Y-Direction

Table 5. Comparison of maximum joint displacement in X-direction

	Comparison of maximum displacement in Y-direction (cm)									
NODE	No MI	MI at 6.0m	MI at 9.5m	MI at 13m	MI at 16.5m	MI at 20m	MI at 23.5m	MI at 27m	MI at 31.5m	MI at 34m
334	0.0221	0.0247	0.0244	0.0240	0.0237	0.0236	0.0236	0.0241	0.0251	0.0268

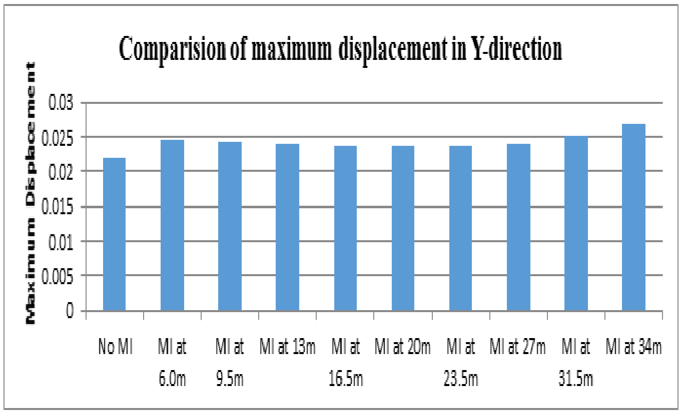

Figure 8.

VI. CONCLUSION

On the basis on present dissertation work, following are the conclusions.

- Building with mass irregularity on top storey shows high value of Joint displacement in X direction. Building with irregularity on top of 1st floor, irregularity on top of 2nd floor, irregularity on top of 3rd floor, irregularity on top of 4th floor, irregularity on top of 5th floor, irregularity on top of 6th floor, irregularity on top of 7th floor, irregularity on top of 8th floor and irregularity on top of 9th floor respectively is 11.75%, 9.57%, 9.88%, 9.28%, 9.25%, 10.03%, 11.81%, 14.6823% and 19.03%.
- Graph result of Storey drift shows that the buildings with mass irregularity on top floor soft storey showing high value of storey drift as 0.2560cm and a maximum storey drift of 0.2253cm in case of regular building. Building with irregularity on top of 1st floor, irregularity on top of 2nd floor, irregularity on top of 3rd floor, irregularity on top of 4th floor, irregularity on top of 5th floor, irregularity on top of 6th floor, irregularity on top of 7th floor, irregularity on top of 8th floor and irregularity on top of 9th floor respectively is 11.67%, 10.74%, 11.62%, 12.43%, 12.74%, 12.92%, 13.14%, 13.36% and 13.63%
- Due to the presence of mass irregularity in a regular building, the peak storey shear is increased by 13.5% when compared to the regular buildings.

VI. FUTURE SCOPE OF STUDY

- The present study is limited to reinforced concrete multi-storey framed buildings that are regular in plan and irregular in elevation. It can be extended to buildings having plan irregularities in building also. This involves analysis of three-dimensional building frames that accounts for Torsional effects. Also, these type of studies can be carried out on steel framed multi storied buildings.
- Vertically irregular buildings with shear walls are not considered in the study. The present methodology can be extended to such buildings.
- Soil -structure interaction effects are neglected in the present study. It is very interesting to study the response of the vertically irregular buildings considering the soil -structure interaction.

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