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SEISMIC ANALYSIS OF HIGH RISE (RCC) STRUCTURES WITH MASS IRREGULARITY

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Abstract—This is a rapid urbanization era, in future there will be scarcity of land for agriculture, Industrial and residential purpose due to increase in population. This is the reason why high rise building has come in picture in last some decades. Sometime due to different architectural shape buildings in different shapes has been constructed, sometimes due to ventilation and light requirement setback buildings are used. Such shapes of building leads to generate Stiffness, Plan and strength irregularity in building. Some time at higher floor heavy masses such as swimming pool, Library or heavy machinery generates mass irregularity in building. Increase in mass at a storey causes to generate higher inertial force at the time of earthquake which leads to higher storey displacement and higher forces in member. The effect of mass irregularity is more when there is greater difference in masses of adjacent floors and vice versa. From past earthquake it has been observed that mass irregularity has dominating effect in collapse of building in high seismic zone. Therefore it is necessary to study the effect of mass irregularity in buildings.

In this work a 13 storey building having mass irregularity at different level has been considered. Total 13 models has been prepared in ETABS out of which one model has regular mass distribution and other 5 models has heavy mass situated at 2nd, 4th, 6th, 8th, 10th and 12th storey respectively. A mass ratio of 2.5 and 5.0 has been considered and all the buildings are modeled in ETABS. Buildings has been designed by IS 456 and IS1893 and linear static, nonlinear static and response spectrum analysis has been done. Results in the form of Storey shear, Storey drift, Time period, capacity curve and performance point has been evaluated and compared. Finally conclusion has been made by observing the obtained results

IndexTerms—: Mass Irregularity, Irregularity, Nonlinear Static Analysis, Mass ratio etc.

I. INTRODUCTION

Availability of land for construction of Residential or commercial building in Metro city is a major problem now. Therefore from last few decades high-rise building has come in picture. High rise building with creative elevation and plans are common now a days, sometimes due to other reason such as ventilation and light purpose setback buildings are also constructed. All such type of building leads to generate different type of irregularity such as Stiffness, Strength, Mass and Diaphragm irregularity. Building having any one of above irregularity behaves abnormally at the time of earthquake as compare to building having no irregularity. Further due to increase in living standard people swimming floor on middle or upper storey of buildings are very common in metro city. Such huge mass of water at higher storey creates mass irregularity at that floor. Such type of mass irregularity can be also be generate due to presence of heavy mass such library at upper storey or presence of heavy machinery at upper storey. Mass irregularity is an important type of irregularity to be considered at the time of analysis and design of midrise and high rise building to reduce risk of collapse of building at the time of earthquake. At the time of earthquake at a floor sudden increase in mass as compare to adjacent floor mass increases inertial force at that level which leads to larger lateral displacement and shear force of that storey. When such inertia force increases beyond the capacity of structural members collapse occurs. Therefore structures which are situated in high seismic zone and having irregularity should be analyse, design and detailed properly to avoid collapse.

II. When there is a higher mass difference between adjacent storeys then inertial forces are more and vice versa. Generally building with mass ratio of adjacent storey greater 2 are considered as a mass irregular building. These ratio of mass varies with different international earthquake design codes. Some of the irregularity defined by codes has been mentioned in chapter 3. It has been observed after Bhuj, Gujrat earthquake that building having irregularity are susceptible more than regular building at the time of earthquake. Therefore it is necessary to study mass irregularity in building.

III. In this work it is proposed to carryout linear static analysis, nonlinear static analysis and response spectrum analysis of 13 storey building having mass irregularity at different floors. A total 13 models of building out of which one having regular mass and other five with irregular mass situated at different level has been taken for study. Building considered in study has a total 5 bay in each direction with 5 meter each, all storeys are of 3 m height. For analysis and design of building Finite element software ETABS has been used. First a preliminary design of building with Indian code IS 456 and IS1893 has been done. After linear static analysis and Response spectrum analysis nonlinear static analysis has been done. For carrying out nonlinear static analysis nonlinear hinges has been first assigned to beams and columns defined by ATC 40. After analysis results in the form of Storey shear, Storey drift, Time period, Base shear and Capacity curve has been evaluated of each model. A mass ratio of 2.5 and 5.0 has been used, for 12 irregular models mass irregularity is situated on 2nd, 4th, 6th, 8th 10th and 12th floor respectively. Finally obtained results from all the models has been plotted and compared and final conclusion has been made.

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II.SYSTEM OF DEVELOPMENT

In have developed total 13 model of a 13 storey RC building out of which one regular and 12 models having irregular mass distribution along height of building has been designed and analyzed by using ETABS by Linear static, Response Spectrum and Nonlinear static. After the analysis results are evaluated for each model and compared. Following is the Description of Geometry of different Elevations used in Study.

Model considered in Analysis:

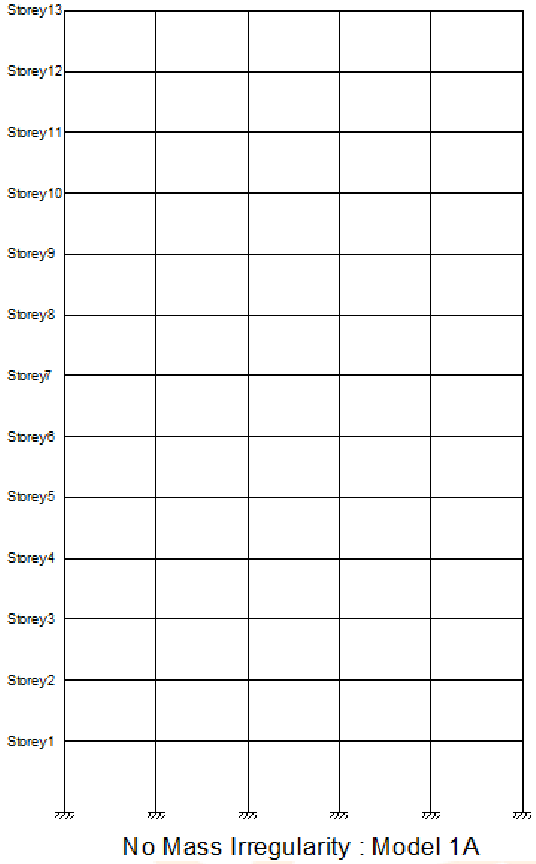
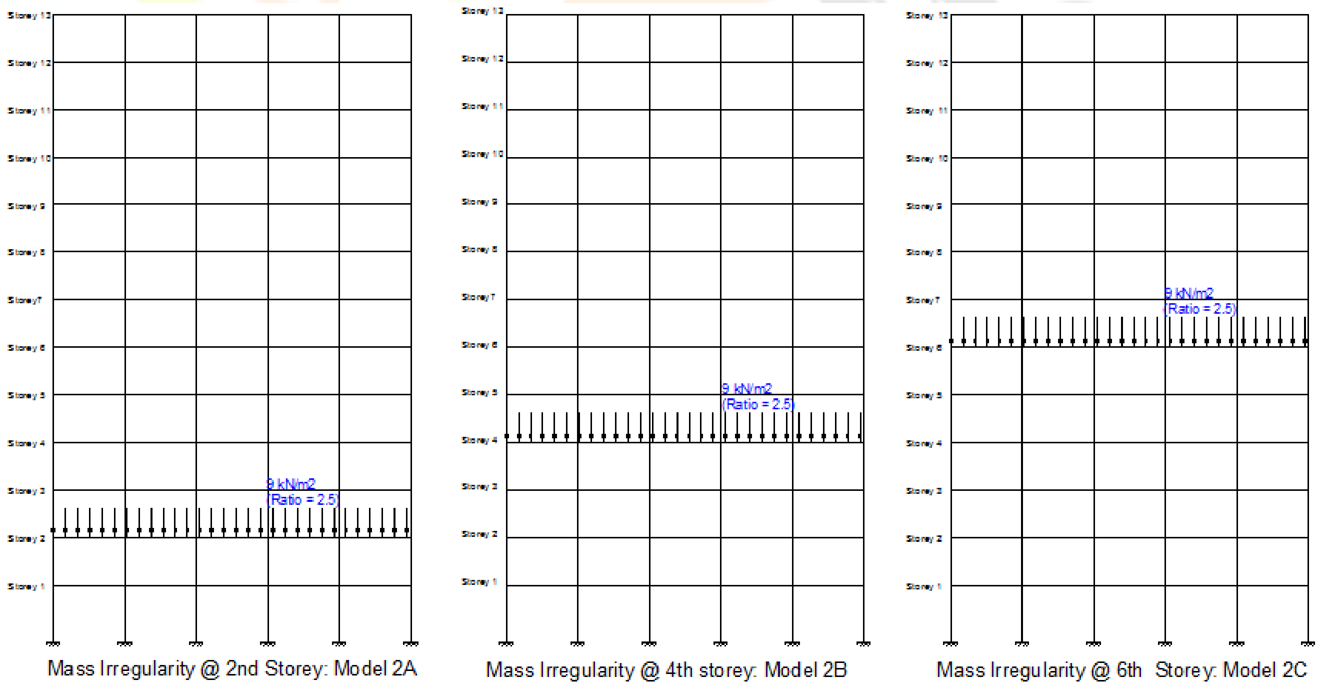
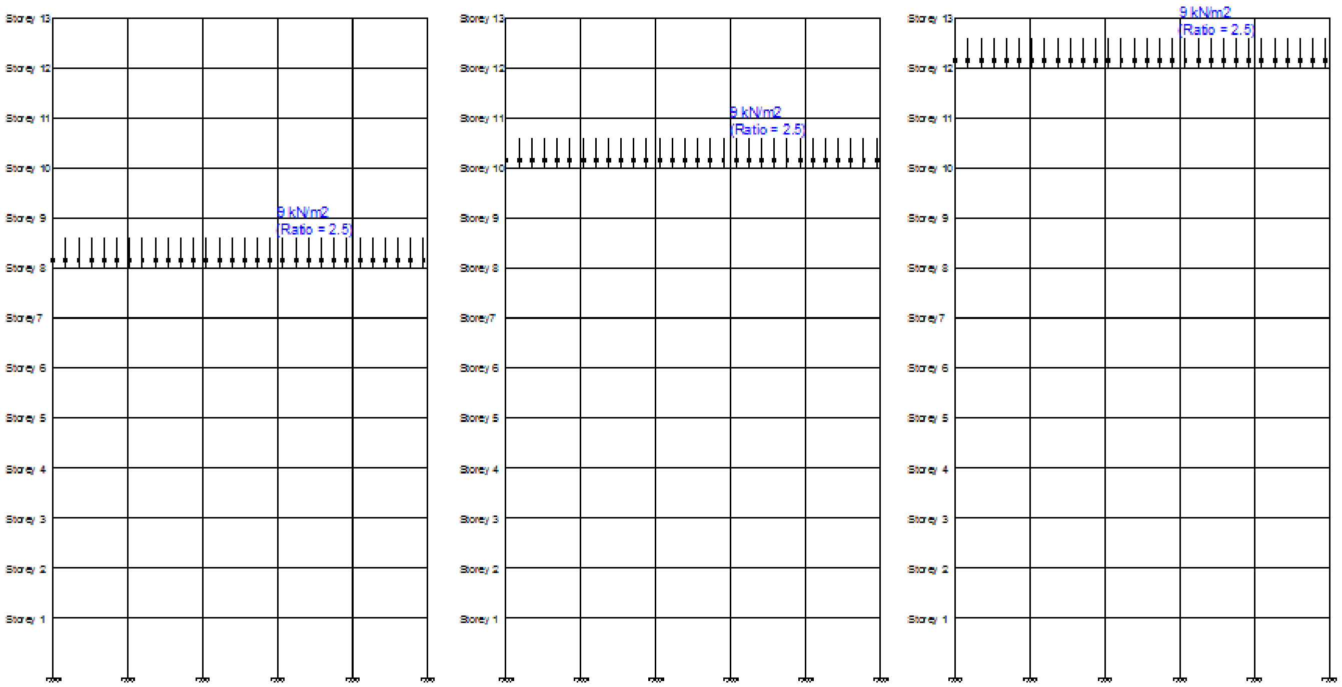


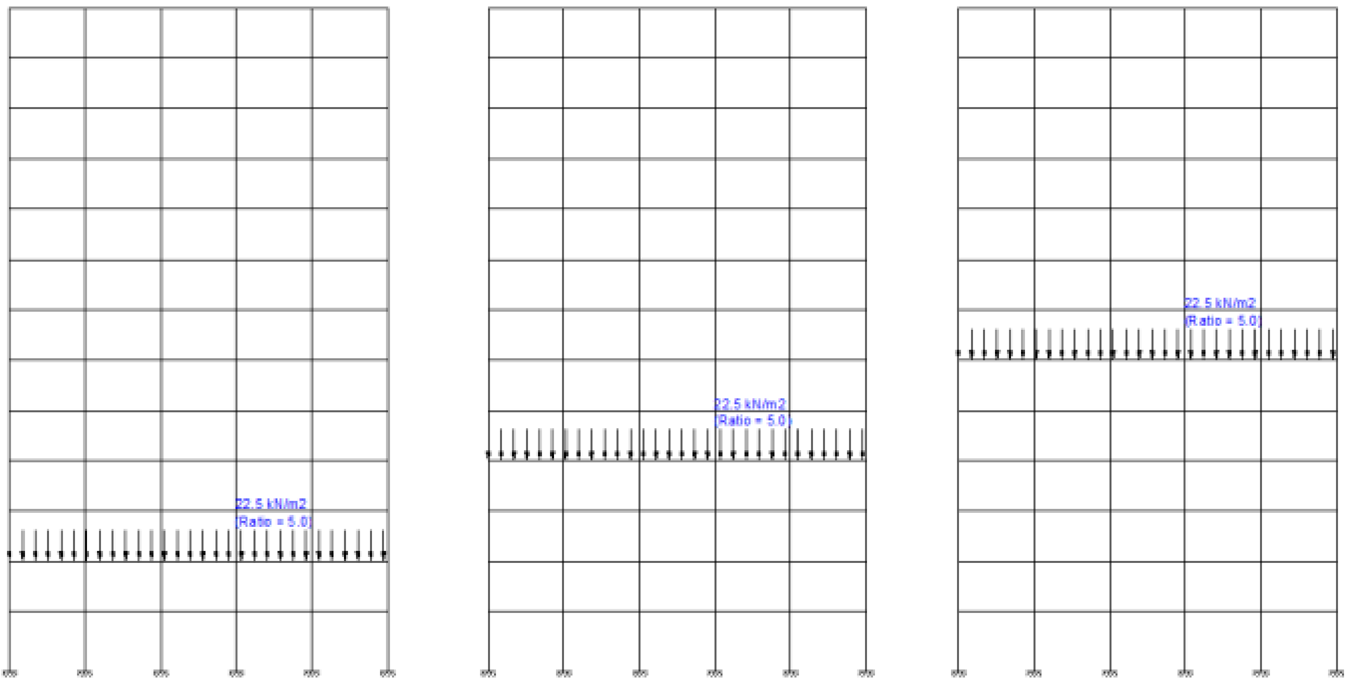
Fig. 1 Elevation of 13 storey RC building without mass irregularity





Mass Irregularity @ 8th Storey: Model 2D   Mass Irregularity @ 10th Storey: Model 2E   Mass Irregularity @ 12th Storey: Model 2F

Fig. 2 Elevation of 13 storey RC building with mass irregularity @ different level (Mass ratio 2.5)



Mass Irregularity @ 2nd Storey: Model 5A   Mass Irregularity @ 4th storey: Model 5B   Mass Irregularity @ 6th Storey: Model 5C

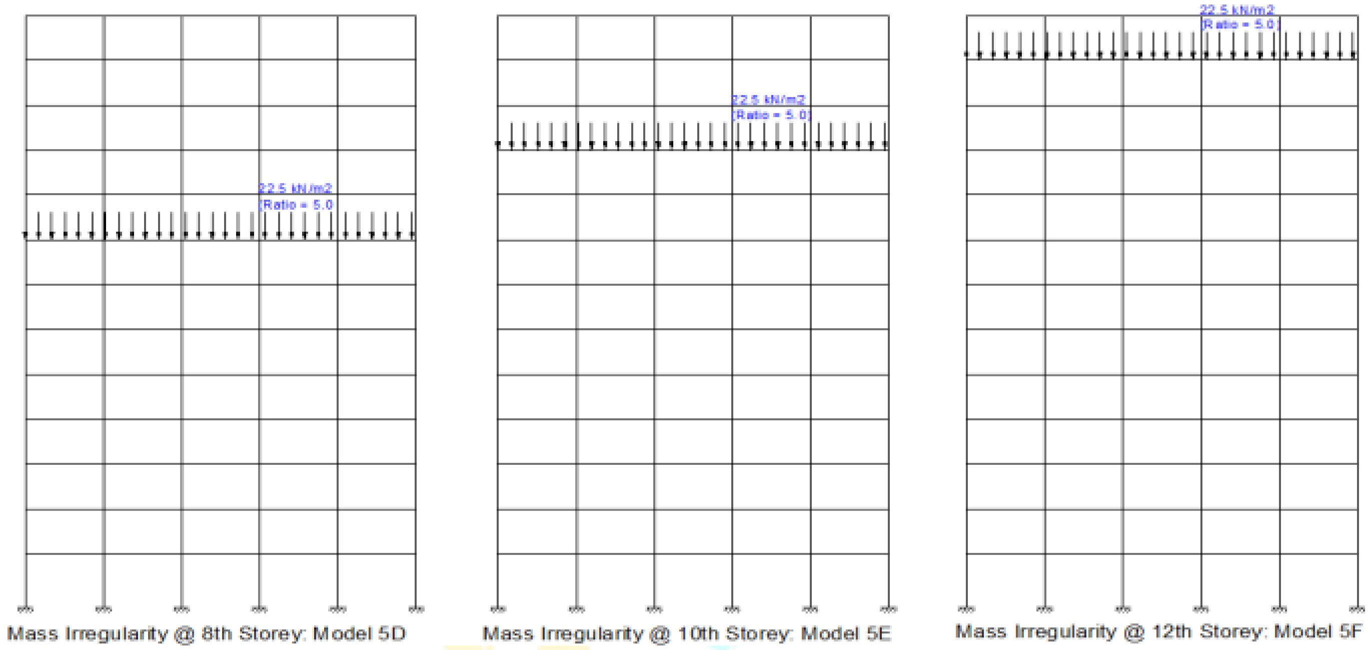


Fig. 3 Elevation of 13 storey RC building with mass irregularity @ different level (Mass ratio 5.0)

Geometric and material Descriptions and loading consideration of Regular and mass irregular building used in Study

Table 1 Loading, zone and material data considered for design and analysis

Description	**Model 1A**	**Model 2A**	**Model 2B**	**Model 2C**	**Model 2D**	**Model 2E**	**Model 2F**
Frame type	SMRF	SMRF	SMRF	SMRF	SMRF	SMRF	SMRF
Zone of EQ	IV	IV	IV	IV	IV	IV	IV
mass Irregularity @ Storey	NA	2nd	4th	6th	8th	10th	12th
mass irregularity ratio	1	2.5	2.5	2.5	2.5	2.5	2.5
Zone factor	0.24	0.24	0.24	0.24	0.24	0.24	0.24
No of Storey	13	13	13	13	13	13	13
Floor height	3 m	3 m	3 m	3 m	4 m	5 m	6 m
UDL on periphery beam	0.23x2.4x20 = 11.04 kN/m						
UDL on interior beam	0.15x2.4x20 = 7.2 kN/m						
Live Load (kN/m2)	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Floor finish Load(kN/m2)	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Concrete grade	M30						
Steel grade	Fe500						
Concrete Density (kN/m3)	25						
Damping	5%						
Soil Type	II						
Beam Size (mm)	230x600						
Slab Depth (mm)	175						

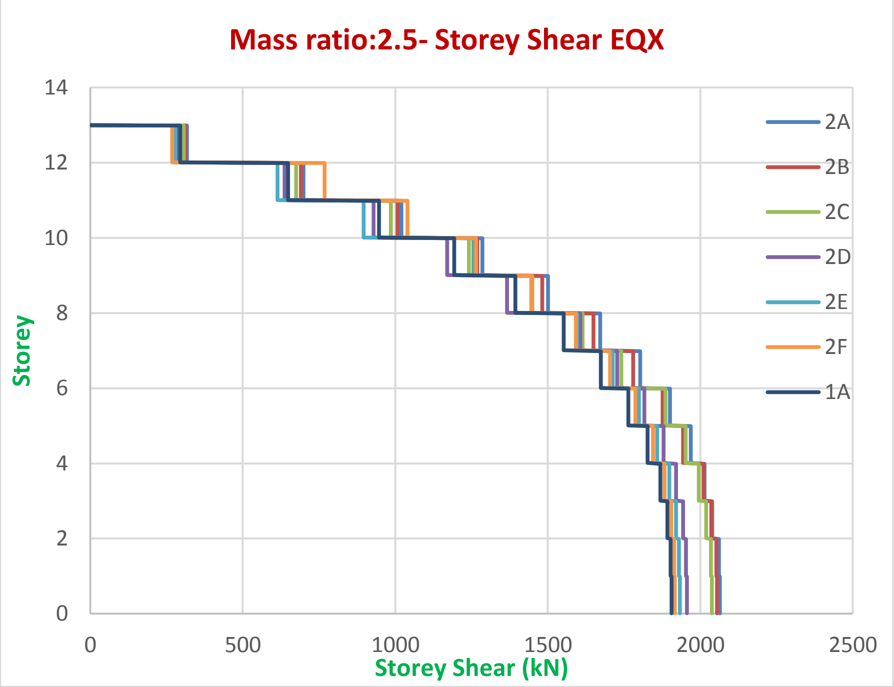
Table 2 Loading, zone and material data considered for design and analysis.

Description	Model 5A	Model 5B	Model 5C	Model 5D	Model 5E	Model 5F
Frame type	SMRF	SMRF	SMRF	SMRF	SMRF	SMRF
Zone of EQ	IV	IV	IV	IV	IV	IV
mass Irregularity @ Storey	2nd	4th	6th	8th	10th	12th
mass irregularity ratio	5	5	5	5	5	5
Zone factor	0.24	0.24	0.24	0.24	0.24	0.24
No of Storey	13	13	13	13	13	13
Floor height	3 m	3 m	3 m	3 m	3 m	3 m
UDL on peripheri beam	0.23x2.4x20 = 11.04 kN/m					
UDL on interior beam	0.15x2.4x20 = 7.2 kN/m					
Live Load (kN/m2)	3.5	3.5	3.5	3.5	3.5	3.5
Floor finish Load(kN/m2)	1.5	1.5	1.5	1.5	1.5	1.5
Concrete grade	M30					
Steel grade	Fe500					
Concrete Density (kN/m3)	25					
Damping	5%					
Soil Type	II					
Slab Depth (mm)	175					

All these above mentioned building/Structures has been modeled in ETABS and load has been applied as per above mentioned. The Type of analysis namely Linear Static, Response spectrum and Pushover analysis has been carried out for each model. Results are evaluated for each model in the form of Storey Drift, Storey shear, pushover curve time period etc. The obtained result has been compared

III.RESULTS AND DESCUSSION

Comparison of Storey shear for all models



<u>Fig.4 Mass ratio: 2.5- Storey Shear EQX</u>

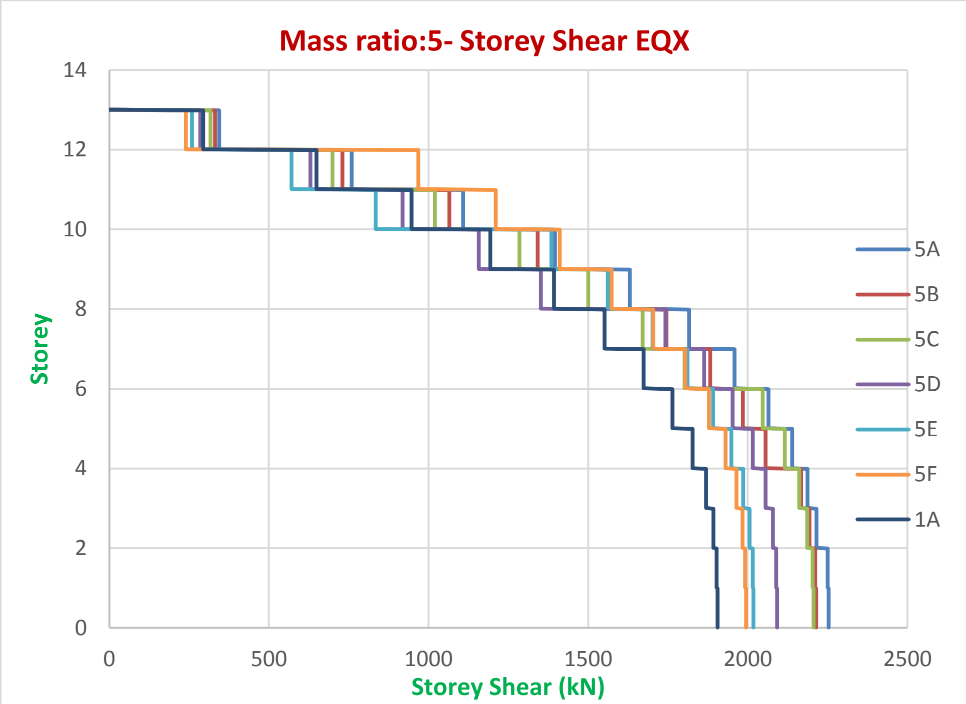


Fig.5 Mass ratio 5 Storey Shear : EQX/LSM

Storey Shear: From the combined storey shear plot for mass ratio 2.5 at different level, it can be seen that storey shear for mass irregularity at 2nd storey (model 2A) is having higher value of storey shear (2064 kN by LSM and 1830 kN by RSM) among all cases which is 8 % higher than regular Model (1A). As the mass distribution is shifting from bottom to top Storey shear is going to reduce. By linear static method Mass irregularity at lower storey has higher storey shear (8% more than regular mass model) and mass irregularity at higher storey has slightly high storey shear than regular mass building (0.7% more than 1A). Linear static method overestimates the stroey shear by almost 14 % as compare to response spectrum method. From the combined storey shear plot for mass ratio 2.5 at different level, it can be seen that storey shear for mass irregularity at 2nd storey (model 5A) is having higher value of storey shear (2253 kN by LSM and 2006 kN by RSM) among all cases which is 18-20 % higher than regular Model (1A). As the mass distribution is shifting from bottom to top Storey shear is going to reduce. By linear static method Mass irregularity at lower storey has higher storey shear (18-20% more than regular mass model) and mass irregularity at higher storey has slightly high storey shear than regular mass building (4 % more than 1A). Linear static method overestimates the stroey shear by almost 13 % as compare to response spectrum method.

Comparison of Storey drift for all models

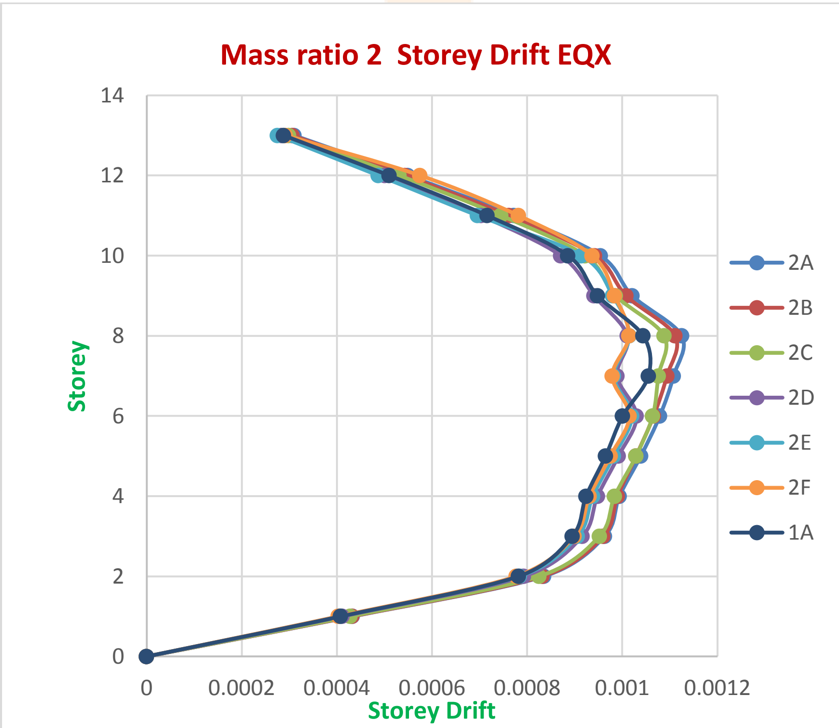


Fig .6 Mass ratio 2.5 Storey Drift EQX

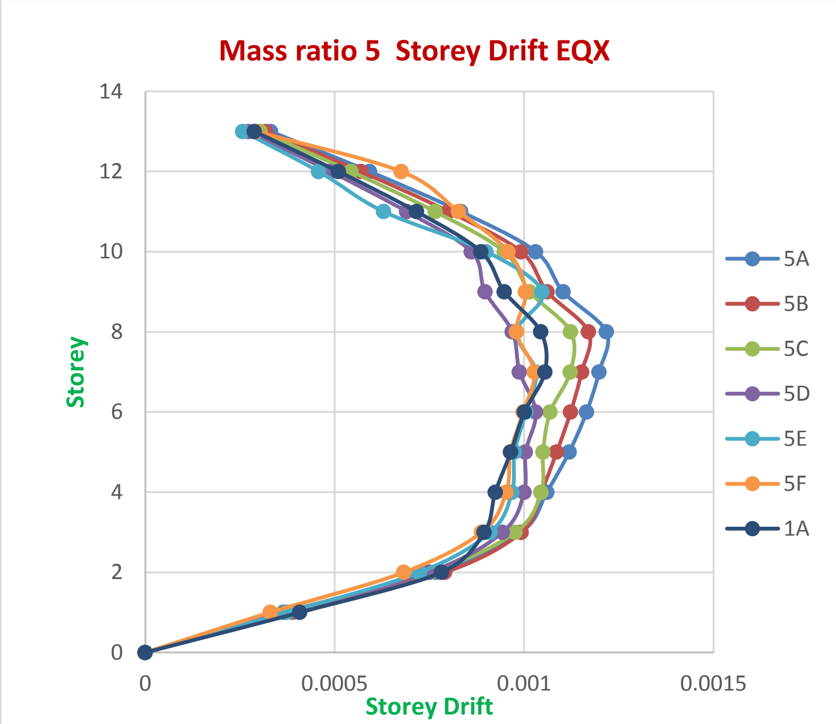


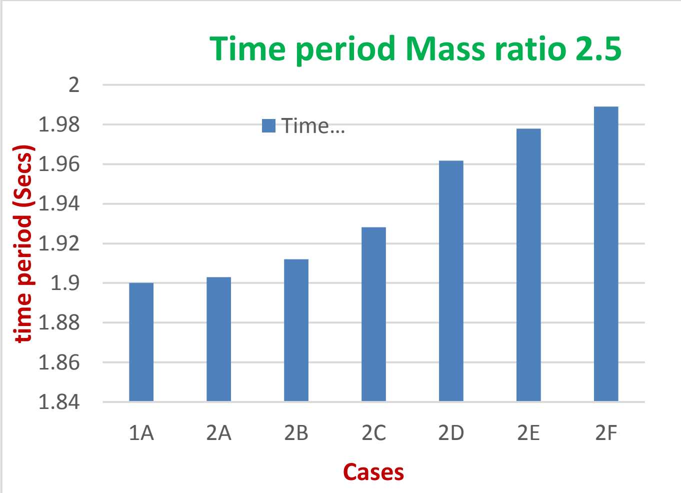
Fig .7 Mass ratio 5 Storey Drift: EQX/LSM

Storey Drift: It can be seen from storey drift plots by LSM and RSM in all 7 cases (1A, 2B, 2C, 2D, 2E, 2F) cases studied in no case storey drift is exceeding allowable limit 0.004 (IS 1893 Part I). The storey drift plot for 2A case is situated on right of all cases and case 1A plot is situated on left as compare to all other shown cases. This means that for building having regular mass is having least drift as compare to all cases of 2.5 mass ratio. The building having mass ratio 2.5 and mass situated at 2nd storey is having higher drift as compare to building having 2.5 mass ratio but on upper storey. It can be concluded from the storey plot that mass irregularity having at lower story of building will give more storey drift as compare to mass irregularity at higher level storey. Storey drift obtained by Response spectrum method is lea as compare to linear static method. It can be seen from storey drift plots by LSM and RSM in all 7 cases (1A, 5B, 5C, 5D, 5E, 5F) cases studied in no case storey drift is exceeding allowable limit 0.004 (IS 1893 Part I). The storey drift plot for 5A case (by LSM) is situated on right of all cases and case 1A plot (LSM) is situated on left as compare to all other shown cases. This means that for building having regular mass is having least drift as compare to all cases of 5.0 mass ratio. The building having mass ratio 5.0 and mass situated at 2nd storey (by LSM) is having higher drift as compare to building having 5.0 mass ratio but on upper storey. It can be concluded from the storey plot that mass irregularity having at lower story of building will give more storey drift as compare to mass irregularity at higher level storey. Storey drift obtained by Response spectrum method is less as compare to linear static method.

Time period:

Table 3 Time period for all 13th models has been obtained from ETABS and represented in tabular and bar chart form as below.

case	Time period(sec)	case	Time period(sec)
1A	1.9	5A	1.8638
2A	1.903	5B	1.895
2B	1.912	5C	1.916
2C	1.9281	5D	1.9591
2D	1.9617	5E	2.014
2E	1.978	5F	2.07
2F	1.989		



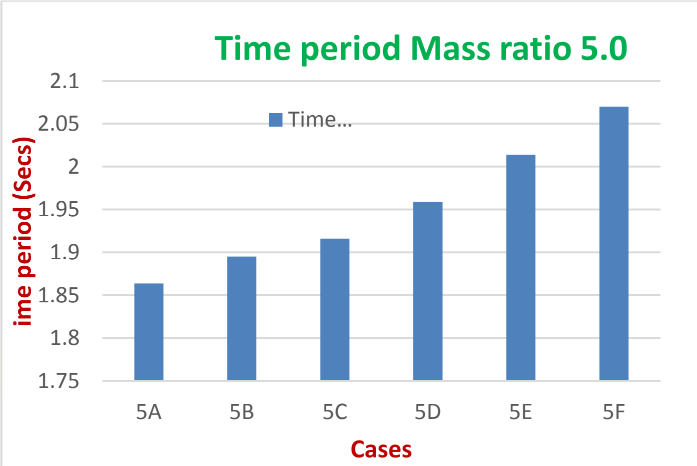


Fig.8 Time period for all cases

By observing the Time period plot it can be seen that as the heavy mass is moving from bottom to top time period is going to increase. For building with heavy mass on top stories is having time period higher than building having heavy mass ratio at lower storey.

Conclusion

A total 13models of RC building with 13 storey has been studied for mass irregularity. Out of 13 model one is having regular mass distribution and 12 models have irregular mass distribution. Two mass ratio 2.5 and 5.0 has been used in analysis. The building considered is having RC building of Special moment resistance frame (SMRF) of 13 storey. The irregular mass distribution has been applied on 2nd, 4th, 6th, 8th, 10th and 12th storey. Three methods of analysis namely Linear Static method (LSM), Response Spectrum method and Nonlinear Static method (NSA) has been used.

1.By observing the Storey shear for mass ratio 5 case (5A, 5B ….5F) in comparison of 2.5 mass ratio, higher the mass ratio higher the storey shear.

2. Building having regular mass distribution has lower storey shear as compare to building having irregular mass distribution with heavy mass, and when heavy mass is situated at lower storey it will give more storey shear as compare to case having heavy mass on top storey.

3. Linear Static analysis overestimates the storey shear and Story drift as compare to Response spectrum method

IV.ACKNOWLEDGMENT

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