International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 08 | Aug-2016 www.irjet.net p-ISSN: 2395-0072

STUDY ON MASS IRREGULARITY OF HIGH RISE BUILDINGS

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Abstract - Growth of the population is increasing day by day. To meet the requirements of the population, high rise buildings are very much needed. The high rise buildings are to be designed to resist earthquake forces. A regular structure is said to have uniform mass, stiffness, strength and structural form. The behaviour of a regular structure to earthquake forces are predictable. The behaviour of an irregular structure to earthquake forces are unpredictable because of mass irregularity, torsion irregularity, weak storey, diaphragm discontinuity etc.

Mass irregularity is considered to exist where the seismic weight of any storey is more than 200 percent of that of its adjacent storey. Mass irregularity is an important factor which affects the response of the structure under seismic loads. This is introduced by increasing the weight of some floors relative to the other floors. The effect of irregularity depends on the structural model used, location of irregularity and analysis method. In this thesis, analysis will be carried out by ETABS software. The building is subjected to dynamic analysis. One regular building with uniform mass is studied with 4 irregular buildings with varying masses for Base shear, Mode shapes, storey drift, story shear, Torsion moment. Suitable codes are used for analysis and design.

Key Words: **stiffness, diaphragm, mass irregularity, dynamic analysis.**

1. INTRODUCTION

The detectable shaking of the earth's surface is called an earthquake. Earthquake is said to be naturally occurring seismic activity. The seismic waves are created due to release of energy in the earth's crust. The seismicity mainly depends on size, type and frequency of the earthquake. The seismometers are used to measure the earthquakes. The earthquakes are measured in moment magnitude when the magnitude is greater than 5 else it is measured in local magnitude i.e. Richter magnitude scale. Earthquakes with magnitude approximately 3 are perceptible and weak and cause less damage whereas magnitude nearby 7 cause more damage along the larger areas with respect to depth. The biggest earthquake in the world have been measured to be approximately 9.5 in Chile by US geological survey. The earthquake shaking intensity is measured by Mercalli scale. Earthquakes cause shaking and displacement of the ground. Greater displacements may lead to tsunamis, landslides and volcanic eruptions too.

The two types of seismic waves are Body waves and Surface waves. The body waves are P or primary waves and S or secondary waves. The primary waves travel faster and the secondary waves are transverse, i.e., the earth vibrates perpendicularly to the direction of their motion. The surface waves are Love waves and Rayleigh waves. The velocities of the P and S waves are affected by changes in the density and rigidity of the material through the crust, mantle and core. This has been been observed by seismologists, scientists who deal with the analysis and interpretation of earthquake waves. To record P, S and L waves the seismographs are used. The vanishing of S waves below the depth of 2,900 km shows that the earth's outer core is liquid.

The small earthquakes burst open small faults or little sections of large faults. During this, the movement of fault is faster. During smaller earthquake the vibration last for a flash.

The large earthquakes burst open large faults that are tens to thousands of kilometers long. These type of ruptures may take more time to complete. The vibration is very strong and lasts for several minutes.

1.1 IRREGULARITY OF THE BUILDING

This can be classified into two types namely

- Plan irregularity – The irregular distribution of the mass, strength and stiffness on the structure towards plan is called plan irregularity.

- Vertical irregularity – The irregular distribution of the mass, strength and stiffness on the structure towards the height of the building is called vertical irregularity.

At present most of the buildings have irregularity behavior. It is said to be that behavior of the regular structure to earthquake forces are predictable. The behavior of an irregular structure to earthquake forces are unpredictable because of mass irregularity, weak storey, torsion irregularity etc., The effect of irregularity depends on the structural models used, location of irregularity and analysis method.

1.2 OBJECTIVES OF THE WORK

The study of irregularity is important since it majorly affects the response parameters.

- Modelling of regular and irregular building using Etabs.
- To analyze the regular and irregular building for Response Spectrum and Time History methods
- To analyze a mass irregular building for base shear, mode shapes, storey drift, storey displacement and torsion.
- To study the response parameters at different storey heights.

2. RESULTS AND DISCUSSIONS

In this Chapter we discuss about the results obtained from the analysis of regular and irregular buildings which are obtained from the ETABS model. Analysis Results obtained from the software ETABS, from the analysis results like, base shear, mode shapes, storey drift, storey displacement and torsion are extracted for five proposed models and are compared with each other to obtain a stable structural system.

The project consists of modelling and analysis **"G+12 commercial building"** using ETABS software. 1 Regular building and 4 Irregular buildings are considered under seismic zone IV.

2.1 PRELIMINARY DATA

For regular building

- The plan of the building - (44.4m X41.4m)
- Number of storeys – G+12
- The structural building is a RC frame building
- Height of the building - 40m
- Bottom storey (ground to 1st floor) – 3.7m and storey to storey height from 1st storey to 12th storey – 3.3m
- Plinth height - 1.5m
- Thickness of the wall – 0.23m
- Grade of concrete – M25
- Grade of steel – 415 N/mm^2
- Thickness of slab – 0.15m
- Sizes of Column – 0.35X0.45m , 0.35X0.6m
- Size of Beam – 0.23X0.45m
- Floor finishes – 1.5 KN/m^2
- Zone of the building - IV (0.36)
- Importance factor - 1.5
- Response Reduction factor - 5
- The loads assigned are

  LL – 2.5 KN/m^2 ,

  Living, Stair case, Reception, Corridor – 4 KN/m^2

  Store – 5 KN/m^2

  Lift – 10 KN/m^2

For irregular building changes are

- Slab thickness – 0.2m
- Floor finishes – 4 KN/m^2
- Live load – 6 KN/m^2
- Size of beam – 0.35m X 0.6m
- Wall load after calculating – 18.9 KN/m^2

2.2 MODELS FOR ANALYSIS

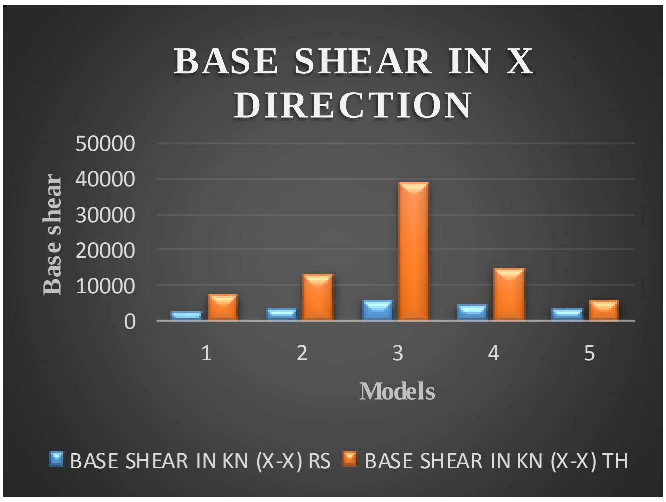
- Model 1: Regular building with no mass irregularity
- Model 2: Irregular building with mass irregularity in alternate storeys.
- Model 3: Irregular building with mass irregularity in bottom storeys.
- Model 4: Irregular building with mass irregularity in middle storeys.
- Model 5: Irregular building with mass irregularity in top storeys.

A. BASE SHEAR

The base shear has been tabulated for all the 5 models with respect to X and Y direction

Base shear in KN (X-X)		
MODEL	RS	TH
1	2378.34	7382.5
2	3124.05	12866.27
3	5747.68	38943.7
4	4218.41	14608.51
5	3250.78	5674.39

Table : Base shear in X-X



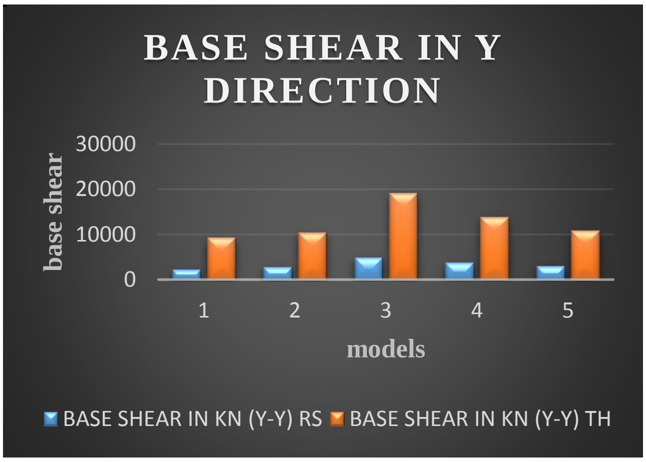
Graph : Base shear in X direction

From the above graph, it is observed that, the decrease in base shear in model-1 (regular building) was nearly 23.87%, 58.62%, 43.62% and 26.84% when compared to model-2, model-3, model-4 and model-5 respectively by response spectrum analysis in X-X direction.

The decrease in base shear in model-1(regular building) was nearly 42.62%, 81.04% and 49.46% when compared to model-2, model-3 and model-4 respectively where as it is increased by 30.10% when compared to model-5 by time history analysis in X-X direction.

Base shear in KN (Y-Y)		
MODEL	RS	TH
1	2185.74	9241.13
2	2730.38	10357
3	4917.76	19119.15
4	3708.15	13851.64
5	2942.85	10863.85

Table 4.2: Base shear in Y-Y



Graph : Base shear in Y direction

From the above graph, it is observed that, the decrease in base shear in model-1 (regular building) was nearly 19.94%, 55.55%, 41.05% and 25.72% when compared to model-2, model-3, model-4 and model-5 respectively by response spectrum analysis in Y-Y direction.

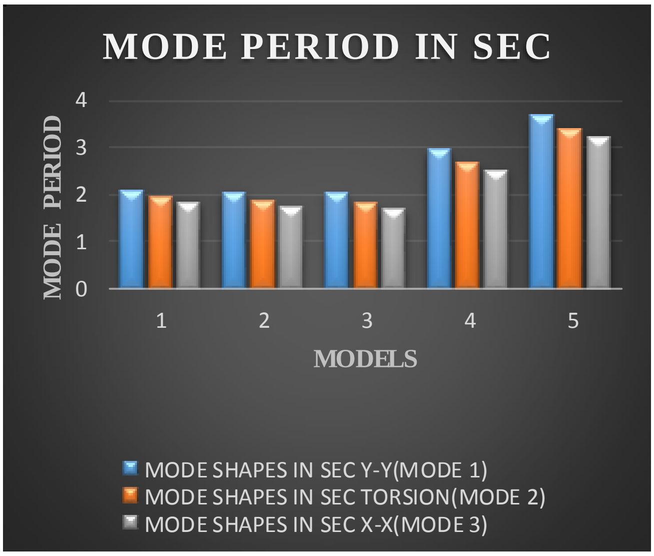
The decrease in base shear in model-1 (regular building) was nearly 10.77%, 51.66%, 33.28% and 14.93% when compared to model-2, model-3, model-4 and model-5 respectively by time history analysis in Y-Y direction.

B. MODE PERIOD

The mode period have been tabulated for all the 5 models

Mode period in Sec			
MODEL	Y-Y(MODE 1)	TORSION(MODE 2)	X-X(MODE 3)
1	2.0725	1.9239	1.8186
2	2.0417	1.8456	1.7144
3	2.0153	1.8006	1.6705
4	2.9455	2.6511	2.5165
5	3.6867	3.3995	3.2208

Table : Mode period



Graph : Mode period

In the observation made in **MODE-1(Y-Y)**, when compared to model-1 the mode period is decreasing by 1.49% and 2.76% as that of model-2 and model-3 respectively whereas it is increasing by 42.12% and 77.89% in model-4 and model-5 respectively.

In the observation made in **MODE-2 (TORSION)**, when compared to model-1 the mode period is decreasing by 4.06% and 6.4% as that of model-2 and model-3 respectively whereas it is increasing by 37.8% and 76.7% in model-4 and model-5 respectively.

In the observation made in **MODE-3(X-X)**, when compared to model-1 the mode period is decreasing by 5.72% and 8.14% as that of model-2 and model-3 respectively whereas it is increasing by 38.37% and 77.1% in model-4 and model-5 respectively.

C. STOREY DRIFT

The storey drift has been tabulated for all the 5 models in both X and Y directions

MODEL 1

Storey drift in mm(X)		
STOREY	RS	TH
12	0.616	3.446
11	0.846	4.809
10	1.047	5.712
9	1.205	6.04
8	1.323	6.224
7	1.413	6.181
6	1.487	6.278
5	1.553	5.941
4	1.614	5.932
3	1.664	6.269
2	1.672	7.086
1	1.475	6.674

Table : Storey Drift of model-1 in X direction

From the above table, in Response Spectrum analysis the storey drift at storey 1 is increased by 139% than storey 12. Whereas in case of Time History analysis the storey drift at storey 1 is increased by 93% than the storey 12. When comapared to time history analysis the storey drift is increased by 459% than response spectrum analysis at storey 12 in X-X direction.

Storey drift in mm(Y)		
STOREY	RS	TH
12	0.629	4.048
11	0.949	6.104
10	1.213	7.374
9	1.417	8.079
8	1.574	8.452
7	1.698	8.915
6	1.801	9.376
5	1.897	9.178
4	1.987	9.332
3	2.071	9.657
2	2.147	11.003
1	2.085	11.613

Table : Storey Drift of model-1 in Y direction

From the above table, in Response Spectrum analysis the storey drift at storey 1 is increased by 231% than storey 12. Whereas in case of Time History analysis the storey drift at storey 1 is increased by 186% than the storey 12. When comapared to time history analysis the storey drift is increased by 543% than response spectrum analysis at storey 12 in Y-Y direction.

MODEL 2

Storey drift in mm(X)		
STOREY	RS	TH
12	0.534	2.41
11	0.672	3.246
10	0.877	4.504
9	0.967	4.983
8	1.09	5.505
7	1.139	5.59
6	1.239	5.461
5	1.289	5.453
4	1.385	5.624
3	1.434	6.31
2	1.577	7.702
1	1.848	9.361

Table : Storey Drift of model-2 in X direction

From the above graph, in Response Spectrum analysis the storey drift at storey 1 is increased by 246% than storey 12. Whereas in case of Time History analysis the storey drift at storey 1 is increased by 288% than the storey 12. When comapared to time history analysis the storey drift is increased by 351% than response spectrum analysis at storey 12 in X-X direction.

Similarly, the table for model 3, 4, 5 have been tabulated and discussed.

D. STOREY SHEAR

The storey shear has been tabulated for all the 5 models in both X and Y directions

MODEL 1

Storey shear in kN(X)		
STOREY	RS	TH
12	446.4	2268.9
11	839.57	3992.77
10	1129.34	4714.6
9	1342.03	4808.76
8	1504.5	4453.77
7	1633.21	5054.19
6	1749.68	5662.17
5	1872.64	6043.7
4	2004.88	5567.03
3	2144.38	5201.02
2	2280.98	6256.21
1	2378.34	7382.5

Table : Storey Shear of model-1 in X direction

From the above we can observe that the decrease in storey shear was nearly by 81.23% in storey-12 compared to storey-1 in X-X direction by response spectrum method. The decrease in storey shear was nearly by 69.26% in storey-12 compared to storey-1 in X-X direction by time history analysis. This shows mass participation factor is more in storey-1 compared to storey-12. The storey shear goes on increasing from storey-12 to storey-1 respectively.

Storey shear in kN(Y)		
STOREY	RS	TH
12	397.08	2240.67
11	754.46	4033.83
10	1019.98	4909.82
9	1217.17	5127.95
8	1372.59	5574.46
7	1499.8	6066.16
6	1613.78	6204.76
5	1728.32	6386.77
4	1845.77	6892.5
3	1967.52	7301.22
2	2090.87	8149.21
1	2185.74	9241.13

Table: Storey Shear of model-1 in Y direction

From the above we can observe that the decrease in storey shear was nearly by 81.83% in storey-12 compared to storey-1 in Y-Y direction by response spectrum method. The decrease in storey shear was nearly by 75.75% in storey-12 compared to storey-1 in Y-Y direction by time history analysis. This shows mass participation factor is more in storey-1 compared to storey-12. The storey shear goes on increasing from storey-12 to storey-1 respectively.

MODEL 2

Storey shear in kN(X)		
STOREY	RS	TH
12	637	3317.2
11	1033.48	5286.01
10	1479.61	7169.56
9	1718.83	7982.21
8	1984.01	8497
7	2134.37	8684.24
6	2324.85	8657.91
5	2459.65	8511.73
4	2660.74	8702.48
3	2808.21	9915.09
2	3013.7	11796.63
1	3124.05	12866.27

Table: Storey Shear of model-2 in X direction

From the above we can observe that the decrease in storey shear was nearly by 79.6% in storey-12 compared to storey-1 in X-X direction by response spectrum method. The decrease in storey shear was nearly by 74.2% in storey-12 compared to storey-1 in X-X direction by time history analysis. This shows mass participation factor is more in storey-1 compared to storey-12. The storey shear goes on increasing from storey-12 to storey-1 respectively.

Storey shear in kN(Y)		
STOREY	RS	TH
12	553.94	3112.76
11	898.4	4625.92
10	1284.43	5396.7
9	1492.11	5955.29
8	1727.42	7179.81
7	1864.1	7445.04
6	2037.56	7740.16
5	2156.81	8656.75
4	2328.21	9077.23
3	2452.25	8646.14
2	2629.77	9007.98
1	2730.38	10357

Table: Storey Shear of model-2 in Y direction

From the above we can observe that the decrease in storey shear was nearly by 79.71% in storey-12 compared to storey-1 in Y-Y direction by response spectrum method. The decrease in storey shear was nearly by 70% in storey-12 compared to storey-1 in Y-Y direction by time history analysis. This shows mass participation factor is more in storey-1 compared to storey-12. The storey shear goes on increasing from storey-12 to storey-1 respectively.

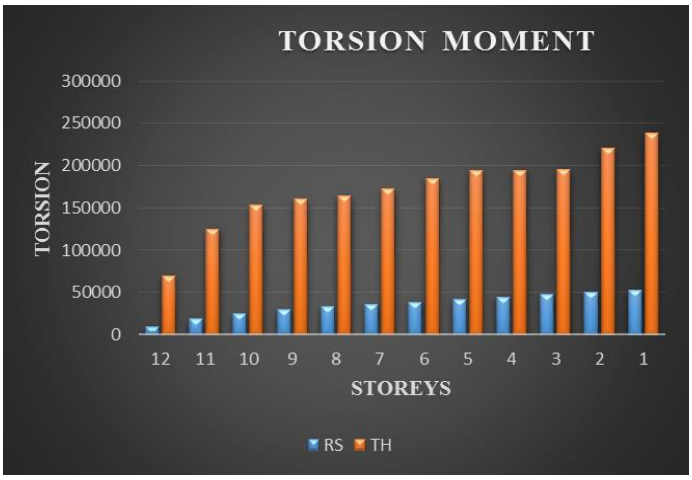
Similarly, the table for model 3, 4, 5 have been tabulated and discussed.

E. TORSION MOMENT

MODEL 1

TORSION MOMENT		
STOREY	RS	TH
12	9836.026	69478.1
11	18530	124626
10	24916.83	153100
9	29597.84	160017
8	33207.61	164279.5
7	36112.03	172339.1
6	38745.95	185050.3
5	41487.27	194263.9
4	44391.55	194451
3	47439.62	195015
2	50458.79	220602.3
1	52670.49	238866

Table: Torsion Moment of model-1



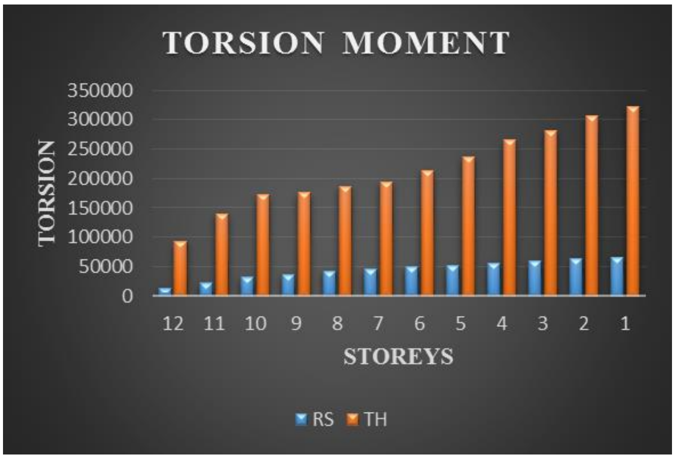
Graph: Torsion Moment of model-1

From the above graph, it is observed that the twisting moment(torsion) is decreased by 81.32% in storey-12 compared to storey-1 by response spectrum method. Whereas in time history analysis it is decreased by 70.91% in storey-12 compared to storey-1.

MODEL 2

TORSION MOMENT		
STOREY	RS	TH
12	13635.74	92168.9
11	22055.3	139846
10	31423.8	172173
9	36411.5	175849
8	41959.16	186466
7	45132.16	194663
6	49175.36	213275.4
5	52025.56	237075
4	56244.77	265550.9
3	59336.88	281857
2	63703.93	305988
1	66100.64	322303

Table : Torsion Moment of model-2



Graph: Torsion Moment of model-2

From the above graph, it is observed that the twisting moment(torsion) is decreased by 79% in storey-12 compared to storey-1 by response spectrum method. Whereas in time history analysis it is decreased by 71% in storey-12 compared to storey-1.

Similarly, the table for model 3, 4, 5 have been tabulated and discussed.

3. CONCLUSIONS

Based on analytical study of the 12 storey building models, following conclusions are made,

- **BASE SHEAR**

  The mass of the building in model-3 lead to increase in base shear compared to other models. This shows that increase in mass in model-3 (1^{st}, 2^{nd}, 3^{rd} and 4^{th}) increases the base shear compared to other models.
- **MODE PERIOD**

  The mode period of model-5 with mass irregularity in top four storeys is found to be maximum when compared to other models.

  From analysis it is found that model-3 with mass irregularity in bottom storeys has less mode period as compared to other models. The mode period of model-5 increases by 43.78%, 44.62%, 45.33% and 20.10% compared to model-1, model-2, model-3 and model-4 in mode-1.

  Mode period increases as the location of mass irregularity increase towards the top of the structure as in case of model-5.
- **STOREY DRIFT**

  The storey drift in both the analysis (RS and TH), it has been found that model-3 shows more storey drift in both X-X and Y-Y direction compared other models. Whereas model-1 and model-2 shows less storey drift compared to other models. So distribution of mass should be equal in all the storeys which will results in the less story drift.
- **TORSION**

  Twisting moment (torsion) of the structure will depend on the distribution of mass in each model. Model-3 is affected by more torsion as the mass irregularity is at the bottom four storeys (1^{st}, 2^{nd}, 3^{rd} and 4^{th} storeys) compared to all other models.

  Out of all five models model-1 shows better performance to resist lateral loads due to earthquake compared to all other models such as mass irregularity in alternate storeys, bottom storeys, middle storeys and top storeys. Hence any structure with equal distribution of mass in all the storeys will give better performance.

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BIOGRAPHIES

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