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# SEISMIC ANALYSIS OF MULTISTORIED BUILDING WITH AND WITHOUT VERTICAL MASS IRREGULARITY

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**ABSTRACT:**

**The sudden slip at the fault, planar fracture or discontinuity in a volume of rock, across which there has been significant displacement as a result of rock mass movement, causes the earthquake a violent shaking of the Earth during which large elastic strain energy released spreads out in the form of seismic waves that travel through the body and along the surface of the Earth. Structures designed for gravity loads, in general, may not be able to safely sustain the effects of horizontal earthquake shaking. Hence, it is necessary to ensure adequacy of the structures against horizontal earthquake effects. There are many studies carried out about earthquakes but however it has not been possible to predict when and where earthquake will happen. In this study, 3D Analytical model of G+15 storeyed buildings have been generated for vertical mass irregularity. Three models are generated with difference in vertical mass irregularity analysed by using analysis tool 'ETABS Non-linear Version 9.5.0'. The parameters considered in this paper are fundamental time period, base shear and displacement. The analysis is done with two different methods namely linear static Method (Equivalent Static Method) and Linear Dynamic Analysis (Response Spectrum Analysis). In this study, the displacements values are increasing as the irregular mass shifts towards top. The base shear values are considerably high in buildings having vertical mass irregularity and as the vertical mass shifts towards top, base shear decreases.**

**KEYWORDS: Seismic waves, Vertical Mass irregularity, ETABS, linear Static method, Linear Dynamic method.**

## INTRODUCTION:

Irregular buildings constitute a large portion of the modern urban infrastructure. Structures are never perfectly regular and hence the designers routinely need to evaluate the likely degree of irregularity and the effect of this irregularity on a structure during an earthquake. About 90% of all earthquakes result from tectonic events, primarily movements on the faults (Agrawal and Shrikhandeet al., 2006).Structures designed for gravity loads, in general, may not be able to safely sustain the effects of horizontal earthquake shaking. Hence, it is necessary to ensure adequacy of the structures against horizontal earthquake effects(C. V. R. Murty et al., 2002).Need for research is required to get economical and efficient lateral stiffness system for high seismic prone areas. For optimization and design of high rise building with different structural framing systems subjected to seismic loads.The innovative and revolutionary new ETABS is the ultimate integrated software package for the structural analysis and design of buildings. From the start of design conception through the production of schematic drawings, ETABS integrates every aspect of the engineering design process. Creation of models has never been easier – intuitive drawing commands allow for the rapid generation of floor and elevation framing.

## LITERATURE REVIEW:

The R.C.C and Composite structures with one of the important consideration of Mass irregularity in the form of swimming pool at 9th floor, Equivalent static and Response spectrum methods are used to analyse the building as per IS 1893(Part1):2002 using SAP 2000 software. The study shows that Composite structures having mass irregularity will better perform than R.C.C. structures. Design base shear values are reduced by 18% for composite structures. The dead weight of the composite structures is less compared to R.C.C. structures by 18%, hence earthquake forces also reduced by 18%. Shear force in Composite structures is reduced by 20%. Results obtained for Equivalent static method for R.C.C and composite structures are quite high than Response spectrum method (Cholekar & Basavalingappa et al., 2015). Reinforced cement concrete building of G+10 having mass irregularity in 3rd and 6$^{th}$ floors and building without mass irregularity are analysed. It was observed that there is an increase of 67% in the moments of mass irregular buildings than buildings without mass irregularity. Size of the structural members also increases for buildings with mass irregularity(N.Anvesh, Yajdani and Pavankumar et al., 2015). Different irregularity and torsional response due to plan and vertical irregularity and to analyse cross shape and L shape building while earthquake forces acts and to calculate additional shear due to torsion in the columns. From the torsion point of view the re-entrant corner columns must be strengthen at lower floor levels and top two floor levels and from the analysis it is observed that behaviour of torsion is same for all zones. Effect of torsion is much more when diaphragms at some level are removed, so in re-entrant corner building it is better to avoid irregularity in diaphragm(Modakwar, Meshram and Gawatre et al., 2014). The seismic performance of G+6 storey regular and irregular Reinforced Concrete (RC) buildings using ETABS (V. 9.7.1), to evaluate the impact of vertical irregularity on RC buildings in terms of static linear-Equivalent Static Lateral force Method (ESLM) and nonlinear analysis (PUSHOVER). Maximum base shear occurs in the mass irregularity building as compared to other models. Maximum lateral displacement is obtained mass irregular building and less in vertical geometric irregularity building shows less displacement(Pathi, Guruprasad, DharmeshAndMadhusudhana et al., 2014). Building model of G+ 5 storey, the building models are studied for vertical geometric irregularity in seismic zone V of India. Steel bracings are provided on the outer periphery of the models on all the four sides and analysed. Types of bracings considered for the study are X-type, V-type and K-type bracing. Lateral displacement and Storey drift increases as the amount of irregularity present in the building increases. Addition of bracings to the bare frames shows reduction in lateral displacement and storey drift(Karthik and Vidyashree et al., 2015). Modelling of the building for five different systems viz. unbraced frame, Chevron Braced Frame, Eccentrically Braced Frame, Single Diagonal Braced Frame and X Braced Frame under same loading conditions is done using ETABS. From comparative study, we conclude that introducing bracing system increase lateral stiffness and improve seismic performance of the building. Use of Chevron braced frame system is more efficient than any other braced frame system(Odedra and Tarachandani et al., 2016). The effect of mass irregularity on different floor in RCC buildings with as Response Spectrum analysis was performed on regular and various irregular buildings using Staad-Pro. It was found that mass irregular building frames experience larger base shear than similar regular building frames (Khan and Dhamge et al., 2016).

**MODELLING:**

The Reinforced Concrete building models used in this study is G+15 storied, have same floor plan with 5m bays along longitudinal direction and 4.5m bays along transverse direction as shown in figure 1. The storey height is 3m for all the stories. The live load taken has 3 KN/m$^2$ for all floors and no live load on roof, while the floor finish load is taken as 1 kN/m$^2$ on all other floors. Thickness of brick wall over all floor beams is taken as 0.230 m. Thickness of slab is taken as 0.15 m. The unit weight of reinforced concrete is 25kN/m$^3$ and brick masonry is taken as 20 kN/m$^3$. The compressive strength of concrete is 25 N/mm$^2$ and yield strength of steel reinforcements is 415 N/mm$^2$.The modulus of elasticity of concrete and steel are 25000 N/mm$^2$ and $2\times10^5$ N/mm$^2$ respectively. All the structures have been considered to be located in seismic region V with an importance factor 1 and sub-soil type 2 (medium) and response reduction factor 5 (SMRF).

MODEL 1 – Regular building

MODEL 2 – Regular building with heavy mass on 6$^{th}$ floor.

MODEL 3 –Regular building with heavy mass on Roof.

The model is prepared of G+15 Storey. The regular building model is without mass irregularity as shown in figure 1. The model 1 regular building is as shown in figure 2. Heavy mass, it is taken as SIL (Superimposed Load)20 KN/m$^2$ on 6$^{th}$ floor and on RF (Roof) as shown in figures 3 and 4 respectively.

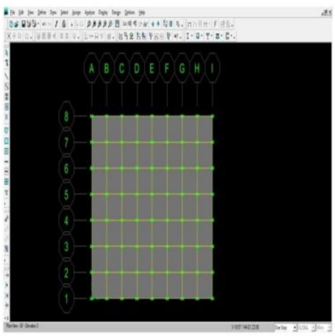


Fig 1: ETABS MODEL

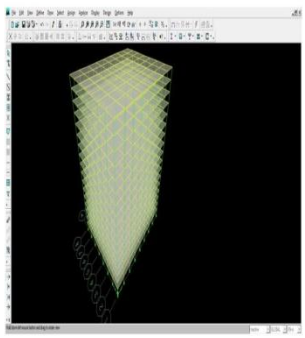

Fig 2: ETABS MODEL 1

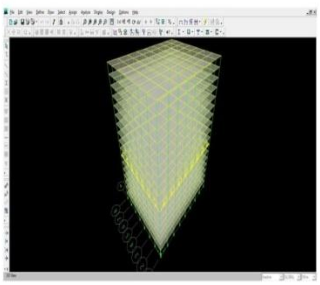

Fig 3: ETABS MODEL 2

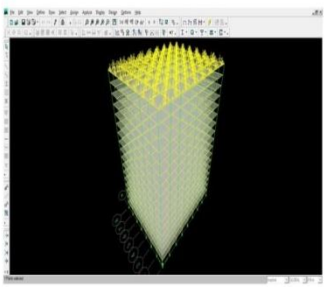

Fig 4: ETABS MODEL 3

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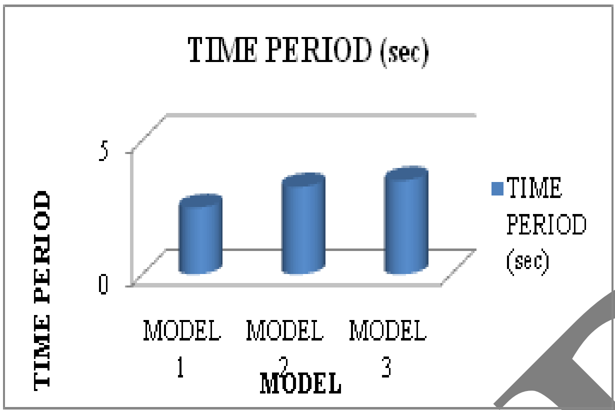
**RESULT AND DISCUSSION:**

Results of the building models studied are presented and discussed in detail. The results of fundamental natural period of vibration, lateral displacements and storey drifts are included for building models and compared. The fundamental time period of models is tabulated in table 1 and graph of model v/s time period is as shown in graph 1.

Table 1: Fundamental Time period of buildings

| | TIME PERIOD (sec) |
|---|---|
| MODEL 1 | 2.4837 |
| MODEL 2 | 3.2642 |
| MODEL 3 | 3.4990 |

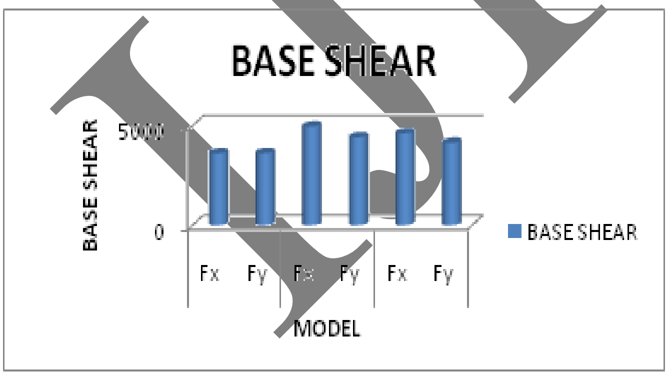



Graph 1: Model v/s Time period

The Base shear of models is tabulated in table 2 and graph of model v/s Base shear is as shown in graph 2.

Table 2: Base shear

| MODEL 1 | | MODEL 2 | | MODEL 3 | |
|---|---|---|---|---|---|
| Fx | Fy | Fx | Fy | Fx | Fy |
| 3603.2 | 3612.7 | 4959.56 | 4408.09 | 4612.27 | 4136.17 |

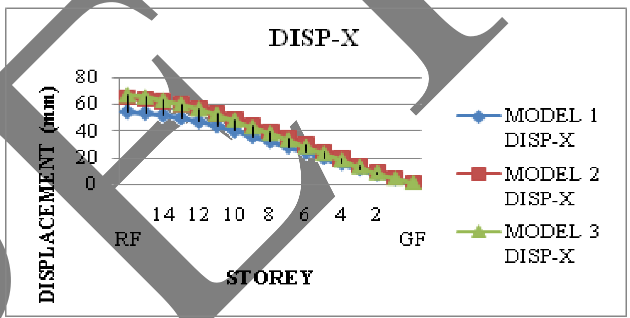



Graph 2: Model v/s Base shear

The Storey displacement in X-direction of Models (Linear static analysis) of models is tabulated in table 3 and graph of model v/s storey displacement is as shown in graph 3.

Table 3: Storey displacement in X-direction of Models (Linear static analysis)

| STORY | MODEL 1 DISP-X | MODEL 2 DISP-X | MODEL 3 DISP-X |
|---|---|---|---|
| RF | 54.19507 | 64.56399 | 67.35597 |
| 15 | 53.20627 | 63.601 | 65.65396 |
| 14 | 51.64134 | 61.9493 | 63.29944 |
| 13 | 49.46588 | 59.54315 | 60.35951 |
| 12 | 46.7363 | 56.43894 | 56.88597 |
| 11 | 43.52077 | 52.71848 | 52.86658 |
| 10 | 39.87491 | 48.4538 | 48.21096 |
| 9 | 35.84453 | 43.67317 | 43.09535 |
| 8 | 31.99713 | 39.09357 | 38.31236 |
| 7 | 28.03158 | 34.33579 | 33.41995 |
| 6 | 23.94743 | 29.39769 | 28.43592 |
| 5 | 19.78218 | 24.30186 | 23.39884 |
| 4 | 15.59072 | 19.13965 | 18.36855 |
| 3 | 11.45412 | 14.034 | 13.43743 |
| 2 | 7.501022 | 9.160235 | 8.756389 |
| 1 | 3.951328 | 4.802704 | 4.585579 |
| GF | 1.203389 | 1.455263 | 1.388285 |

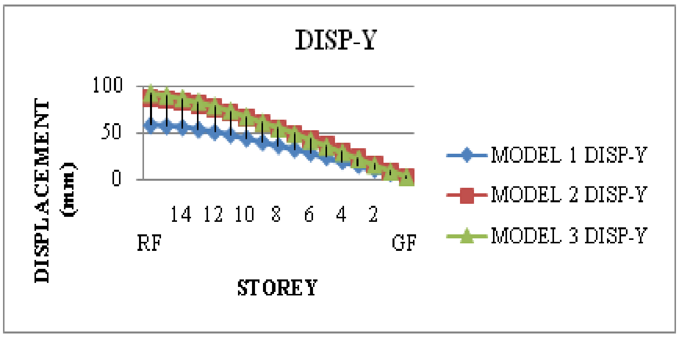



Graph 3: Storey v/s Displacement

The Storey displacement in Y-direction of Models (Linear static analysis) of models is tabulated in table 4 and graph of model v/s storey displacement is as shown in graph 4.

Table 4: Storey displacement in Y-direction of Models (Linear static analysis)

| STORY | MODEL 1 DISP-Y | MODEL 2 DISP-Y | MODEL 3 DISP-Y |
|---|---|---|---|
| RF | 58.61781 | 87.18903 | 91.35678 |
| 15 | 57.66702 | 86.08871 | 89.23102 |
| 14 | 56.07082 | 84.02141 | 86.20736 |
| 13 | 53.84127 | 80.96229 | 82.44241 |
| 12 | 51.05447 | 77.01954 | 78.02651 |
| 11 | 47.78766 | 72.31332 | 72.94607 |
| 10 | 44.11156 | 66.95616 | 66.99073 |
| 9 | 40.0976 | 61.0488 | 60.53099 |
| 8 | 36.2902 | 55.42598 | 54.52776 |
| 7 | 32.29223 | 49.49337 | 48.31896 |
| 6 | 28.13076 | 43.25476 | 41.93873 |
| 5 | 23.84728 | 36.67984 | 35.43155 |
| 4 | 19.47883 | 29.91762 | 28.84036 |
| 3 | 15.06011 | 23.0689 | 22.20907 |
| 2 | 10.63054 | 16.21473 | 15.5966 |
| 1 | 6.271914 | 9.504475 | 9.13672 |
| GF | 2.279935 | 3.426833 | 3.292923 |

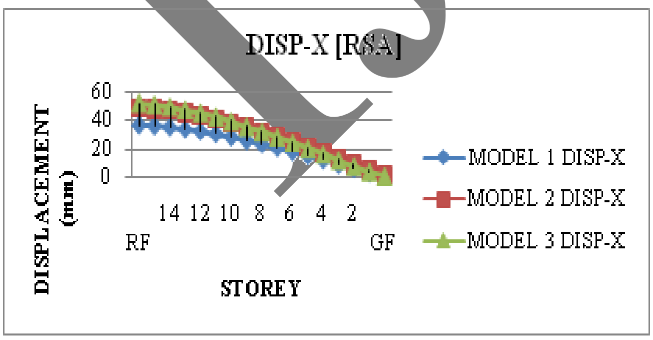



Graph 4: Storey v/s Displacement

The Storey displacement in X-direction of Models (Response spectrum analysis) of models is tabulated in table 5 and graph of model v/s storey displacement is as shown in graph 5.

Table 5: Storey displacement in X-direction of Models (Response spectrum analysis)

| STORY | MODEL 1 DISP-X | MODEL 2 DISP-X | MODEL 3 DISP-X |
|---|---|---|---|
| RF | 36.45179 | 48.26687 | 52.25426 |
| 15 | 35.87936 | 47.67066 | 51.11141 |
| 14 | 34.98041 | 46.64899 | 49.55946 |
| 13 | 33.73423 | 45.16265 | 47.64609 |
| 12 | 32.16918 | 43.23842 | 45.38269 |
| 11 | 30.31259 | 40.90465 | 42.70074 |
| 10 | 28.17323 | 38.17391 | 39.44137 |
| 9 | 25.72464 | 34.9995 | 35.72518 |
| 8 | 23.30124 | 31.84843 | 32.15561 |
| 7 | 20.74946 | 28.49881 | 28.44992 |
| 6 | 18.04016 | 24.89147 | 24.5928 |
| 5 | 15.17609 | 20.98171 | 20.58939 |
| 4 | 12.18006 | 16.84448 | 16.4649 |
| 3 | 9.105157 | 12.58943 | 12.2787 |
| 2 | 6.056933 | 8.374914 | 8.157594 |
| 1 | 3.233128 | 4.47411 | 4.354207 |
| GF | 0.995156 | 1.382066 | 1.344131 |

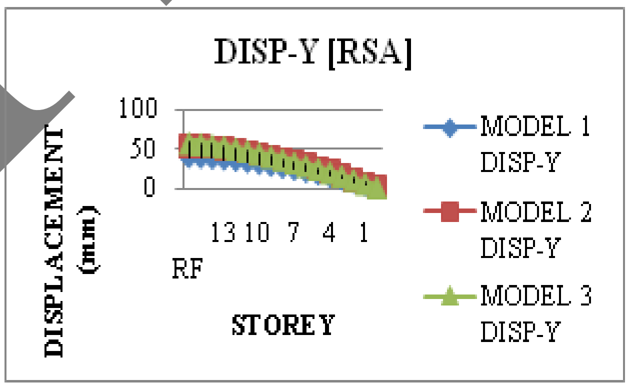



Graph 5: Storey v/s Displacement

The Storey displacement in Y-direction of Models (Response spectrum analysis) of models is tabulated in table 6 and graph of model v/s storey displacement is as shown in graph 6.

Table 6: Storey displacement in Y-direction of Models (Response spectrum analysis)

| STORY | MODEL 1 DISP-Y | MODEL 2 DISP-Y | MODEL 3 DISP-Y |
|---|---|---|---|
| RF | 40.07488 | 53.56794 | 57.85442 |
| 15 | 39.5371 | 53.01913 | 56.71389 |
| 14 | 38.64017 | 52.00448 | 55.12022 |
| 13 | 37.38501 | 50.50767 | 53.15582 |
| 12 | 35.80747 | 48.57065 | 50.84935 |
| 11 | 33.93728 | 46.2258 | 48.13753 |
| 10 | 31.79618 | 43.49689 | 44.79197 |
| 9 | 29.40249 | 40.40882 | 41.08048 |
| 8 | 27.06382 | 37.38441 | 37.55791 |
| 7 | 24.52499 | 34.08953 | 33.8176 |
| 6 | 21.78041 | 30.45695 | 29.85468 |
| 5 | 18.83881 | 26.3372 | 25.68328 |
| 4 | 15.70729 | 21.90264 | 21.31801 |
| 3 | 12.39177 | 17.24365 | 16.76385 |
| 2 | 8.909706 | 12.38927 | 12.03028 |
| 1 | 5.335778 | 7.422934 | 7.198911 |
| GF | 1.959594 | 2.733338 | 2.648098 |




Graph 6: Storey v/s Displacement

## CONCLUSION:

More mass means higher inertia force. Therefore, lighter buildings sustain the earthquake shaking better. The vertical acceleration during ground shaking either adds to or subtracts from the acceleration due to gravity. Since factors of safety are used in the design of structures to resist the gravity loads, usually most structures tend to be adequate against vertical shaking.ETABS is an integrated analysis, design and drafting of buildings systems tool. ETABS dynamic analysis capabilities include the calculation of vibration modes using Ritz or Eigen vectors, response-spectrum analysis and time history analysis for both linear and nonlinear behaviour. According to the results, it is concluded that the fundamental natural time period of the building increases with the increase in vertical mass irregularity. The base shear values (i.e. Fx an Fy) are considerably high in buildings having vertical mass irregularity and as the vertical mass shifts towards top, base shear decreases. Displacement values of buildings with vertical mass irregularity are more compared to the regular building.The displacements values are increasing as the irregular mass shifts towards top.

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