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Response of Multi-Storeyed Buildings Having Vertical Irregularities using ETABS

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Abstract: ***The objective of this research is to analyze the regular and vertical irregular buildings for understanding the response of vertically irregular buildings by using advanced software like ETABS. The analysis is carried out to understand the behaviour of the buildings by performing Non-Linear Dynamic analysis (Nonlinear Time-History Analysis) in software. The response of buildings is analyzed for three different irregularities, they are i) mass irregularity ii) stiffness irregularity iii) setback irregularity. The response of the vertically irregular buildings with regular building is done by considering the Base shear, Displacement and Story Drift of the buildings. The buildings which are irregular in plan will undergo to torsion effects easily because their centre of mass does not coincide with the centre of gravity, since the torsion will be developed in the building. When comes to the buildings which are irregular in elevation and located in seismic zones, the understanding of behaviour of such vertically irregular buildings will be difficult. It is a challenging task to the structural engineers to study the behaviour of vertically irregular buildings. This paper will provide the response of vertical irregular buildings so the engineers can design the buildings accordingly.***

Keywords: Joint displacement., Non-Linear Time History analysis, Story drift, Base shear, Vertical irregularity.

I. INTRODUCTION

The construction of structures involve in different types, depends on structural or architectural. At some instances the conditions of the site may not be suitable for construction as we desired and we modify the plan so that it can fit into the site conditions, so that the structure may or may not be regular. During an earthquake the behaviour of structure depends on several factors, stiffness, adequate lateral strength, ductility, simple and regular configurations. The regular geometry buildings with uniformly distributed mass and stiffness in plan as well as in elevation suffer much less damage compared to irregular configurations. Earthquake resistant design of RC buildings is an area of research since the earthquake engineering has started not only in India but in other developed countries also. The buildings damage due to some or other reason during earthquakes.

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The building configuration can be described as regular or irregular in term of size and shape of the building, arrangement of structural elements and mass. Regular building configuration is almost symmetrical in plan and elevation about the axis and it have uniform distribution of lateral force-resisting structure such that, it provides a continuous load path for both gravity and lateral loads. A building that is unsymmetrical and has discontinuity in geometry, mass, or load resisting element is called irregular. These irregularities may cause unconditional force flow and stress concentrations. Asymmetrical arrangements of mass and stiffness of elements may cause a large torsional force where the center of mass does not coincide with the center of rigidity.

A. Types of vertical irregularities

Some buildings will be regular in plan but when comes to elevation they may change. This change or variation along the elevation is known as vertical irregularity. The irregularities in buildings are as follows.

- Stiffness Irregularity
- Mass irregularity
- Geometry Irregularity

Tall buildings do not have equal size of column dimensions from base to top floor. The variation in the column dimension from base to top results in variation of stiffness along the height of building. This irregularity is known as stiffness irregularity. Some buildings may have additional super dead load at some particular floors, this result in mass irregularity along the height. Few buildings may construct b leaving some bays at a particular height, this result in setback irregularity along the height.

B. Non-Linear Time History Analysis

A full-time history will give the response of a structure over time during and after the application of a load. To find the full-time history of a structure's response, you must solve the structure's equation of motion. This analysis is carried out in two different cases, they are

Linear case: Always start from zero, and the corresponding time function also must start from zero.

Nonlinear case: May either starts from zero or may continue from previous case. When starting from zero, the time function is simply defined to start with a zero value. When analysis continues from a previous case, it is assumed that the time function also continues relative to its starting value. A long record may be broken into multiple sequential analyses which use a single function with arrival times. This prevents the need to create multiple modified functions.

II. METHODOLOGY

This present study involved in some steps in order to obtain the results. This study is about comparison of vertically irregular structure with regular structure. This comparison is observed by the consideration of Base shear, Displacement and Story Drift. Following are the works involved in this study,

- Creating a regular model with suitable number of bays and number of stories along suitable section properties. To this regular model the necessary loads has to be assigned. This loading should be same for all regular and vertically irregular models. The Fig. 1 shows the plan 3D view of regular model.
- The stiffness irregular model has to design. This stiffness irregular model is achieved by decreasing the column dimensions from floor to floor. But for every floor we should not decrease the dimensions of the column if so the continuity between the columns will decrease. For that the column dimensions need to be change for every few floors. Except the column dimensions the model is created like regular model i.e. loadings, sectional properties of beams and slabs.

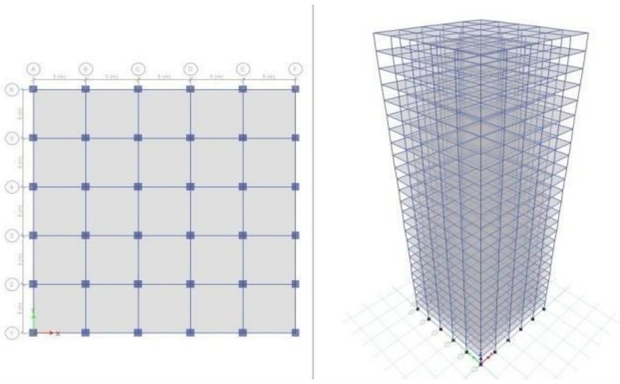

Fig.1. Plan and 3D view of regular model

- The mass irregular model is designed same as regular model. The mass irregularity is achieved by increasing the loading in particular floors, so that the floor is heavily loaded than other floors. In this model we need to apply the extra loading in floors that are not adjacent. Except this loading, the sectional properties are same as regular model
- The setback irregular model is different from all other models. This set back irregularity is achieved by reducing the bays as number of stories increases. The following figure shows the setback irregularity.
- After all modes is developed, same load case has to give for all the models. For this analysis the Time-History Analyses is used. The time history function is created before applying the load case to the models. The time history function consists of ground motion displacements.
- The ground acceleration in terms of Time- History function is applied is applied in X- Direction only, because the regular model behaves same in both directions. So that only in one direction is taken into account for analysis.
- For this time history function the models are analyzed. The analytical results are taken for the comparison of the vertically irregular models with regular model.
- The comparison for the regular and vertical irregular model is considered by following parameters.
  - Base shear of the building
  - Maximum Displacement of the building
  - Story Drift of the building
- The following are the models that are used to analyze and investigate the response

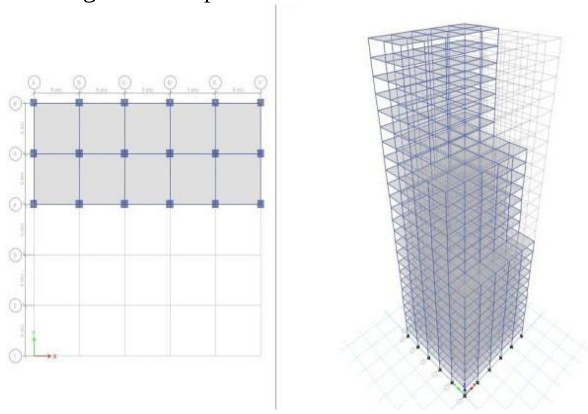

Fig.2. Plan and 3D view of setback irregular model

A. Model Cases

In this research, one model of regular building and three models of vertical irregular buildings are analyzed for studying building response.

- **Model-A**

This model is symmetrical building with no irregularity (Regular model). In this model the structural sections are same at each level of building.

- **Model-B**

This model is symmetrical building with vertical stiffness irregularity (Stiffness irregular model). This model is similar to the regular model except the dimensions of the column. In this model the column sections are varied in 3 different types. First 9 floors are built with one type of sections, the next 8 floors are built with second type of sections and the remaining floors are of third type of sections.

- **Model-C**

This model is symmetrical building with vertical mass irregularity (Mass irregular model). This model is also similar to the regular model except the loading at some floors are varied. In this model the loading is varied at 15th and 23rd floors.

- **Model-D**

This model is symmetrical building with setback irregularity in the direction of force (setback irregular model). This model is similar to the regular model except some of bays of building are restricted to certain floors, this result in height variation of building from bay to bay. First 9 levels are built with one type of sections, the next 8 levels are built with second type of sections and the remaining levels are of third type of sections.

B. Details of models

- **Model-A**

5x5 bay frame with 5M length. 3m floor height
750mmx750mm columns 330mmx450mm beams
120mm thickness of slab
Fe250 steel for stirrups

HYSD500 for tension reinforcement
M40 grade of concrete
E= 200,000 N/mm^2
Live load 3kN/m^2 on slabs
Super dead load 15 kN/m on beams

- **Model-B**

All the sectional properties and loads are same as Model-A except some column sizes at particular floors. In this model the following column are used the rest of all properties are same as Model-A.
750mmx750mm columns from Base to 9th floor
550mmx550mm columns from 10th floor to 17th floor
400mmx400mm columns from 18th floor to 25th floor

- **Model-C**

The properties for this model are same as Model-A. But the loads are varied in 15th and 23rd floor. The following additional loads are applied on those particular floors. Additional super dead load on 15th and 23rd floors is 18Kn/m

- **Model-D**

This model has all equal properties with regular model. But the bays are discontinued towards top. The Fig. 2 shows the model for setback irregularity.

C. Time history loading

The time history loading is applied from earthquake data functions. The real earthquake data is used. The Silchar-2009 earthquake data file loading is used in global-X direction with 5 points per line at a time interval 0.005 seconds.

III. RESULTS AND DISCUSSIONS

A. Results

The Regular and vertically irregular models are analyzed by using Silchar earthquake ground motion and the observations are presented as follows.

Floor (m)	Model-A	Model-B	Model-C	Model-D
75	513.0	550.0	452.2	307.2
72	1020.0	1059.4	897.9	609.6
69	1463.6	1479.1	1729.5	868.2
66	1830.9	1786.7	2042.3	1085.2
63	2114.2	1977.4	2273.7	1264.0
60	2312.8	2063.6	2424.5	1395.4
57	2433.0	2071.1	2597.9	1482.3
54	2508.9	2105.4	2731.5	1584.9
51	2641.4	2122.2	2797.9	1649.8
48	2707.6	2162.9	2799.6	1749.5
45	2711.2	2162.3	2804.4	1793.2
42	2704.1	2128.2	2776.3	1943.6
39	2697.5	2164.2	2783.3	2065.3
36	2651.5	2180.8	2828.3	2130.8
33	2714.6	2223.8	2929.4	2201.4
30	2730.3	2271.9	2985.8	2296.0
27	2725.3	2362.6	2978.2	2353.8
24	2721.6	2407.6	2909.8	2374.6
21	2662.5	2418.8	2791.8	2405.3
18	2566.0	2411.3	2694.4	2470.7
15	2631.8	2417.1	2797.6	2500.4
12	2803.8	2483.4	2977.4	2526.6
9	2928.5	2559.9	3108.2	2600.8
6	2999.7	2659.6	3183.1	2645.8
3	3022.9	2691.6	3207.5	2661.0
0	0	0	0	0

Table.1. Base Shear at each floor level for all Models

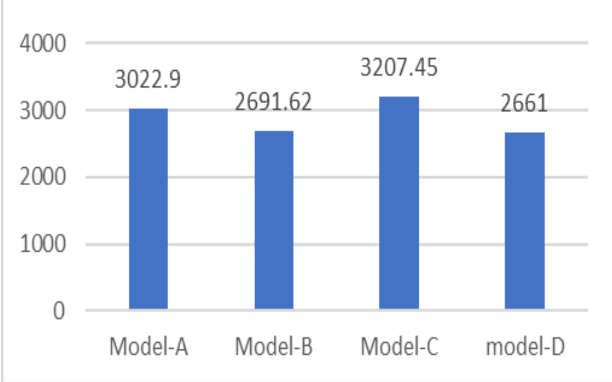

Fig.3. Maximum Base Shear results of all Models

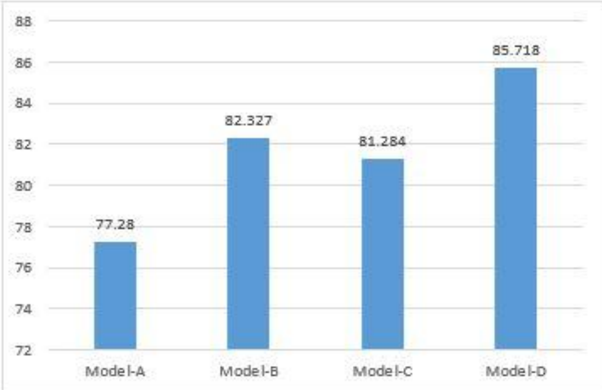

Fig.4. Maximum Joint Displacement of all Models

Floor (m)	Model-A	Model-B	Model-C	Model-D
75	77.3	82.3	81.3	85.7
72	76.2	81.0	80.1	84.5
69	74.9	78.9	78.6	83.0
66	73.3	76.1	76.9	81.0
63	71.3	72.8	74.8	78.6
60	69.0	69.0	72.4	75.8
57	66.3	65.3	69.7	72.6
54	63.4	61.7	66.7	69.1
51	60.1	58.3	63.5	65.5
48	56.7	54.5	60.2	61.8
45	53.2	51.6	56.6	57.8
42	49.5	48.6	52.7	54.1
39	45.7	45.3	48.8	50.3
36	41.7	41.8	44.9	46.3
33	37.7	38.1	41.0	42.4
30	33.9	34.3	37.2	38.3
27	30.3	30.3	33.3	34.1
24	26.7	26.2	29.3	29.7
21	23.0	22.4	25.2	25.3
18	19.3	18.6	21.1	21.0
15	15.4	14.7	16.8	16.7
12	11.5	10.9	12.5	12.4
9	7.7	7.2	8.3	8.3
6	4.1	3.9	4.5	4.5
3	1.3	1.2	1.4	1.4
0	0.0	0.0	0.0	0.0

Table.2. Joint Displacement at each floor level for all Models

Floor (m)	Model-A	Model-B	Model-C	Model-D
75	0.000604	0.000723	0.000606	0.000752
72	0.000768	0.001136	0.000790	0.000967
69	0.000957	0.001498	0.001024	0.001210
66	0.001134	0.001766	0.001218	0.001432
63	0.001281	0.001933	0.001359	0.001592
60	0.001392	0.002009	0.001456	0.001653
57	0.001466	0.002015	0.001563	0.001557
54	0.001507	0.002032	0.001635	0.001398
51	0.001576	0.002008	0.001671	0.001414
48	0.001614	0.001522	0.001671	0.001466
45	0.001621	0.001508	0.001672	0.001495
42	0.001602	0.001482	0.001666	0.001496
39	0.001603	0.001471	0.001657	0.001475
36	0.001584	0.001480	0.001681	0.001450
33	0.001588	0.001483	0.001701	0.001430
30	0.001594	0.001507	0.001725	0.001461
27	0.001576	0.001537	0.001717	0.001488
24	0.001555	0.001397	0.001679	0.001498
21	0.001523	0.001390	0.001615	0.001488
18	0.001466	0.001368	0.001545	0.001457
15	0.001438	0.001334	0.001537	0.001410
12	0.001444	0.001281	0.001535	0.001378
9	0.001362	0.001195	0.001447	0.001270
6	0.001103	0.000959	0.001171	0.001016
3	0.000503	0.000439	0.000534	0.000462
0	0	0	0	0

Table.3. Story Drift at each floor level for all Models

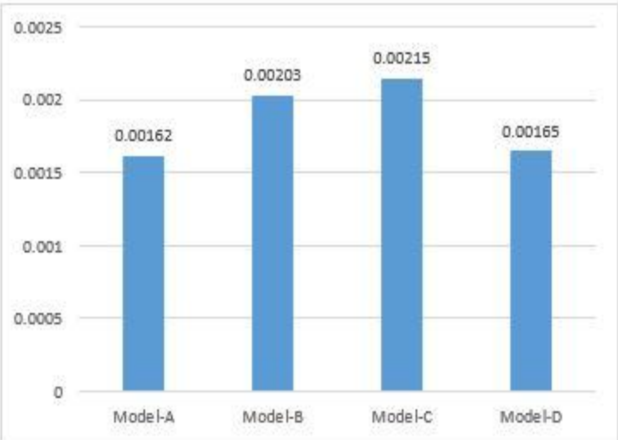

Fig.5. Maximum Story Drfit results of all Models

B. Discussions

- **Base shear**

From Fig. 3 building with mass irregularity has Base shear than all other models. The Base shear is found with 6% increment than the Regular model. For stiffness irregular model and setback irregular model have less base shear than Regular model.

- **Joint Displacement**

From Fig. 4 we can observe that Maximum Displacement is taking place in Stiffness irregular model. The Displacement is increased by 8% for stiffness irregular and 4% for Mass irregular model than Regular model. When comes to setback irregular model, the displacement is reduced by5%.

- **Storey Drifts**

From Fig. 5 we observe that the mass irregular and stiffness irregular models having more story drift about 33% and 25%. For the setback irregular model, the story drift is slightly i.e. 2% increased. The Story Drift curve of the mass irregular model is nearly same when compared to the regular model. There is no sudden change in Drift, but the Drift at each level of the model is less than regular model.

The Story Drift of the stiffness irregular model is varied when compared to the regular model. The story drift at 9th floor and 16th floor is suddenly varied. The stiffness is varied at 9th floor and 17th floor because of reduction in column dimensions so that the story drift is suddenly changed. From story drift results for setback irregular model we can conclude that there is a considerable story drift in building in Y-Direction also even we apply ground acceleration in only X-Direction.

IV. CONCLUSION

The observations and conclusions are as follows:

From observed results of the different models, this paper conclude that the base shear will vary irregularly if the loading varies on the building from floor to floor, the stiffness of building varies from base to roof and the ratio of span to roof lengths varies.

The joint displacement of the building is varied from base to roof. As the weight of building increases, the stiffness of the building varies from base to roof and the ratio of span to roof lengths varies the joint displacements increased. As far as possible maintain the stiffness of building from base to roof by keeping an eye on base shear.

The story drift results in the building conclude that the sudden change in geometry of building results in the sudden change in Story Drift. More self-weight of the building results in decrease in the story drift. The geometry setback along vertical direction leads to increase in story drift. The results are saying that it is better to maintain the regular plan from base to roof without any setbacks.

V. SCOPE FOR FUTURE STUDY

- Only 25 stories buildings are considered in this study; this provides a further scope to study by considering different number of stories and compare their response.
- This analysis is done for only one earthquake ground motion data, this provides in further scope to study by considering different earthquake ground motion data.
- This study focused in comparing the irregular model with regular model, since this provide for further study in comparing the mass irregular model with extra loading at some floors by mass irregular model with extra loading at different floors.

REFERENCES

1. Akhil R and Aswathy S Kumar, (2017), "Seismic Analysis of Regular and Irregular Buildings with Vertical Irregularity using Staad.Pro", International Research Journal of Engineering and Technology (IRJET), e-ISSN: 2395 -0056 Volume: 04, Issue: 06, June -2017.
2. Amardeep More, Bhavana Bilgoji and Shrishail Sambanni, (2016), "Study of Torsion in Building with Horizontal and Vertical Irregularities", International Journal for Technological Research in Engineering, Volume: 3, Issue: 10, June-2016.

3. Ravi Kiran and Sridhar.R, (2016), "Comparative Study of Regular and Vertically Irregular Building Under Seismic Loading", International Journal of Research in Engineering and Technology, Volume: 05, Issue: 09, Sep-2016.
4. J Shaik Sameer, (2016), "Seismic Response of Vertically Irregular RC Frame with Mass Irregularity", International Journal of Civil Engineering and Technology (IJCIET) Volume: 7, Issue: 5, September-October 2016, pp. 257–264.
5. Anilkumar S Katageri and Sharanabasava G, (2016), "Seismic Performance Study of R.C. Buildings having Vertical Geometric Irregularity using Pushover Analysis", IJSRD - International Journal for Scientific Research & Development, Volume: 3, Issue: 11, 2016.
6. Nonika. N and Gargi Danda De, (2015), "seismic analysis of vertical irregular multistoried building", International Journal of Research in Engineering and Technology eISSN: 2319-1163, pISSN: 2321-7308, Volume: 04 Issue: 09, September-2015.
7. Rajalakshmi K R and Harinarayanan S, (2015), "Study of Torsion Effects on Building Structures having Mass and Stiffness Irregularities", International Journal of Engineering Research & Technology (IJERT) ISSN: 2278, Volume: 4 Issue: 06, June-2015.
8. Dr.Mohd.Hamraj and Mohammed Moiz Khan, (2015), "Seismic Performance Evaluation of RC Buildings with Vertical Irregularities Subjected to Biaxial Excitation",Post Graduate Student, Civil Engi neering Department, Muffakham Jah College of Engineering and Technology, International Journal of Science, Engineering and Technology, Volume: 3 Issue: 4, 2015.
9. Ashvin G. Soni, Prof. D. G. Agrawal and Dr. A. M. Pande, (2015), "Effect of Irregularities in Buildings and their Consequences", International Journal of Modern Trends in Engineering and Research (IJMTER), Volume: 02, Issue: 04, April – 2015.
10. S Monish and S Karuna, (2015), "Effect of Vertical Irregularity in RC Framed Buildings in Severe Seismic Zone", International Journal of Emerging Technology and Advanced Engineering, Volume: 5, Issue: 6, June 2015.
11. Sri. M.Pavan Kumar and Sateesh Konni, (2015), "Effect of Vertical Irregularities of RC Framed Structures by Using Non-Linear Static Analysis" International Journal of Engineering Research, Volume No: 4, Issue No:11, pp : 631-634, Nov-2015.
12. Mr. Sagar B.Patil1 and Prof. Gururaj B.Katti, (2015), "Study of Behavior of Plan & Vertical Irregularity by Seismic Analysis", IJSRD - International Journal for Scientific Research & Development, Volume: 3, Issue: 04, 2015.
13. Himanshu Bansal and Gagandeep, (2014), "Seismic Analysis and Design of Vertically Irregular RC Building Frames", International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064 Impact Factor (2012): 3.358, Volume 3 Issue 8, August 2014.
14. Shaikh Abdul Aijaj, Abdul Rahman and Ansari Ubaidurrahman Salik, (2013), "Seismic analysis of vertically irregular buildings", Research Article, Department of Civil Engineering, SND College of Engineering and Research Centre, Current Science, Volume: 111, No. 10, Nov-2013.
15. S. Varadharajan, V.K. Sehgal and B.Saini, (2012), "Review of different Structural irregularities in buildings", Journal of Structural Engineering, Volume: 39, No. 5, Dec-2012 - January 2013, pp. 393-418.

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