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Study on Torsional Effects of Irregular Buildings Under Seismic Loads

Shaik Muneer Hussain
Research Scholar, Department of Civil Engineering,
REVA University, Bengaluru – 560064, Karnataka, India.

Dr. Sunil Kumar Tengli
Professor, Department of Civil Engineering,
REVA University, Bengaluru – 560064, Karnataka, India.

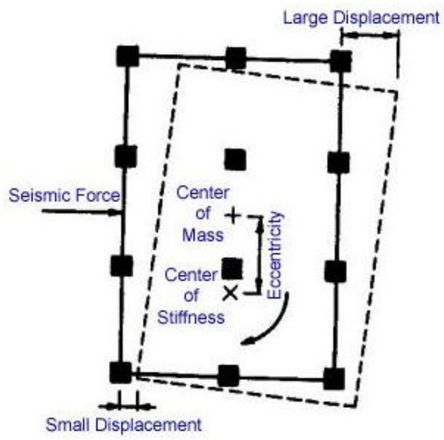
Abstract
It is very essential to identify the behavior and damages of buildings, which initiate at locations of the structural weak planes present in the building systems, due to various irregularities. The contribution of lateral load resisting system, number of stories, type and degree of asymmetry has to be properly assessed and evaluated in order to avoid damages and collapse of the structure. The objective of this work is aimed at understanding the torsional behavior of asymmetric buildings by modeling and analyzing a 14 storey buildings using three dimensional dynamic analysis (Response Spectrum Method) procedure with ETABS as per the IS Code 1893:2002 (part 1). For this study a regular building model and irregular building models have been modeled and analyzed. All the models / buildings are analyzed and compared for the outcomes such as maximum storey drifts, storey displacements, time periods and modes of frequencies and the conclusions are presented at the end of the paper.

Keywords: Dynamic analysis, Etabs, Frequencies, Lateral loads, Storey drift, Maximum storey displacement.

Introduction

The earthquakes are the most unpredictable and devastating among the natural disasters and in recent years, a trend of high rise buildings with complex planning and irregular vertical elevations are trending in a big way and challenging the structural engineers to design these irregular structures to cater the seismic loads, especially for the effects of torsion. However, it is a difficult task to evaluate the seismic behaviour of irregular buildings. Torsion in buildings during earthquake is caused due to various reasons and the most common is unsymmetrical distribution of mass and stiffness along the height of building. Recent codes have given provision to counter these torsional effects by introducing accidental eccentricity which has to be considered at the time of analysis and design. A special care and attention must be taken, so that, torsional effects do not avert the ductile behaviour of the structure. It is well known that the larger the eccentricity between the center of mass and center of stiffness, the larger will be the torsional effects, which leads to larger displacements and drifts in the buildings. Another important aspect in the configuration of building is the inelastic behaviour of the asymmetric structures is the considerations of the degree of control over inelastic twist and our main design aim will be to restrict the inelastic twist.

The main objective of the study is to study the effects and behavioral patterns of irregular multi-storied buildings against different forces acting on it during the earthquakes. A two dimensional analysis can allow only for an approximate consideration of the stiffness, where as a three dimensional analysis will give total interaction and response of the entire structure. This three dimensional analysis can be carried out by using “Etabs”.



As per IS code 1893:2002, the irregularities are classified in two types:

1. Plan Irregularities
    - Torsion Irregularity, Re-entrant Corners, Diaphragm Discontinuity, Out-of-Plane Offsets, Non Parallel Systems
2. Vertical Irregularities
    - Stiffness Irregularity – Soft Storey & Extreme Soft Storey, Mass Irregularity, Vertical Geo-metric Irregularity, In-plane Discontinuity.

Literature Review

Salunkhe and Kanase (2017) investigated that response of mass irregular structure need to be studied for the earthquake scenario. In this paper researcher deal with RCC framed structure in both regular and mass irregular manner with different analysis methods.

Oman Sayyed (2017) focused his study on the effect of infill and mass irregularity on different floor in RC buildings. The results were concluded that the brick infill enhances the seismic performance of the RC buildings and poor seismic responses were shown by the mass irregular building, therefore it should be avoided in the seismic vulnerable regions.

Sagar et al. (2015) analysed the performance on various type of irregularity Considered i.e. (a) Horizontal Irregularity-plan irregularity (b) Vertical Irregularity -Mass Irregularity. To achieve objective of the project Time history Analysis & Response spectrum analysis method were carried out.

Ramesh Konakalla (2014) analysed four different 20 story building for effect of vertical irregularity under Dynamic Loads Using Linear Static Analysis. Response of all cases is compared and concluded that in regular structure there is no torsional effect in the frame because of symmetry. The response for vertically irregular buildings is different for the columns which are located in the plane perpendicular to the action of force. This is due to the torsional rotation in the structure.

Bansal, and Gagandeep (2014) studied ductility based design is carried considering vertical irregular building and methods used are RSA and THA. Three types of irregularities namely mass irregularity, stiffness irregularity and vertical geometry irregularity were considered.

Himanshu Bansal (2014) analysed vertical irregular building with Response spectrum analysis and Time history Analysis. Irregularities considered are mass irregularity, stiffness irregularity and vertical geometry irregularity. The storey shear force was found maximum for the first storey and it decreases to minimum in the top storey in all cases.

S.Varadharajan et al. (2013) reviewed existing works regarding plan irregularities and justified the preference of multistory building models over single storey building models.

Aijaj and Rahman (2013) tried to analyse the proportional distribution of lateral forces involved in earthquake for individual storey due to changes in stiffness of vertically irregular structure.

Poncet, L. And Tremblay (2004) proposed the impact and effect of mass irregularity considering case of an eight-storey concentrically braced steel frame structure with different setback configurations. Methods used in present paper are equivalent static load method and the response spectrum analysis method.

Devesh P. Soni (2006) considered several vertical irregular buildings for analysis. Various criteria's and codes have been discussed and reviewed in this paper. Vertical irregular structure performance and response is reviewed and presented. The studies suggested that for combined stiffness and strength irregularity large seismic demands are found.

Objective of the Study

- To study the behavioural pattern of structures and their torsional behaviour during earthquakes having irregularities in plan.
- To study the parameters of storey shear, storey displacements, Maximum storey drift of all models during earthquake.
- To study the frequencies and periods in different modes.

Modeling and Analysis of Building

In this paper, for analysis purpose, regular and irregular building models with plan irregularity, with certain percentage of irregularities have been used with constant heights of G+14 Stories. The buildings are modeled using finite element software ETABS and dynamic analysis (RSA) is performed.

Building Description:

The building is a RC moment resisting frames. The plans of the buildings are regular shape (25m x 25m) and "L" shaped irregular with certain percentage of plan irregularities are considered for the analysis. The properties and building configurations in the present study are summarized below:

Parameter	Type / Value
Structure Type	RCC Building
Type of Structure	Regular & Irregular
Size of the Building	25m x 25m
Number of Stories	14
Floor to Floor Height	3m
Bay width in both directions	6m
Slab Thickness Grade of Concrete	150mm M30
Size of Columns Grade of Concrete	600mm x 600mm M30
Size of Beams Grade of Concrete	300mm x 600mm M30
Brick Wall Thickness	230mm
Live Load	3 Kn/m^2
Seismic Zone	V (Z=0.36)
Importance Factor	1.0
Soil Condition	II (Medium)
Response Reduction Factor	5 (SMRF)

Building Models:
The models used are as follows:

Model 1: Regular Model

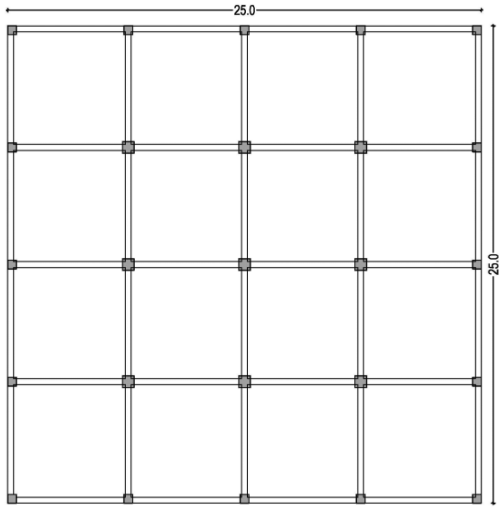


Figure 1: Regular Plan

Model 2: "L" Shaped Model with Less Irregularity

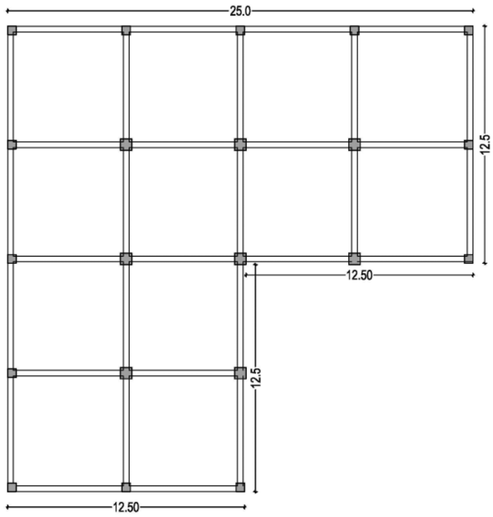
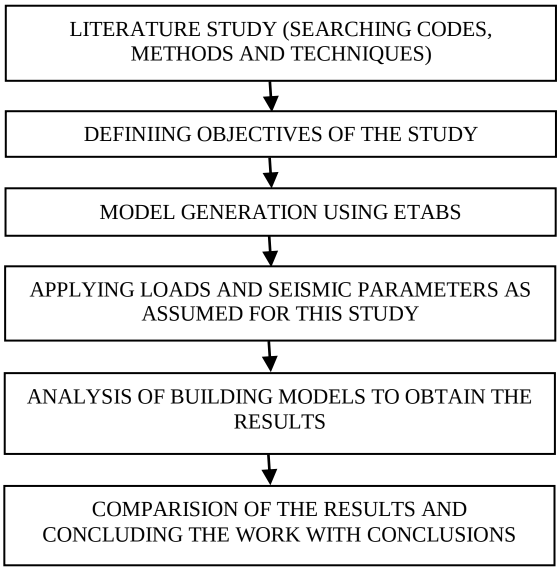


Figure 2: Irregular ("L" Shaped) Plan

Analysis Method:
Seismic analysis methods are generally classified as two types viz., static analysis and dynamic analysis. In this paper the method of analysis adopted is dynamic analysis i.e., Response Spectrum Method.
The response spectrum method plays an important role in analysis and design of multistorey buildings for seismic loads. The maximum response of the building is estimated directly from the elastic and inelastic design spectrums. The building codes are characterized for earthquake motions are based on simplification of the response spectrum method, so this method is extremely significant in the analysis and design procedures. The load combinations will be used for analysis of these models will be according to IS code 1893:2002.

Methodology



Analysis and Results
In this study, the results were presented in tabular form and graphs were also presented. The results of time periods and frequencies, maximum storey drifts, maximum storey displacements are presented for all the models, and simultaneously the results of regular building is compared with irregular building and the performance of these models / buildings were observed for seismic loads.

TIME PERIODS & FREQUENCIES FOR DIFFERENT MODES OF VIBRATION

Table 1: Time Periods for the Modes of Vibration

Mode No.	Model 1	Model 2
1	2.489	2.461
2	2.489	2.459
3	2.181	2.199
4	0.79	0.779
5	0.79	0.779
6	0.699	0.703
7	0.449	0.441
8	0.449	0.441
9	0.402	0.401
10	0.304	0.297
11	0.304	0.297
12	0.272	0.271
13	0.222	0.217
14	0.222	0.217
15	0.2	0.198
16	0.171	0.166

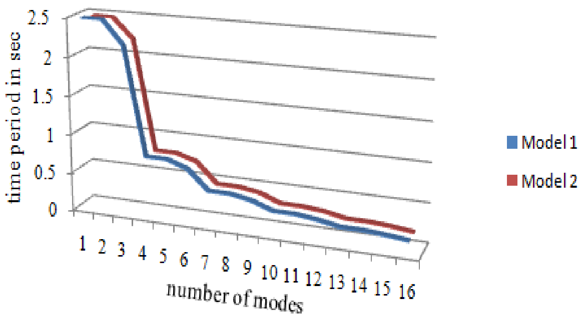


Figure 3: Modes vs. Time Period

The Fig.3 is a graph between the modes and the time period, which shows the variation of models for different periods in different number of modes. It is observed here that the time period is decreasing with the increase in number of modes.

Table 2: Frequencies for the Modes of Vibration

Mode No.	Model 1	Model 2
1	0.402	0.406
2	0.402	0.407
3	0.458	0.455
4	1.266	1.283
5	1.266	1.284
6	1.431	1.423
7	2.226	2.267
8	2.226	2.269
9	2.489	2.491
10	3.291	3.362
11	3.291	3.363
12	3.67	3.687
13	4.501	4.611
14	4.501	4.611
15	5.005	5.048
16	5.863	6.019

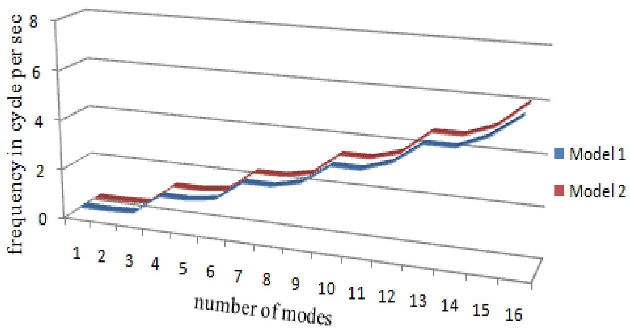


Figure 4: Modes vs. Frequency

The Figure 4 is a graph between the modes and the frequencies; it has been observed that, the frequency increases as the mode number increases. For the irregular structure (Model 2) the frequency is greater than the regular structure (Model 1).

MAXIMUM STOREY DRIFTS AND STOREY DISPLACEMENTS FOR NO. OF STORIES

Table 3: Max. Storey Drifts

No. of Stories	Model 1	Model 2
14	0.000538	0.000573
13	0.000848	0.000879
12	0.001161	0.001190
11	0.001434	0.001465
10	0.001661	0.001694
9	0.001846	0.001879
8	0.001990	0.002024
7	0.002098	0.002132
6	0.002175	0.002206
5	0.002220	0.002247
4	0.002222	0.002242
3	0.002124	0.002127
2	0.001685	0.001659
1	0.000605	0.000586

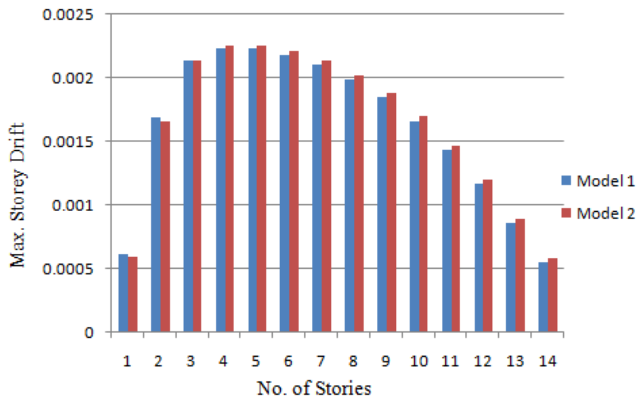


Figure 5: Max. Storey Drift vs. No. of Stories

The Figure 5 is a graph between the max. storey drift and the no. of stories; it has been observed that, the storey drifts values are higher for irregular structure (Model 2) as compared to the regular structure (Model 1).

Table 4: Storey Displacements

No. of Stories	Model 1	Model 2
14	66.9	67.8
13	65.2	66.1
12	62.7	63.4
11	59.2	59.9
10	54.9	55.5
9	49.9	50.4
8	44.4	44.8
7	38.4	38.7

6	32.1	32.3
5	25.6	25.7
4	18.9	18.9
3	12.3	12.2
2	5.9	5.8
1	0.9	0.9

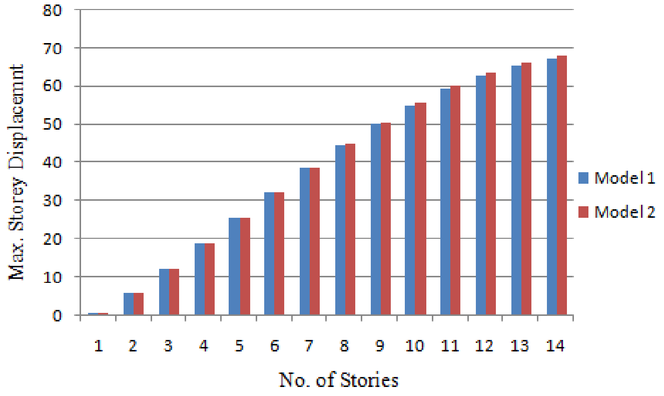


Figure 6: Max. Storey Displacement vs. No. of Stories

The Fig.6 is a graph between the maximum storey displacement and the no. of stories; it has been observed that, the storey displacements values are higher for irregular structure (Model 2) as compared to the regular structure (Model 1).

Table 5: Storey Shear in Kns

Storey	Model 1	Model 2
14	541.96	426.20
13	1141.93	899.49
12	1653.38	1302.85
11	2083.60	1642.03
10	2439.86	1922.81
9	2729.44	2150.91
8	2959.63	2332.09
7	3137.67	2472.10
6	3270-80	2576.63
5	3366.17	2651.35
4	3430.79	2701.79
3	3471.32	2733.23
2	3493.53	2750.29
1	3495.53	2751.87

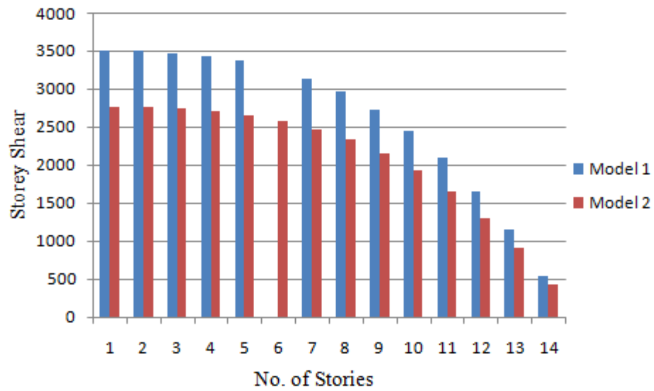


Figure 7: Storey Shear vs. No. of Stories

The Figure7 is a graph between the storey shears and the no. of stories.

Conclusions

The results obtained for the buildings carried out through dynamic analysis (RSA) method will be near to realistic and the responses of the structure will be very close to actual. In this study, the models with regularity and irregularity have been studied and few conclusions were drawn from the results obtained:

- The plan irregularities in structures have significant impact on the seismic response of the structure, especially in terms of displacement and base shear.
- The results show that there is an increase in shear forces in columns especially in irregular structure due to torsion.
- Buildings with irregular plan configurations causes severe damage than the regular building during earthquake in high seismic zones are caused due to increase in the drifts and displacements.
- Special moment resisting frame is more suitable in severe seismic zones than ordinary moment resisting frame.

Since torsion is the most critical factor leading to major damage or complete collapse of buildings therefore, it is very essential that irregular buildings should be carefully analysed for torsion and the designer should try avoid excess irregularities especially in the multi storied buildings.

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References

[1] Salunkhe, U., and Kanase, J.S., (2017). "Seismic Demand of Framed Structure with Mass Irregularity

International Journal of Science." Engineering and Technology Research (IJSETR) 6(1)

[2] Prabesh Sharma, D.R. Rajendra .S, Vanisree C.N. (2016). "Scrutinizing the Structural Response of Regular and Irregular Structure (With and Without Shear Wall) Subjected to Seismic and Wind Loading." International Journal on Recent and Innovation Trends in Computing and Communication, 4(3), 353 – 359.

[3] Ali Demir, Duygu Donmez Demir, Recep Tugrul Erdem & Muhiddin Bagc, "Torsional Irregularity Effects of Local Site Classes in Multiple Storey Structures", IJRRAS, August 2010.

[4] G. V. Sai Himaja., Ashwini. L. K., N. Jayaramappa., (2015). "Comparative Study on Non-Linear Analysis of Infilled Frames for Vertically Irregular Buildings." International Journal of Engineering Science Invention. 4(6) 42.

[5] Raul Gonzalez Herrera and Consuelo Gomez Soberon, "Influence of Plan Irregularity of Buildings", The 14th World Conference on Earthquake Engineering, October 12-17, 2008, Beijing, China.

[6] Au E.V., MacRae G.A, Pettinga D., Deam B and Sadashiva V., (2009), "Torsionally Irregular Single Storey Structure Seismic Response", Submitted to the Bulletin of the NZ Society of Earthquake Engineering.

[7] Amin Alavi and Prof.P.Srinivasa Rao (2013),"Influence of Torsional Irregularities of RC Buildings in High Seismic Zone", Australian Journal of Basic and Applied Sciences.

[8] K. Güler, M. G. Güler, B. Taskin and M. Altan, "Performance Evaluation of a Vertically Irregular RC Building", 14th World Conference on Earthquake Engineering, (2008), Beijing, China.

[9] Aziminejad A., Moghadam A.S. and Tso W.K. (2008), "A New Methodology for Designing Multi-storey Asymmetric Buildings", The 14th World Conference on Earthquake Engineering, Oct. 14-17, Beijing, China.

[10] Georgoussis G.K. (2010), "Modal Rigidity Center: It's Use for Assessing Elastic Torsion in Asymmetric Buildings", Earthquakes and Structures, An International Journal, 1(2), 163-175.

[11] De la Llera and Chopra A K, "Inelastic behaviour of asymmetric multistorey buildings", Journal of Structural Engineering, ASCE 1996; 122 (6):597–606.

[12] Sayyed O., Kushwah S.S., Rawat A., (2017). "Effect of Infill and Mass Irregularity on RC Building under Seismic Loading." International Research Journal of Engineering and Technology (IRJET) 04 (2)

[13] RakshithGowda. K. R, Bhavani Shankar (2014)."Seismic Analysis Comparison of Regular And Vertically irregular RC Building with soft storey at different level".(IJETE) International journal of emerging Technologies and Engineering. Volume 1 issue 6.

[14] HimanshuGaur, R.K. Goliya, Krishna Murari, Dr.A.K.Mullikh. "A Parametric Study of Multi-storey R\C Buildings with Horizontal Irregularity''. IJRET Volume: 03. Issue: 04|April 2014.