JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Effect of Plan Geometry and Irregularities on Seismic Excitation for Multistorey Buildings - A review

[1]Pradeep Pandya, [2]Imran Hussain
[1]Assistant Professor (G.F.), [2]Assistant Professor (G.F.)
[1]Department of Civil Engineering,
[1]College of Technology and Engineering, MPUAT, Udaipur, Rajasthan-313001

Abstract: The current scenario of high-rise buildings have different shape of configuration along the plan and height. Such buildings are prone to lateral loads such as earthquake or wind. These buildings under the effect of earthquake show displacements and torsional behaviour. The modes of vibrations of building also depends on the torsional, stiffness, mass and drift of such buildings. Storey drifts corresponds to the natural time period of the building and the acceleration came from the earthquake. The buildings should be restricted to the provision given by the analysis and design codes of the country. To minimise the effect of earthquake many methods have been adopted. Shape of the building is also one of the such approach. This paper is a review on the effect of shape on earthquake by various researchers and engineers. The paper consists of short review on the test computer model analysis and the software results by the different models.

***IndexTerms* -** plan, vibration, earthquake, displacement, torsional behaviour, stiffness, mass, storey drift, time period, software

I. INTRODUCTION

Earthquakes have occurred for millions of years and will continue in the future as they have in the past. Some will occur in remote, undeveloped areas where damage will be negligible. Others will occur near densely populated urban areas and subject their inhabitants and the infrastructure they depend on to strong shaking. It is impossible to prevent earthquakes from occurring, but it is possible to mitigate the effects of strong earthquake shaking: to reduce loss of life, injuries, and damage. Since they are unpredictable, the only way left to prevent structures from earthquake is to design earthquakes resistant buildings. In accordance to prevent the earthquake, shape of the building is also a great option. The plan of highrise buildings are often regular in shape, most of the buildings have irregular shape. This is the most constitutive point to look about, there have been several attempts done by the researchers globally. The outgrowth of such attempts are motivating many countries in the direction of designing highrise buildings. The structure with regular configuration, uniformly distributed mass and stiffness in plan and in elevation are considered to endure substantially lesser harm than structure with irregular configuration. The structural irregularity is broadly seen in buildings because of architectural and service necessity in the design process, mistakes and adjustment during the development stage and changes in building use all through its service life. These design in the structures leads to the non-uniform distributions in their masses, stiffness and strength due to which the structure are prone to damage during earthquake. The fundamental objective of earthquake resistance design is to avoid building collapse during earthquake, limiting the danger of death or damage to individuals in or around those structures. Since Earthquake forces are irregular in nature and unpredictable, the static and dynamic investigation of the structures have turned into the essential worry of structural Engineer. Load carrying capacity, ductility, stiffness, damping and mass are the principle parameters of the seismic investigation. The tendency of resisting earthquake force for various shaped building are different with respect to their torsional and mass irregularities, re-entrant corners, structural systems, diaphragm and acceleration.

II. Literature Review

a) Effect of plan geometry

Raul Gonzalez et al. (2008) have selected the basic geometric figures and some of its eccentricity variations from the plans which were extracted through the google earth. Shown irregular plans in figure 1.1, present rectangular, square, and sections L-1, T, U and L-2, The elastic models were made in program SAP2000 v10.0.1 Advanced and with ten accelerograms signal registered in the Mexican Pacific Coast.

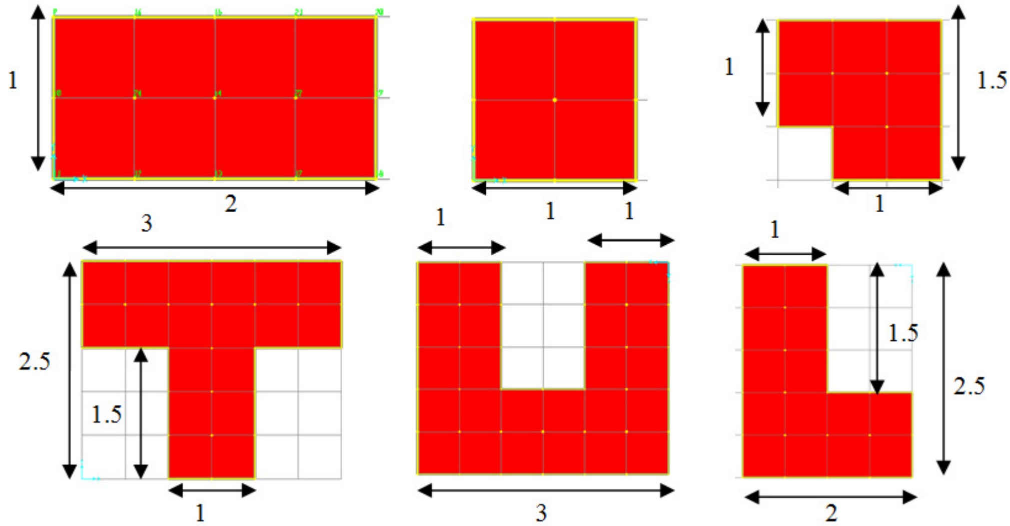
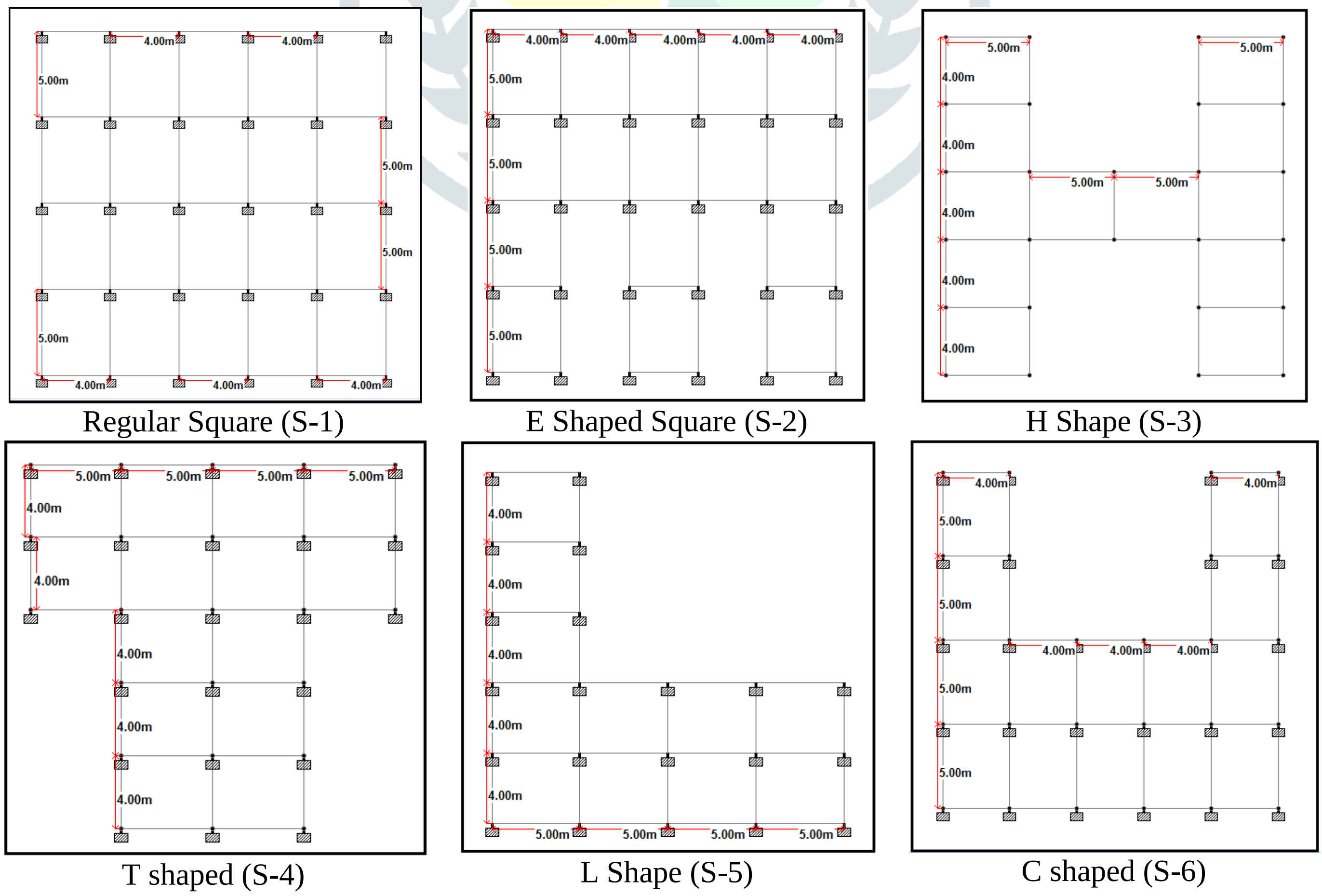
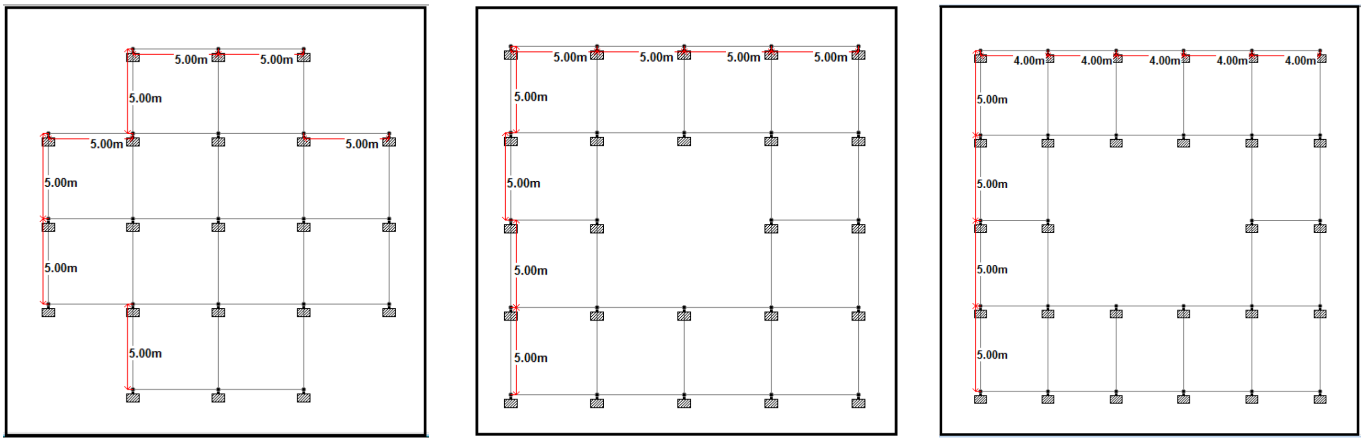


Figure 1.1 : Relation of geometric forms selected in analysis and its general dimensions standardizing in reference to the square plan. The forms were selected from the aerial photography. In the paper call the forms like: rectangular, square, L-1, T, U and L-2.

By considering asymmetric section T, U and L in both axes, they analyze that the demand is smaller in all the length of the longest arm with respect to the demand in the projection of the short side. In the connection of the main body with the projection of smaller dimension, a concentration is observed of high stress level, although in the majority of the cases the inertial mass of the projection of the short side is minor who stops the connection of the long side. they have also given that the linear analyses provide important information for torsion behavior of weak structures like the studied. Despite we can understand that elastic analysis underestimates the interstory drifts when the superstructure enters in nonlinear performance, and the behavior is adopted torsion mode.

Milind V. Mohod (2015) has considered 9 models with plan shape irregularities and the area of the plan is same but the geometry is different. Each model is of 12 storeys. The elevation also same for the all models. Shape of the geometries are shown in figure1.3.





Plus (+) Shape (S-7) Square with Core (S-8) Rectangle with Core (S-9)

Figure 1.2: Plan geometry of the models used for analysis

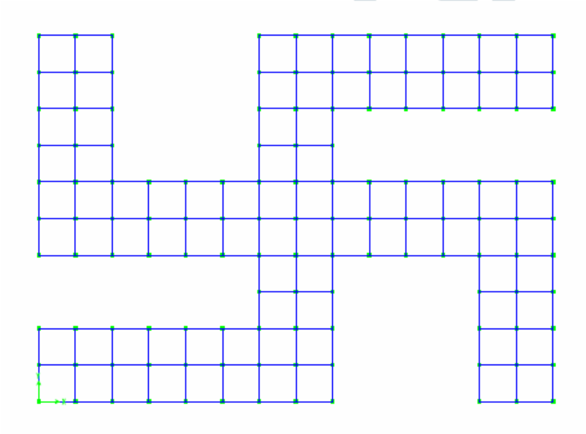
Considering the effect of lateral displacement on different shapes of the buildings the buildings which are having irregular plan have more displacements in both direction compare to other plans i.e. S-1,S8, and S-9. With respect to the drift demand of the structure is consider the L-shaped and C-shaped model showed larger drift than the other models. So the drift demand is more bore L and C shaped buildings as per IS 1893. Simple geometry give good response and attracts less force in earthquake.

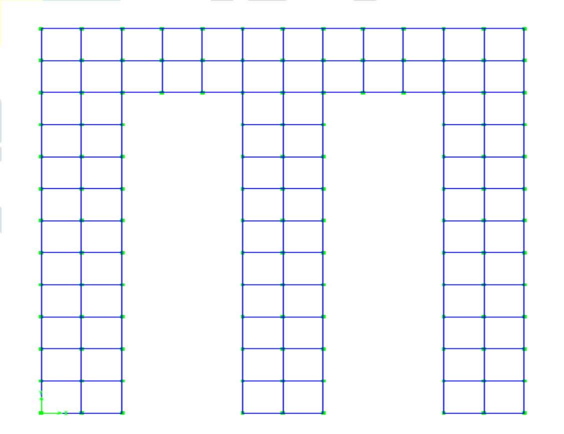
Jereen Ann Thomas et al. (2016) investigate the seismic performance, considering various geometries with reentrant corners. To attain this a comparative study of structure with rigid and semi-rigid diaphragm is considered. In the study four models with E, H, plus and swastika shape plan configuration is considered. The plan configurations are shown in Figure 1.2.

Table 1.1: Properties of model

Specifications of the models	Section Details
Plan area =2100 mm^2 Spacing along x –axis = 5m Spacing along y –axis = 5m Storey height = 4m Total no of storeys =12	Beam size = 300x500 mm Column size = 500x500 mm Slab thickness = 120 mm

The modelling is done using ETABS v9 software with beams and slabs of M25 grade and column of M30 grade. The various loads considered are self-weight , wall load, live load of 3 kN/m, roof live load of 1.5 kN/m^2, floor finish of 1 kN/m^2 and earthquake load as per IS 1893(part 1):2002 is calculated. The zone factor taken is 0.16 with hard rock condition and response reduction factor 5. Fe 415 steel is used. The analysis results is shown below in graph below.





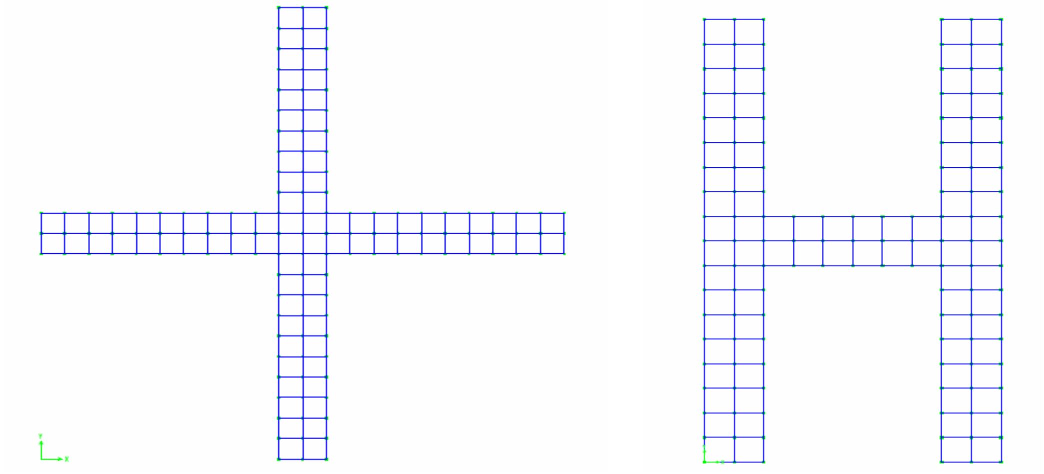


Figure 1.3: Plan configurations

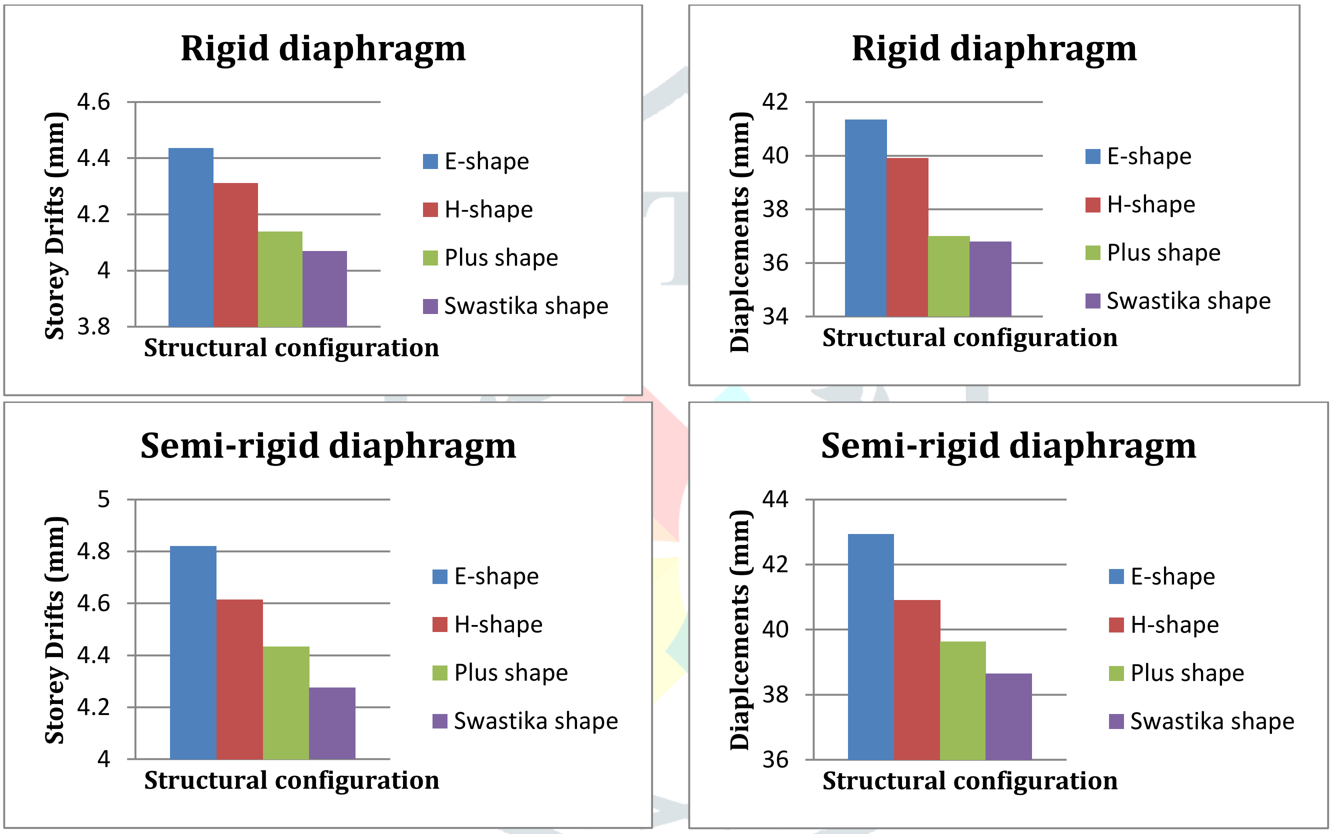


Figure 1.4: Storey drifts and displacements graphs of structural configuration

The displacement values are found out from the static analysis for the four models considering medium soil condition. It is seen that there is difference in the response to lateral load based on the plan configuration. The rigid and semi-rigid diaphragm floor slab significantly affects the displacement. it is observed that variation in plan configuration of the structure affects the displacement and storey drift. The swastika shape configuration showed good performance compared to the other models. The maximum storey drift is obtained for the E-shape structure since it is symmetrical about one axis and length of its leg along the x-axis is smaller compared to that along the z-axis .The swastika shape structure has shown to perform the best due to its structural symmetry.

Ahmed et al. (2016) have studied the effect of seismic response of L shaped buildings. Equivalent static and response spectrum methods were performed using ETABS software. They observed that the response of L shaped building is higher than that of the regular frame due to torsion.

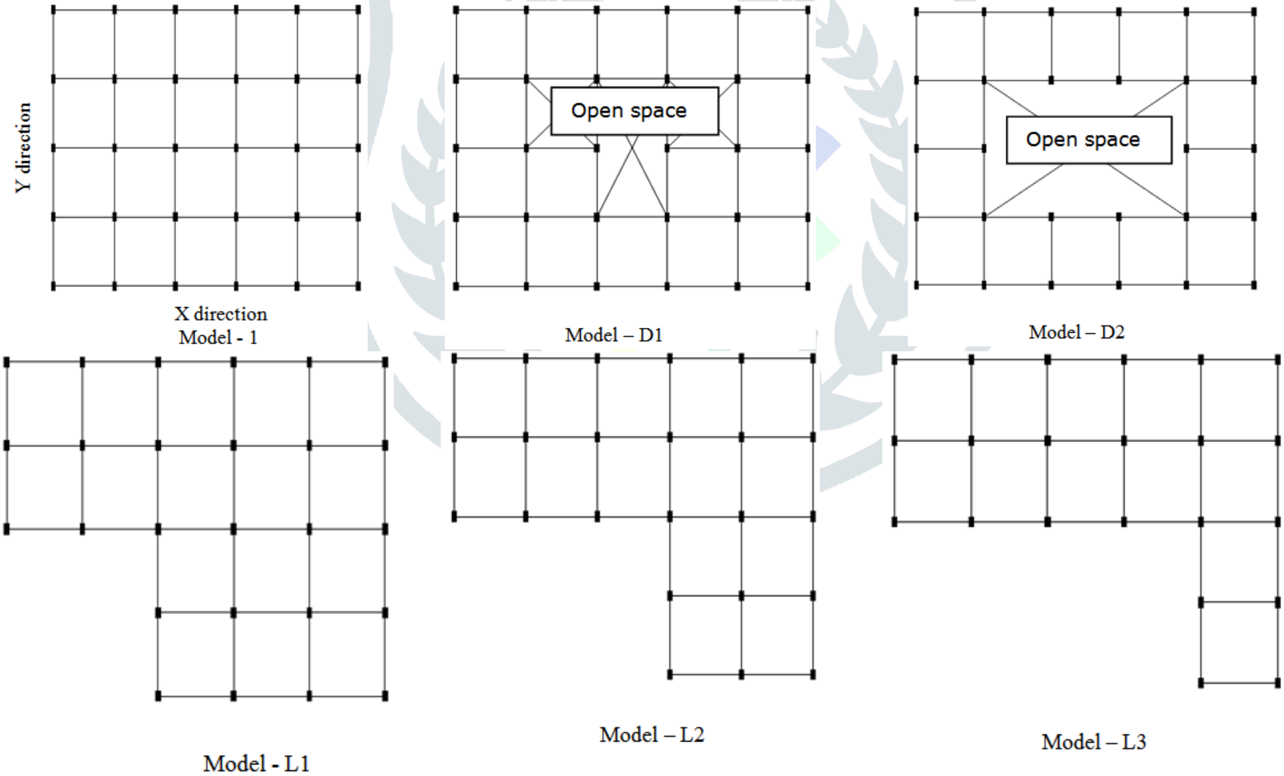
Patil et al. (2017) studied the dynamic response of multi-storey buildings with plan asymmetry. They have numerically analyzed multistoryed frames having different plan shapes. They have reported that the increase in height of T and L shaped buildings increases the displacement response and stress at the re-entrant corners.

Md Shehzad Choudhary et al. (2018) addressed the difference between a building without diaphragm discontinuity and a building with diaphragm discontinuity. In this project a regular 15 and 20 storey RC buildings having shear wall are modelled with and without diaphragm discontinuity and are analysed by ETABS (2013). The models having slab openings has lower storey displacement, storey drift, storey shear, modal period than the regular building model. For 15 storey building, when there is increase in percentage area of slab openings it is found that there is decrease in the storey displacement, storey drift, storey shear and modal period in both x & y direction. Also for 20 storey building, when there is increase in percentage area of slab openings it is found that there is decrease in the storey displacement, storey drift, storey shear and modal period in both x & y directions. The study shows that variation in the slab thickness reduces the performance of the buildings during earthquakes. It is found that the slab openings in a building having shear wall gives better performance during earthquakes.

Vincle Mable Vas et al. (2019) Although rigid floor diaphragm is a reasonable assumption for seismic analysis, certain building configurations may exhibit diaphragm flexibility. Detailed investigations have been carried out on modelling of flexible diaphragms compliant with various codes such as ASCE-07 and UBC 1997. Studies have shown that diaphragm flexibility amplifies both the deformation and the shear in the diaphragm. The methodology is outlined by three major elements such as the choice of building models, the adopted method of analysis and the parameters studied. Buildings with large cut-outs and openings are observed to exhibit flexible behaviour. These models are analysed dynamically using a sitespecific response spectrum developed from probabilistic seismic hazard analysis (PSHA) for Mangalore region (a coastal city in Karnataka, Southern India). The analysis is carried out using a G+10 RC building. The effect of percentage of openings in the diaphragm is studied using structural parameters such as storey drift, base shear and storey displacement with the help of ETABS 2015 software, and the optimum shape for these openings in a building plan is finalized. Further, time history analysis is performed over the models, and the results obtained through response spectrum and time history analysis are compared. The study highlights the importance of diaphragm flexibility in determining the seismic response of a building. This flexibility causes significant increase in the building period, which results in reduction in the earthquake-induced base shear. Since the seismic input used for the study was developed for the moderate seismic zone, the outcomes of this investigation are believed to have vast applications.

b) Irregularities in Plan geometry, Mass, Stiffness and Torsion

Ravikumar C M et al. (2012) have studied seismic performances of different irregular buildings located in severe earthquake zone (V) of India, and also identify the most vulnerable building among them. The study focused in terms of time period, base shear, lateral displacements, storey drifts and eccentricity in linear analysis using a eartghquake code IS1893 (Part 1):2002. Whereas the performance point and hinge status in Non linear analysis using ATC40. Also an attempt was made in pushover analysis to identify the correct lateral load pattern when different irregular buildings were considered. The entire modelling, analysis and design was carried out by using ETABS 6.0 nonlinear version software. They modelled the buildings plan which having 5X4 bays of equal length of 5m. The buildings considered RCC ordinary moment resisting frame of three storeys. Here stiffness of the infill is neglected in order to account the nonlinear behaviour of seismic demands. The storey height is kept uniform of 3m for all building models.



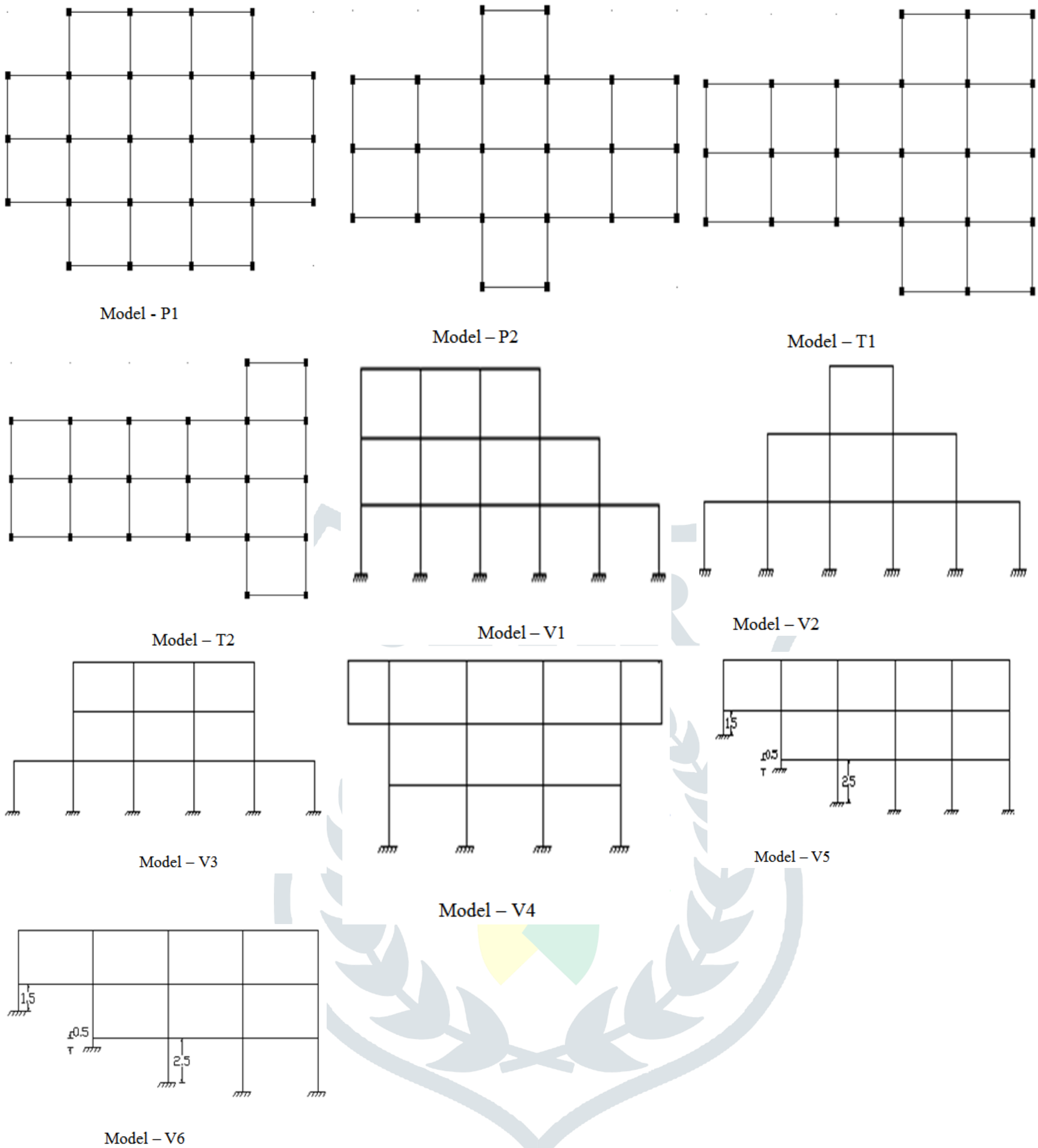


Figure 1.5: Building Models

Plan and storey configuration of models:

(i)The Plan configuration consists of

- Model 1 – Building in rectangular shape
- Model D1 – Diaphragm discontinuity, which is in T shape.
- Model D2 – Diaphragm discontinuity, which is in rectangular shape.
- Model L1, L2, L3 – Re-entrant corners in L Shape.
- Both projections provided are 40% 60%, 80% in X direction and 50% in Y-direction.
- Model P1 and P2 – Re-entrant corners, in plus (+) Shape. Both projections provided are 20% of the plan dimension in their respective directions and 40% of the plan dimension in X direction, 25% in Y-direction.
- Model T1 and T2 – Re-entrant corners in T-Shape. Both projections provided are 60% and 80% of the plan dimension in X direction and 25% in Y-direction.

(ii) a). The Vertical configuration of a structure and lateral force resisting system in

- Model V1 – top story consists of an offset of 40% in X direction only on one side.
- Model V2 – top story consists of an offset of 20% in X direction on both sides.
- Model V3 – top story consists an offset of 40% in X direction on both sides.
- Model V4 – adjacent story consists of an offset of 10.4% in X direction on both sides.

(ii) b). The Vertical configuration of a structure and lateral force resisting system

- Model V5 – Resting on a sloped ground in X direction.
- Model V6 – Resting on a sloped ground in Y direction.

After the analysis of these models the results are shown that equivalent static method doesn't consider the irregular effects in the building and since it depends only on empirical formula the results obtained will be abnormal in comparison to response spectrum method. In pushover analysis the codal type of vertical distribution of lateral force was found more detrimental in low rise models. Since more number of hinges are formed for a given displacement level compared to the other two patterns. The results also give the displacements value higher for Model V4 in x direction and Model V1 in y direction. The base shear value of Model V6 is the most higher in x direction and Model V5 in y direction. The result also shows that, capacity of the buildings may be significant but the seismic demand varies with respect to the configurations so the dynamic analysis should prefer for finding the best results for buildings.

Dileshwar Rana, Prof. Juned Raheem performance & behavior of regular & vertical geometric irregular RCC framed structure under seismic motion. Five types of building geometry are taken in this study: one regular frame & four irregular frames. A comparative study is made between all these building configurations height wise and bay wise. The method used in this study is Seismic Coefficient Method which is an equivalent static analysis considering a design seismic coefficient. In equivalent lateral procedure dynamic effects are approximated by horizontal static
forces applied to the structure. This work is based on three dimensional reinforced concrete building with varying heights and widths. These building configurations represent different degree of vertical irregularity or amount of setback. The same bay width of 3m is taken in both the horizontal direction .Two cases are considered for the bays. In first case, the numbers of bays are four and in second case, these are eight. The uniform storey height of 3.5m is considered in all the cases.

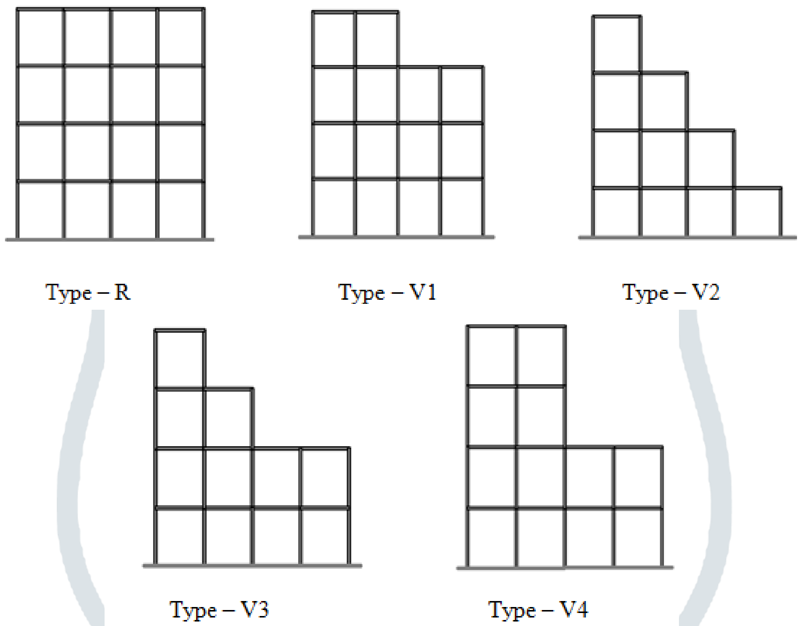


Figure 1.6: Typical building configuration for four-storey building variant

Gravity (dead and imposed) load and seismic load corresponding to seismic zone IV of IS 1893:2002 are considered for the design. Ordinary moment resisting frame is considered in all the cases having response reduction factor (RF) as 3. The slab thickness is taken as 150 mm for all the buildings. All Infill walls are considered to be the external with thickness of 200 mm. The parapet wall is assumed to be of 200 mm thickness and of 1m height for all the selected buildings. The unit weight of brick is taken as 20Kn/m^3 and concrete as 25kN/m^3. All supports are taken as fixed. The structures are modeled by using computer software Staad.Pro V8i. The storey drift and maximum storey nodal displacement of both the horizontal direction X & Z
are noted down. Four bay frames have less critical bending moment than eight bay frames for both four storey and eight storey building. There is not much change for the bending moment of regular frames. It is concluded in this paper that as the amount of setback increases, the critical shear force also increases. The critical bending moment of irregular frames is more than the regular frame for all building heights. This is due to decrease in stiffness of building frames due to setbacks. The critical seismic parameter of 4 bay building frames up to eight storey building height is less than corresponding 8 bay building frames . Therefore 4 bay building is appropriate for lower building heights. The higher storey building (twelve & sixteen storey) 8 bay configurations should be preferred because they have generally lesser values of critical seismic parameters than 4 bay.

Siva Naveen E et al. (2019) have presented effect of irregularities in various form of plan and elevation form. They have studies about 34 configurations with single irregularity and 20 cases with combination of irregularities. Along with regular configuration, 54 irregular configuration are analyzed and compared. The magnitude of variation in response depends on the type, degree and location of irregularities present. The judicious choice of these parameters in the design of structures improves performance of the structure. The seismic response of frames with different configurations were obtained using ETABS software. The major inputs are geometry of the frame including dimensions of storeys and columns, total mass of each floor, modulus of elasticity, damping ratio and earthquake data. The modulus of elasticity for the material is taken as 20000 MPa. Rayleigh damping is assumed with a damping ratio of 4%. It is also assumed that the structure starts from rest on load application. A structure irregularities, when certain structural parameters exceed the limits specified by standards. Table 2 shows the limits for mass (M), stiffness (S), vertical geometric (VG), re-entrant corner (REC) and torsional (T) irregularities prescribed by IS1893:2016 (Part I).

Table 1.2. Irregularity limits prescribed by IS 1893:2016 (Part I) (i = storey number, a = adjacent storey number, Δ_{max} =maximum deformation and Δ_{avg} = average deformation).

Type of irregularity	Classification	Limits
Mass (M)	Vertical irregularity	$M_i < 1.5M_a$
Stiffness (S)	Vertical irregularity	$Si < S_{i+1}$
Vertical geometry (VG)	Vertical irregularity	$VG < 1.25\ VG_a$
Re-entrant Corner (R)	Horizontal irregularity	$R_i <= 15\%$
Torsion (T)	Horizontal irregularity	$\Delta_{max} <= 1.5\Delta_{avg}$

A nine-storey scaled frame with a storey height of 0.229 m is considered for the study. The frame has six bays in the direction of length and three bays in the direction of width. The dimension of each bay in the direction of length and width are 0.305 m and 0.914 m respectively. Each floor carries a lumped mass of 2760 kg. The irregularities are incorporated by changing the vertical and horizontal configurations of the regular frame. Apart from the regular case, 54 irregular configurations are analyzed, out of which, 34 cases possess single irregularity and 20 possess combination of irregularities. The models have mass irregularities (MI), stiffness irregularities (SI), vertical geometric irregularities (VGI), re-entrant corners irregularities (REC) and torsional irregularities (TI).

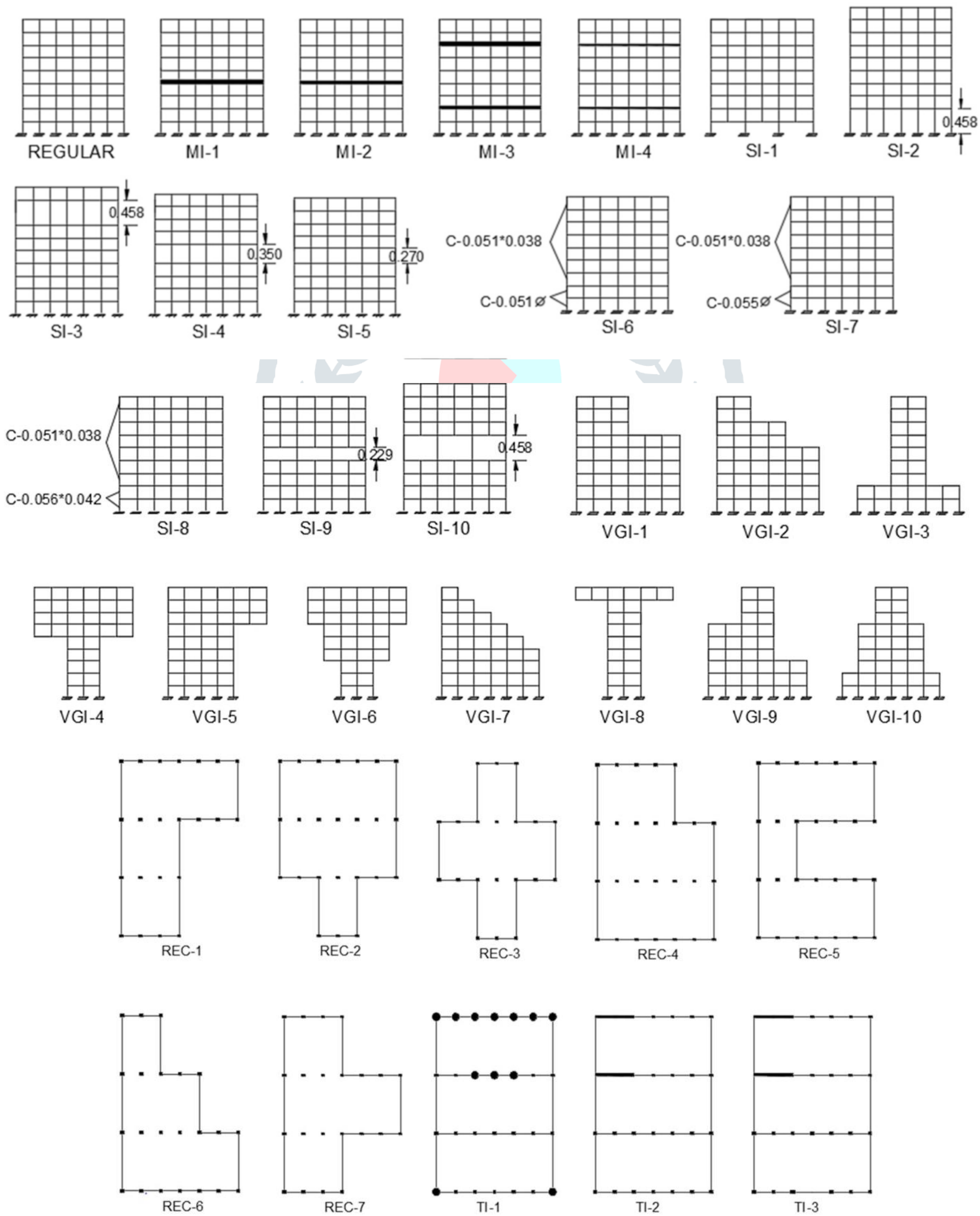


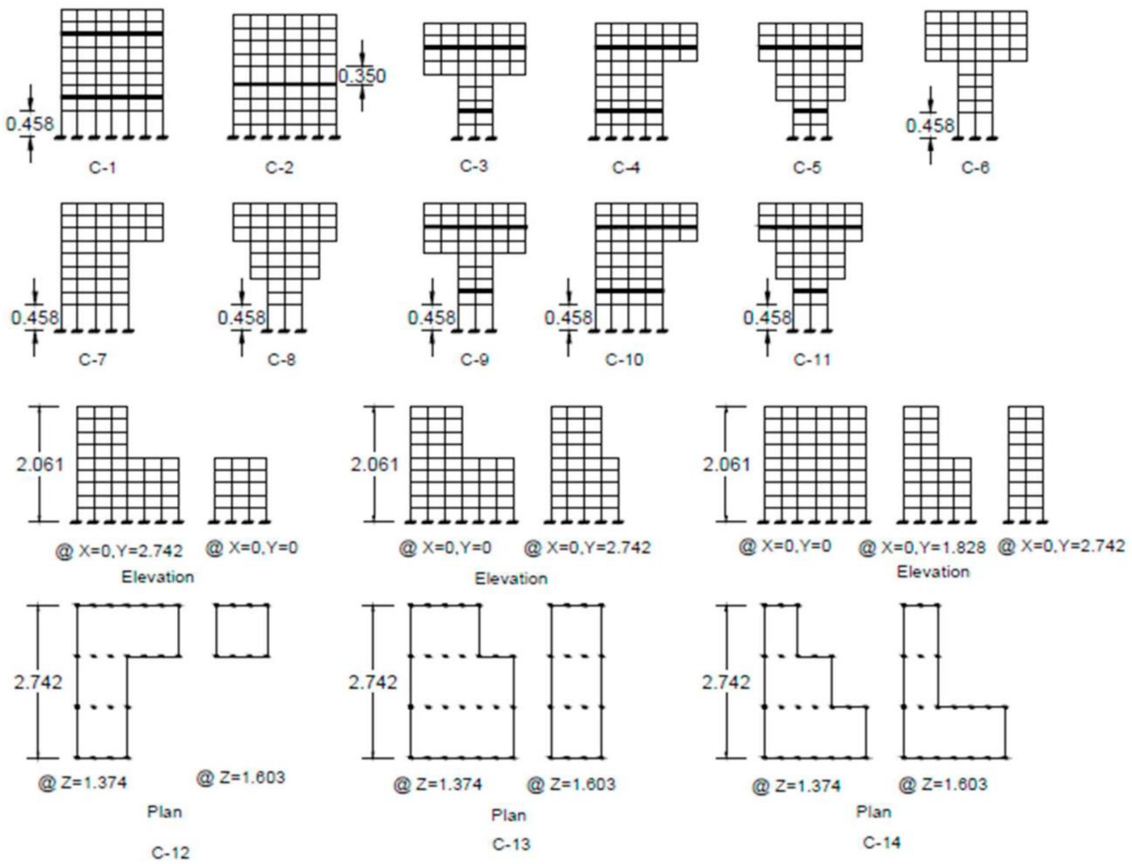
Figure 1.7: (a) Elevation of the regular and horizontally irregular frames: MI-1 to MI-4 have mass irregularity, SI-1 to SI-10 have stiffness irregularity and VGI-1 to VGI-10 have vertical geometric irregularity (All dimensions are in m); (b) Plan of vertically irregular configurations: REC-1 to REC-7 have re-entrant corner irregularity and TI-1 to TI-3 have torsional irregularity.

Table 1.3: Percentage reduction in storey stiffness for the configurations having SI.

Case	Location of irregularity	% of storey stiffness with respect to adjacent storey	% Reduction in storey stiffness with respect to adjacent storey
SI-1	1st floor	57	43
SI -2	1st floor	12.5	87.5
SI-3	8th floor	12.5	87.5
SI-4	5th floor	28	72
SI-5	5th floor	61	39
SI-6	3rd floor	70	30
SI-7	3rd floor	52	48
SI-8	3rd floor	67.5	32.5
SI-9	5th floor	57	43
SI-10	5th floor	16	84

Table 1.4: Details of the cases with combination of different irregularities.

CoI	Combination case number	Irregularity involved	CoI	Combination case number	Irregularity involved
CoI 1	C-1	MI+SI	CoI 4	C-11	MI+SI+VGI
CoI 1	C-2	MI+SI	CoI 5	C-12	REC+VGI
CoI 2	C-3	MI+VGI	CoI 5	C-13	REC+VGI
CoI 2	C-4	MI+VGI	CoI 5	C-14	REC+VGI
CoI 2	C-5	MI+VGI	CoI 6	C-15	MI+SI+REC+VGI
CoI 3	C-6	SI+VGI	CoI 6	C-16	MI+SI+REC+VGI
CoI 3	C-7	SI+VGI	CoI 6	C-17	MI+SI+REC+VGI
CoI 3	C-8	SI+VGI	CoI 7	C-18	MI+SI+REC+VGI+TI
CoI 4	C-9	MI+SI+VGI	CoI 7	C-19	MI+SI+REC+VGI+TI
CoI 4	C-10	MI+SI+VGI	CoI 7	C-20	MI+SI+REC+VGI+TI



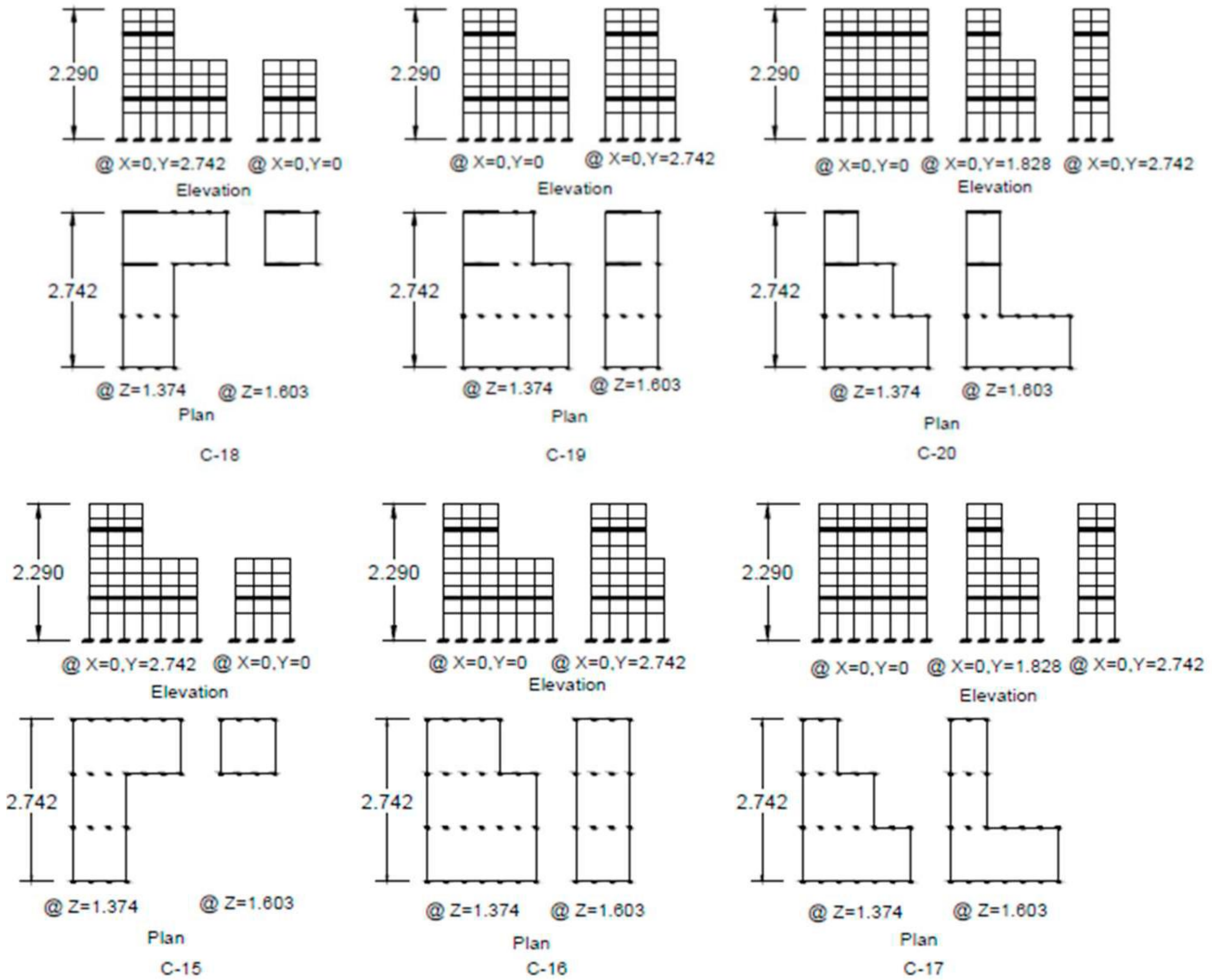


Figure 1.8: Cases with different combinations of irregularities: elevation is shown for C-1 to C-11, both plan and elevation are shown for C-12 to C-20 (All dimensions are in m).

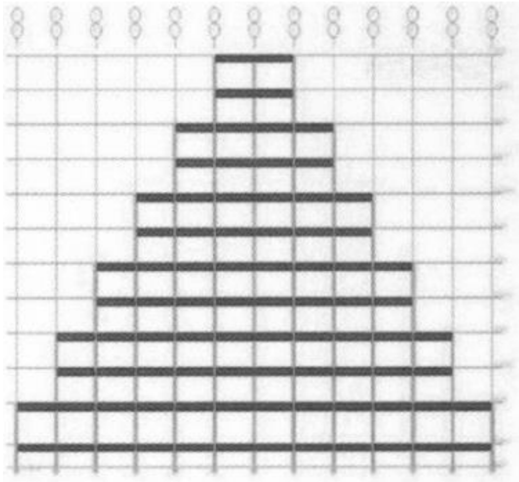
The study concluded that irregularity considerably affects the structural response. The study indicates that the presence of irregularities does not always amplify the response. Certain combinations of irregularities bring down the structural response. All the single irregularity cases analysed have shown an increase in response when compared to the regular configuration under seismic loads. Among these cases, the configurations with vertical geometric irregularity have given maximum response. The combination of stiffness and vertical geometric irregularities has shown maximum displacement response whereas the combination of reentrant corner and vertical geometric irregularities has shown less displacement response. In the modern world, where people are not ready to compromise with their needs, incorporation of combinations of irregularity in structures is inevitable. As the structural response depends on the type, location and degree of irregularity, these factors need to be taken care while designing any structure. This would help in incorporating irregularities in structures without compromising their performance.

Shaikh Abdul Aijaj et al (2021) have presented the earthquake results for structural irregulaties in the buildings as per IS 1893:2002. They have included stiffness irregularities such as soft storey and extreme soft storey as per IS code. The study also adopted mass irregularity i.e. re the effective mass of any storey is more than 150% of effective mass of an adjacent storey. The effective mass includes dead weight of the floor and actual weight of partition and equipment. Vertical geometry irregularity can also be seen in structures. Setback also can be visualized as vertical re-entrant corner. The authors have modeled SMRF RCC buildings of G+10 storeyed. Table 1.4 shows the details of analysis models. The equivalent static analysis has been carried out using ETABS software.

Table 1.5: Model Descriptions

Model No.	Description
1	Base Model
2	Base Model with Mass irregularities at third and seventh floor
3	Base Model with stiffness irregularities at fourth floor
4	Base model with stiffness irregularities at ground floor

The basic model consists of (G+10) vertical geometric irregular structure with basement. It has 12 bays of 5m in both X and Y directions. After each two consecutive stories the plan size of model is reduced by 5 m in both directions. The typical height of storey is 3 m, ground storey height is 3.5 m and foundation height below the plinth is 2 m.



Figur 1.9: Elevation of Base model (Model-1)

The behaviour of G+10 storeyed building with mass and stiffness irregularities has been studied by the authors and concluded about the storey drift that there will be a sudden change in storey displacement at the level where the mass between two storey is changing. If masses are heavy than the values also go beyond the permissible limits as per IS 1893. Vertical stiffness irregularities at a storey in a building cause increase in storey drift beyond the specifies limits at that storey.

III. CONCLUSION

The study from the papers included in this article give reports on research and development on the effect plan geometry and irregularities on earthquake response for multistoreyed buildings.

The high-rise buildings have complex behaviour under seismic excitations which were shown in many research articles. The response depends on many characteristics of the buildings such as plan geometry, setback, diaphragm, mass, stiffness, re-entrant corners and torsional irregularities. The buildings which having regular plan give better response as well as can be used for the regions having severe zone of earthquake. The plan which was having setbacks and re-entrant corners in the floor plan gives large storey drifts.

In the recent world the aesthetic view is very demanding for the people, for this reason the engineer has to design the buildings according the demand. So, it is necessary to look on the behaviour and the code specification for the particular problem. In many cases the response of the buildings are not in the limit than he should apply the respective solution such as structural arrangements and stiffness to the structure so that the buildings give good response in lateral loads.

The mass and stiffness irregularities are also a main objective to safeguard the buildings in earthquake. Mass of the storey with respect to the adjacent can affect the drift of that storey. It is observed that storey shear also increases if there are any irregularities in the stiffness. These types of irregularities give large displacements and building may fails under seismic excitation.

High rise buildings response is very simple when these are analyse under static methods. So, for the buildings which were having any irregularities such as plan, mass, stiffness and torsion than designer should prefer dynamic analysis such as response spectrum, pushover analysis and time history analysis. Dynamic analysis gives the actual response of the building in the seismic vibration as these functions have actual acceleration of the waves with respect to the time. So, the effect of these acceleration can be seen on the buildings.

In conclusion, research activity on the effect of plan geometry and irregularities on seismic excitation for multistorey buildings is very much lively, as obtained by the impressive number of papers published. Main issues of both building response and irregularities are clarify in the best manner.

REFERENCES

[1] Raúl González Herrera, Consuelo Gómez Soberón "Influence Of Plan Irregularity Of Buildings" The 14 World Conference on Earthquake Engineering, 2008, Beijing, China

[2] Milind V. Mohod "Effect Of Shape And Plan Configuration On Seismic Response Of Structure" International Journal Of Scientific & Technology Research Volume 4, Issue 09, September 2015

[3] IS 1893-1 (2002): Criteria for earthquake resisting design of structures part 1: General provisions and buildings

[4] Jereen Ann Thomas, Soumya Anand, Binu M Issac "Seismic Evaluation of Buildings with Plan Irregularity" Applied Mechanics and Materials, ISSN: 1662-7482, Vol. 857, pp 225-230

[5] Momen, M. M., Ahmed, Shehata., E. Abdel Raheem., Mohamed, M., Ahmed and Aly, G.A., Abdel, shafy. "Irregularity Effects on the Seismic Performance of L-shaped Multi-story Buildings". Journal of Engineering Sciences 44(5)-2016, 513-536.

[6] Patil, SS., Ajim Mujawar, G., PrritamMali., Murugesh Katti, R. "A Study of Torsional Effect on Multi-storied Building with Plan Irregularity". International Journal of Advanced Research 5(1)- 2017, 1625-1632.

[7] Md. S. Choudhary, S. Arfath, M. Ahmed, N. Pasha, "Comparative Study on Seismic Analysis of Multi Storey Building Having Diaphragm Discontinuity Using Etabs", International Journal of Research in Advent Technology, 6(5), (2018).

[8] Vincle Mable Vas, Prajwal Nagaraja, and Katta Venkataramana, "Effect of Diaphragm Discontinuity on the Seismic Response of an RC Building", Trends in civil engineering and challenges for sustainability, Select proceedings of CTCS 2019, Springer

[9] Ravikumar C M et.al "Effect of Irregular Configurations on Seismic Vulnerability of RC Buildings ", Journal of Architecture Research 2(3): 20-26

[10] Dileshwar Rana, Prof. Juned Raheem "Seismic Analysis of Regular & Vertical Geometric Irregular RCC Framed Building" International Research Journal of Engineering and Technology (IRJET), Volume: 02 Issue: 04, July-2015

[11] Siva Naveen E, Nimmy Mariam Abraham, Anitha Kumari S D "Analysis of Irregular Structures under Earthquake Loads". 2nd International Conference on Structural Integrity and Exhibition 2018, Procedia Structural Integrity 14 (2019) 806–819.

[12] IS 1893-1 (2016): Criteria for earthquake resisting design of structures part 1: General provisions and buildings

[13] Shaikh Abdul Aijaj Abdul Rahman, Ansari Ubaidurrahman Salik "Seismic analysis of vertically irregular buildings" Current Science association , 25 November 2016, Vol. 111, No. 10 (25 November 2016), pp.1658-1663

[14] Ravikanth Chittiprolu (2014) "Significance of Shear Wall in High-rise Irregular Buildings", International Journal of Education and applied research",Vol.4:35-37

[15] Sandesh N. Suryawanshi, Prof. S. B. Kadam, Dr. S. N. Tande (2014), "Torsional Behaviour of Asymmetrical Buildings in Plan under Seismic Forces", International journal of emerging engineering research and Technology, Vol.2 (4): 170-176

[16] M. Mouzzoun (2013), "Seismic performance assessment of reinforced concrete buildings using pushover analysis", IOSR Journal of Mechanical and Civil Engineering, Vol.5 (1):4449

[17] Abhilash R, Biju V, Rahul Leslie "Effect of lateral load patterns in Pushover analysis", 10th National Conference on Technological Trends (NCTT09) 6-7, India, 2009.

[18] Birajdar.B.G, "Seismic analysis of buildings resting on sloping ground", 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada, Paper No. 1472, 2004

[19] Murty C.V.R., "Earthquake tips", Indian institute of Technology, Kanpur 2005

[20] G. Kumar, V. R. Singh, "Effect of Irregular Configurations on Seismic Behavior of RC Buildings", International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE), 3(4), 2456-1290, (2018).