SEISMIC ANALYSIS OF TRIANGULAR SHAPE PLANNED MULTI-STORY BUILDING

Rajesh Siroya[1], Dr. V. R. Patel[2]

[1]*PG Student, Applied mechanics Department, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat, India.*
[2]*Assistant professor, Applied mechanics Department, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat, India.*

***

Abstract - *Torsion–induced failures are disastrous for multi–story buildings because the torsional reaction of the structure not only alters the uniform translational seismic floor displacement but also causes stress concentration, necessitating higher structural strength and ductility. Because of its discontinuous geometry, mass, and/or stiffness, a structure becomes a prime source of collapse during an earthquake. The goal of this research is to have a thorough understanding of the torsional behavior of building structural systems for asymmetric buildings with plan irregularity. Asymmetric structures feature an asymmetric distribution of mass and stiffness, which causes torsion and is the most important component impacting the structure's seismic damage. To have a comprehensive review on structural response for involved torsional irregularities, the performance of such structures is evaluated using procedures described in current codes of practice for significant parameters such as story drift, base shear, maximum lateral displacement and natural time-period.*

Key Words: Torsional irregularity, Plan asymmetry, Eccentricity, Response spectrum analysis.

1.INTRODUCTION

Recent earthquake damage reports have shown that torsional motions frequently cause significant damage to buildings, ranging from visible distortion to structural collapse, and earthquake field investigations have repeatedly confirmed that irregular structures suffer more damage and distortion than regular and symmetric structures. Furthermore, among all natural disasters, earthquakes are the most unpredictable and destructive. As a result, understanding the torsional behaviour of buildings during an earthquake is vital. The majority of the time, structures are subjected to torsional vibration in addition to lateral oscillations during earthquake ground motions. Torsion occurs when a building's centre of mass does not correspond with its centre of stiffness, as a result of seismic pressures. Positioning stiff parts asymmetrically with respect to the story's centre of gravity; placement of huge masses asymmetrically with respect to stiffness are some of the reasons that can lead to this issue in the building plan. The scenarios described above are the outcome of a combination of the two, mass and stiffness distribution.

In the event of an earthquake, the structure rotates around its stiffness centre. This raises the amount of both lateral forces and displacements, putting lateral load resisting structural elements under increasing demands proportional to their distance from the centre of rotation. The traditional torsion analysis simply calculates the force due to moment generated by an eccentric static force. It ignores the torsional vibrations and accelerations that come with them. When the eccentricity between the centres of mass and stiffness surpasses 10% of the horizontal plane dimensions under consideration, it is deemed significant. Corrective actions in the structural design of the structure should be taken in such circumstances. When there are vertical anomalies, such as setbacks, torsion can become even more complicated. In fact, regardless of the structural symmetry or asymmetry of the upper and lower levels, the higher part of the building transfers an eccentric shear to the lower section, causing downward torsion of the transition level. Due to combined lateral and torsional movements causing non-uniform displacement demands in building elements and concentrations of loads and strains on structural parts, asymmetric or torsionally unbalanced buildings are vulnerable to earthquake damage. Currently, there are no suggestions for irregular constructions in the codes. As a result, a straightforward analysis technique based on rigorous analytical and experimental evidence on the inelastic seismic response of irregular structures appears to be required. Due to different practical and architectural considerations, asymmetric building structures are almost inescapable in modern construction.

The uncoupled torsional to translational frequency of the structure, the eccentricity between the centre of mass and the centre of stiffness, the uncoupled vibration frequencies, and the damping ratio are all important governing parameters of the torsional responses of asymmetric structures, according to numerous studies. Over the last few decades, these factors have been extensively examined, and some general observations on elastic torsional reactions of structures to earthquake ground motions have been made. Many researchers have also carried out inelastic torsional response analyses and drawn conclusions based on their findings. However, unlike elastic torsional response, no general conclusions about the inelastic behaviour of asymmetric buildings and the governing parameters can be drawn. Because the stiffness, radius of gyration, location of the centre of rigidity, and eccentricities all change during plastic deformation, the factors regulating the torsional response change as well. As a result, the goal of this research was to gain a better knowledge of the torsional behaviour of building structural systems for asymmetric building with irregular plan shape. To have a comprehensive review on structural response for involved torsional irregularities, the performance of such structures is evaluated using procedures described in current codes of practise for significant parameters such as storey drift, base shear, maximum lateral displacement and natural time-period.

2. RELATED WORK

Shaik Muneer Hussain and Dr. Sunil Kumar Tengli aimed at Modeling and analysis of 14 story buildings utilizing three-dimensional dynamic analysis (Response Spectrum Method) approach using ETABS in accordance with IS Code 1893:2002 with the goal of understanding the torsional behavior of asymmetric buildings (part 1). A regular building model and irregular building models were modelled and analyzed for this study. For all of the models, the results of time periods and frequencies, maximum story drifts, and maximum story displacements are reported, and the results of regular and irregular structures are compared, and the performance of these models / buildings was observed for seismic loads. The findings reveal that torsion increases shear forces in columns, particularly in irregular structures, and that special moment resisting frames are more suited to severe seismic zones than standard moment resisting frames.
Momen M. M. Ahmed, Shehata E. Abdel Raheem, Mohamed M. Ahmed and Aly G. A. Abdel-Shafy examines the seismic behavior of structures with an uneven L-shape floor plan by examining the effects of re-entrant corner configuration irregularity on observed seismic response needs. Inter-story drift, story shear force, overturning moment, torsion moment at the base and along the building height, top floor displacement, and torsional Irregularity Ratio are among the observed responses. As a reference model, a three-dimensional finite element model of nine story moment resisting frame buildings was created; six L-shaped models were created with the plan of the reference model gradually reduced. Equivalent Static Load (ESL) and Response Spectrum (RS) Methods were used to analyses the models with ETABS. Because of torsion behavior and the additional shear stress created in the perpendicular direction to the earthquake input, buildings with significant irregularity are more vulnerable than those with regular configuration. Furthermore, the codal empirical equation for calculating the fundamental period of vibration failed to account for considerable higher vibration modes, such as torsional vibration of irregular buildings, which could have a significant impact on seismic demands.
Govind M, Kiran K. Shetty, K. Anil Hegde. ETABS software was used to investigate the response of G+20 story R.C. frame buildings (H shape in plan, with and without T shaped column) subjected to earthquakes in seismic zone III. It is designed in accordance with IS 456 and is subjected to gravity loads as defined by IS 1893-2002. It is carried out a displacement-controlled pushover analysis. The results revealed that the model with T shaped column can sustain higher base shear than the model with rectangular column for the same EQ load applied in both X and Y axes.

3. METHODOLOGY

The current work can be classified as a quantitative study because it is primarily centered on the collection of numerical data for four alternative building plan configurations when subjected to seismic loads. The analysis was conducted on a G+4 story triangular planned commercial asymmetrical reinforced concrete building. These four plan configurations of buildings consist of 4 typical stories, with typical story height of 12 feet and base story height of 12 feet. To have a thorough comparison of factors affected by seismic loads, seismic load analysis factors such as building occupancy category, basic and design ground motion parameters, soil type, site classification and site coefficient adjustment factors, and seismic design category are kept constant for all structural systems under consideration. The impact of seismic pressures on lateral load specific characteristics such as story drift, base shear, maximum lateral displacement, and natural time period as a result of a change in building plan configuration is investigated.

4. ANALYSIS METHOD

Static and dynamic seismic analysis methods are the two most common types of seismic analysis. The method of analysis used in this research is dynamic analysis, also known as the Response Spectrum Method.
In the research and design of multistory buildings for seismic loads, the response spectrum approach is crucial. The elastic and inelastic design spectrums are used to estimate the building's maximal reaction. Building codes for earthquake motions are based on the response spectrum approach's simplification, therefore this method is incredibly important in the analysis and design procedures. IS code 1893:2016 will be utilized to determine the load combinations that will be employed in the analysis of these models.

5. DETAILS OF THE STRUCTURES

Story height- 12 feet
Column1- 9X24 inches
Column2- 18X30 inches
Column3- 24X30 inches
Column4- 18X36 inches
Column5- 24X48 inches
Column6- 28.5X96 inches
Beam1- 9X12 inches
Beam2- 18X23 inches
Beam3- 18X27 inches
Beam4- 24X36 inches

Shear wall- 9 inches
Lift pardi- 6 inches
The Figures below shows the plan of the trials of structures that are taken into consideration for the torsional analysis. Earthquake load is defined as per IS 1893 (2016). The seismic details of the structures are tabulated in Table 5.1.

Type of structures	Multi-storey RC bulding	
Number of stories	G+4	
Materials	concrete	M30
	Reinforcing bar	Fe500
Slab section	Slab	8 inches
Zonal considerations	Zone	IV
	Zone factor	0.24
	Soil type	II
	Importance factor	1
	Reduction factor	5
Live load	typical floor	4KN/m2
	Terrace floor	1.5KN/m2
	Staircase	4KN/m2

Table -1: Seismic details of the structures

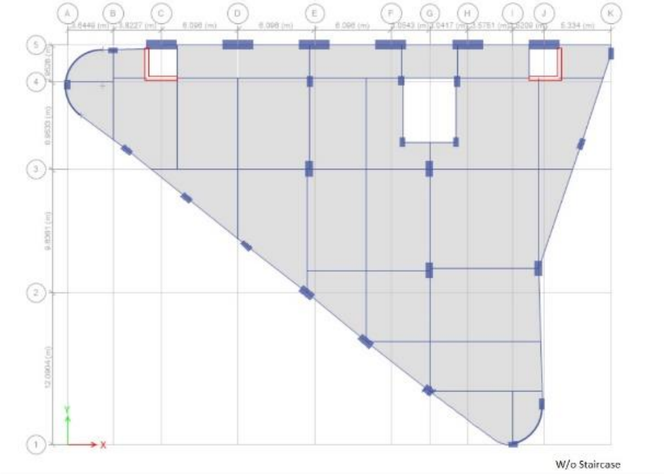


Fig -1: Model 1

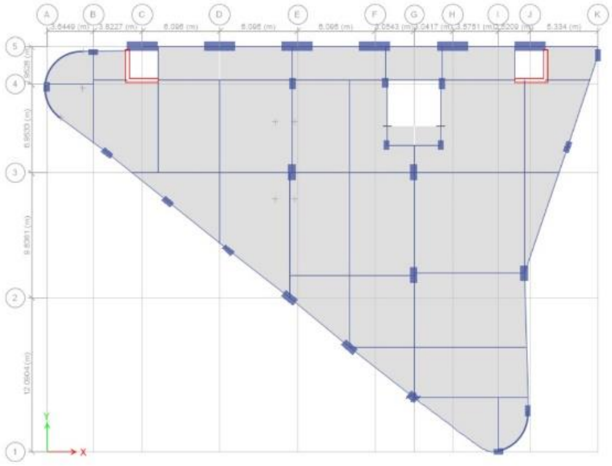


Fig -2: Model 2

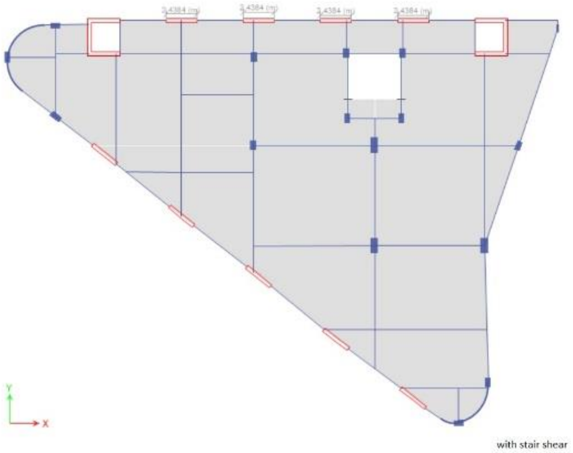


Fig -3: Model 3

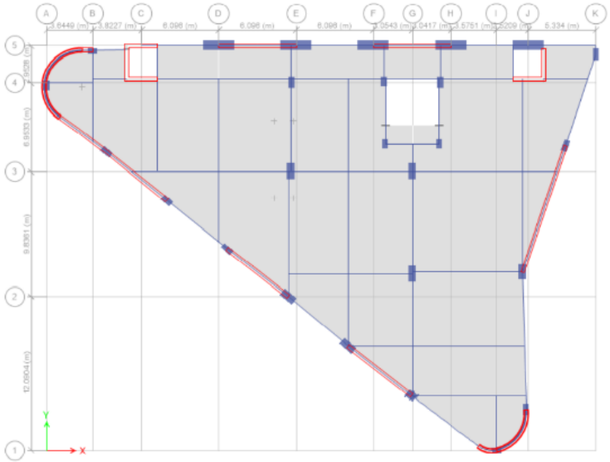


Fig -4: Model 4

6. RESULTS AND DISCUSSION

ETABS 2018 software was used to do the response spectrum analysis for the models. According to IS code 1893:2016, seismic details were incorporated. The torsional irregularity was discovered using IS CODE 1893:2016. The study was carried out to discover the most torsional irregular structure based on different torsion parameters.

6.1 MODES

Figure 5 shows the twelve mode numbers vs the natural period of vibration. The strongest structure (model 4) has a natural period of 0.75 seconds, while the weakest structure (model 4) has a natural period of 0.194 seconds, showing that structures with longer periods of vibration have lower seismic resistance. The model 1 has a longer period of vibration because it is flexible (smaller stiffness k), and no stiff elements are introduced for the model 1, such as a staircase or shear wall, which increases its flexibility, whereas in the case of Model 4, stiff elements such as shear walls have been introduced to get the first two lateral translational modes of the structure, and thus it is less flexible and will show a crack, whereas in the case of Model 4, stiff elements such as shear walls have been introduced to get the It's worth noting that a more flexible, longer-period design is likely to endure proportionately lower accelerations than a stiffer structure.

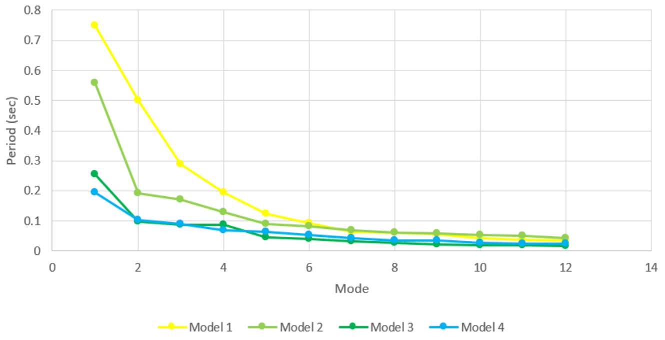
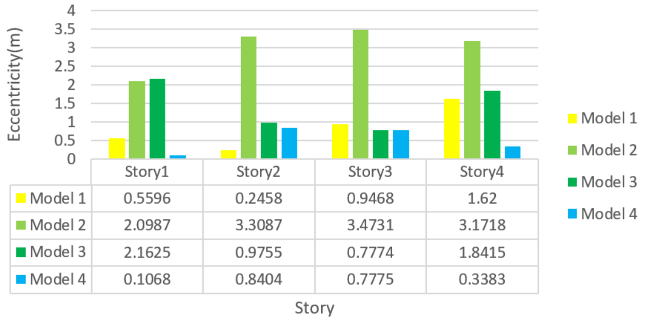


Fig -5: Natural periods of vibration

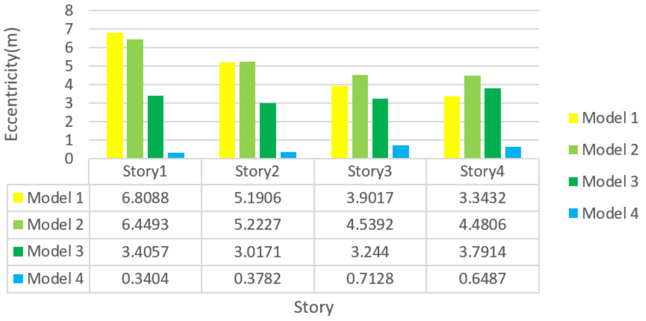
6.2 ECCENTRICITY

Chart 1 and 2 depict the eccentricity of the models in the X and Y directions. The torsional impact is proportional to the eccentricity between the centre of stiffness and the centre of mass. Model 2 has more eccentricities than Model 1 when comparing X and Y directions, which shows the difference in modelling staircase. The floor rotates and translates as a result of the eccentricity between the load and the resistance, necessitating extra strength and ductility at particular points of the structure.



	Story1	Story2	Story3	Story4
Model 1	0.5596	0.2458	0.9468	1.62
Model 2	2.0987	3.3087	3.4731	3.1718
Model 3	2.1625	0.9755	0.7774	1.8415
Model 4	0.1068	0.8404	0.7775	0.3383

Chart -1: Eccentricity in X direction

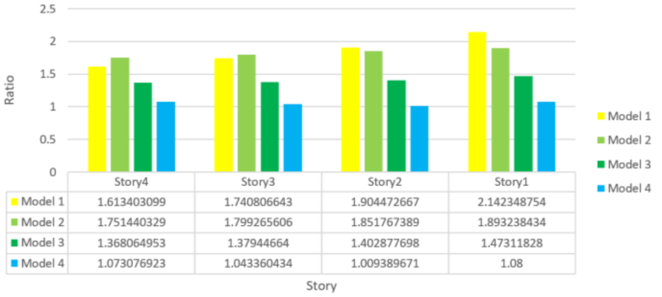


	Story1	Story2	Story3	Story4
Model 1	6.8088	5.1906	3.9017	3.3432
Model 2	6.4493	5.2227	4.5392	4.4806
Model 3	3.4057	3.0171	3.244	3.7914
Model 4	0.3404	0.3782	0.7128	0.6487

Chart -2: Eccentricity in Y direction

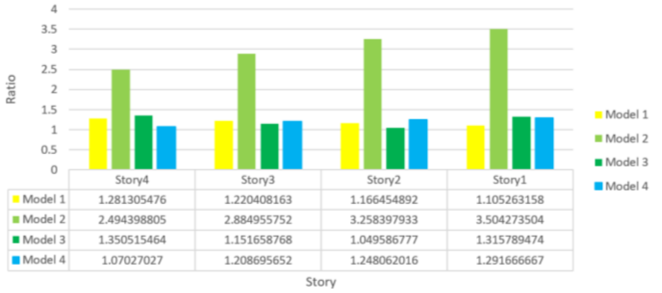
6.3 TORSIONAL IRREGULARITY

Chart 3 and 4 demonstrate the torsional irregularity, or the ratio of maximum to lowest displacement, for different stories of models 1 to 4. The graph shows that constructions with shear walls distributed in plan so that the centre of mass and centre of stiffness are not separated by more than a certain distance have the least percentage of change in maximum to minimum displacement ratio. As a result, strengthening has been done for the same. Models 4 had a similar variety of irregularities. Because the mass and stiffness distributions in models 1 and 2 are uneven, the first two modes for that structure are not entirely lateral translational (as suggested by the code). The torsional irregularity ratio for the Model 4 has decreased dramatically as a result of the addition of stiff parts capable of supporting the structure against twisting or torsion, and it has also fallen inside the code recommended ratio of 1.5.



	Story4	Story3	Story2	Story1
Model 1	1.613403099	1.740806643	1.904472667	2.142348754
Model 2	1.751440329	1.799265606	1.851767389	1.893238434
Model 3	1.368064953	1.37944664	1.402877698	1.47311828
Model 4	1.073076923	1.043360434	1.009389671	1.08

Chart -3: Torsional irregularity in X direction



	Story4	Story3	Story2	Story1
Model 1	1.281305476	1.220408163	1.166454892	1.105263158
Model 2	2.494398805	2.884955752	3.258397933	3.504273504
Model 3	1.350515464	1.151658768	1.049586777	1.315789474
Model 4	1.07027027	1.208695652	1.248062016	1.291666667

Chart -4: Torsional irregularity in Y direction

6.4 DRIFT

IS 1893:2016 Cl 7.11.1 specifies a permissible drift range. When comparing model 1 to other structures in the X and Y directions, model 1 has a greater drift value in all stories. It has a drift value of 0.00066 in the third storey in the X direction and 0.0008 in the third storey in the Y direction, which is within the code's limitations. The acceptable drift value is 0.0146, and the highest allowed drift value is 0.004H, where H is the storey height (H=3.65m).

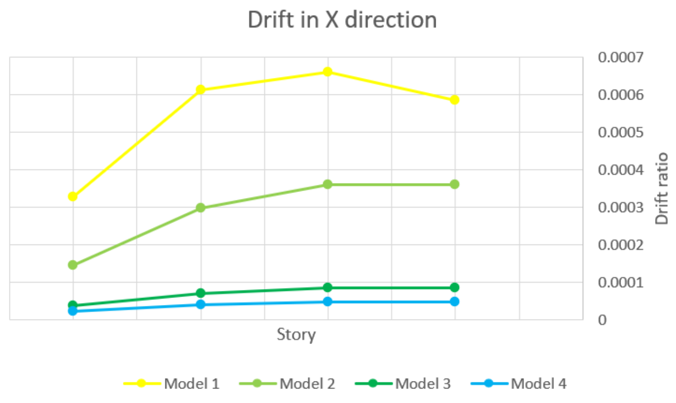


Chart -5: Drift in X direction

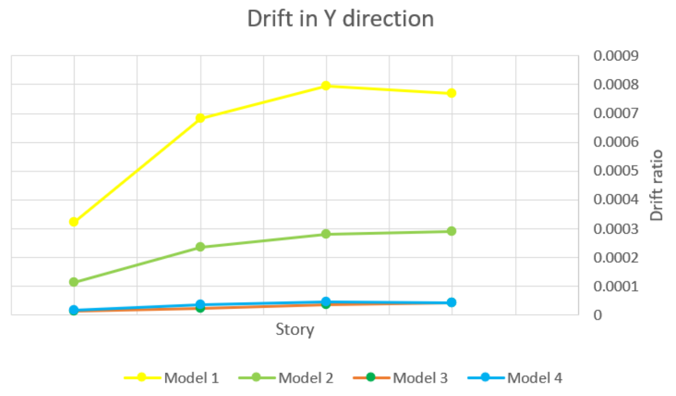


Chart -6: Drift in Y direction

6.5 STOREY DISPLACEMENT

Chart 7 and 8 depict the storey displacements for each of the four models. It illustrates an increase in storey displacement as the structure rises in height. Model 1 has the greatest displacement along the X axis, followed by models 2, 3, and 4. The rigidity of the reinforced model 4 has risen as seen by the minimal displacement.

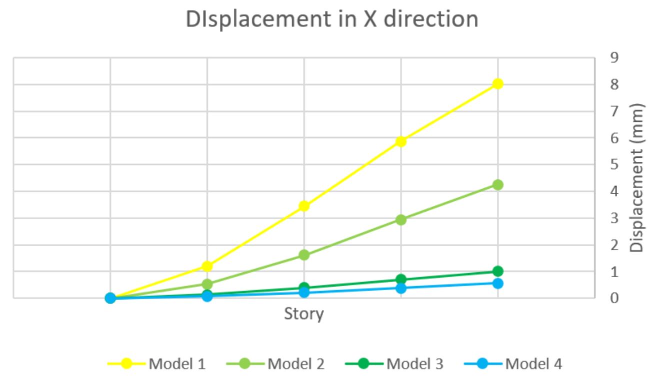


Chart -7: Displacements in X direction

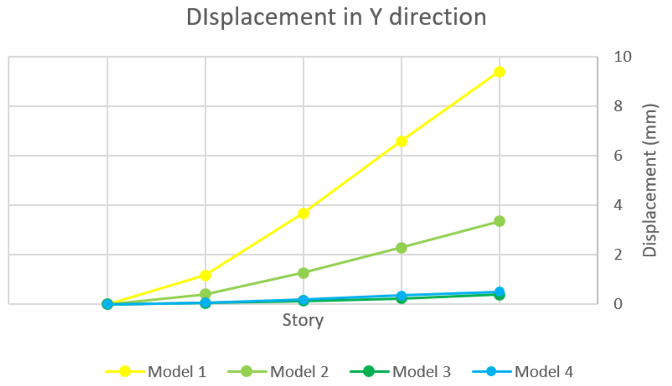


Chart -8: Displacements in Y direction

7. CONCLUSIONS

1. The existence of stiff components within the structure caused a substantial variance in values of torsion related metrics, despite the fact that the exterior perimeters of the structures were comparable.
2. Buildings with adequate shear walls have a shorter natural life span than buildings with insufficient and inappropriately placed shear walls. Furthermore, the modal mass participating ratio of the simulated buildings in this study is within permitted limits, i.e., larger than 90% of seismic weight according to codal requirements.
3. Change in responses of model 1 and 2 shows the difference of not modelling stair case and modelling it, modelling staircase increases eccentricities and stiffnesses.
4. Torsional irregularity is maximized when shear walls are placed as close to the center of mass as feasible without colliding with it.
5. Torsional irregularity can also be decreased by lowering the stiffness of structural walls in the middle.

REFERENCES

[1] A. K. Sinha, and P. R. Bose, “Seismic Vulnerability Assessment of Asymmetric Structures”, 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada, Paper No. 1478, 2004.

[2] 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.

[3] Md. Mahmud Sazzad, and Md. Samdani Azad, “Effect of building shape on the response to wind and earthquake”, International Journal of Advanced Structures and Geotechnical Engineering, ISSN 2319-5347, Vol. 4 (4), pp. 232 – 236, October 2015.

[4] IS 1893 (PART 1) – 2016, “Criteria for Earthquake Resistant Design of Structures” (Sixth Revision).

[5] ETABS 2018. Structural analysis, design, and drafting software for building systems. Computers and Structures, Inc, Berkley. Version18.0.2. Build 2064, 2018.

BIOGRAPHIES

PG Student, Applied mechanics Department, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat, India.

Assistant professor, Applied mechanics Department, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat, India.