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Seismic Response of Irregular Structures

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Abstract: Structural irregularity is a common characteristic in modern buildings due to architectural and functional requirements. However, such irregularities significantly influence the seismic performance of structures, often making their behavior more complex and vulnerable compared to regular configurations. This study investigates the torsional response of reinforced concrete (RC) irregular buildings subjected to seismic loading. The analysis is carried out using the Equivalent Lateral Force (ELF) method as per IS 1893 (Part 1): 2002 provisions. Finite Element Modelling (FEM) is adopted to analyze four different 16-storey building models with varying irregularities, including mass irregularity, stiffness irregularity, and plan irregularity. These models are evaluated under different seismic zones of India. The primary objective of this study is to examine the influence of codal provisions on torsionally irregular structures and identify the most critical type of irregularity affecting seismic performance. Special emphasis is given to discontinuities in the lateral load-resisting system, such as offsets in vertical elements. The results highlight the importance of considering structural irregularities during seismic design to ensure safety and performance.
Keywords: Irregular structures; Seismic design; Irregularity; Torsional behaviour; Earthquake.

I. INTRODUCTION

In practical scenarios, most structures exhibit some degree of irregularity, as perfectly regular configurations are rarely achievable. These irregularities may arise in plan, elevation, or as a combination of both, leading to complex structural behavior under seismic loading.

Seismic design codes such as IS 1893 (Part 1): 2002 classify irregularities and provide guidelines for their analysis. In particular, torsional irregularity plays a significant role in influencing structural response during earthquakes. The code specifies criteria for identifying such irregularities and recommends suitable analysis methods based on building height, configuration, and seismic zone.

In this study, seismic analysis is performed using the Equivalent Lateral Force method, which evaluates structural response within the elastic range. However, it is well recognized that irregular structures may exhibit highly nonlinear and complex behavior under strong ground motion. The present work focuses on understanding the effect of different types of irregularities—such as uneven mass distribution, asymmetric stiffness, and re-entrant plan configurations—on seismic response. Additionally, the study aims to compare the performance of irregular structures with that of a regular building model to identify the most critical irregularity influencing torsional behavior. In the present study, seismic analysis has been performed by Equivalent Lateral Force Method (ELF) i.e. the codal method. It is possible to evaluate seismic response of the structure only in the elastic range. However, it is mentioned in the literatures that, behaviour of the asymmetric structure is highly complex in the inelastic range and this can be investigated by performing inelastic analysis. The effect of torsion is studied with various irregularities as specified in IS: 1893-2002 to evaluate the worst affected irregularity under the influence of torsional moments considering various irregularities.

(a) Highly Irregular Building

(b) Collapse due to Seismic Torsion

Fig. 1 - Asymmetric Structures

1) The present examination targets understanding the significance of codal arrangements, which are especially accommodated the investigation of torsionally unequal structures. IS Code gives the data about number of parameters which impacts the anomaly of the structure. Be that as it may, in the present examination the most exceedingly awful influenced abnormality affected by torsion are contemplated in detail. Consequently, the accompanying targets were distinguished dependent on these parameters. The present examination centers around the discontinuities in a parallel power opposition way, for example, out-of-plane counterbalances of vertical components and so on.Tostudy the effect of irregular distribution of mass in planon the seismic response of structures.
2) To study the influence of asymmetric distribution of stiffness on the structural responses.
3) To study the influence of plan configurations of a structure and its lateral force resisting system containing re-entrant corners.
4) To study the stiffness irregularity i.e. the lateral stiffness in less than 70% of above storey.
5) To study the effect of regular structure on the seismic response and comparing it with irregular distribution of mass, asymmetric distribution of stiffness and irregular plan configurations.

Since, the present study focuses mainly on the torsional moments in the structure, the structural modelling is done without infills. However to capture the realistic behaviour of the structure, finite element modelling consisting of frame, wall and interface elements is recommended.For the analysis of structures having irregular geometric configurations, building codes of various countries recommended, an earthquake spectrum which shall be applied along the direction of principal axis, so that the responses will be maximum. In the present study, this issue is not considered in the analysis of structures. Fixed base condition is assumed for the columns in the present study, however it should be noted that torsional response may increase because of foundation movement. This aspect is not studied.

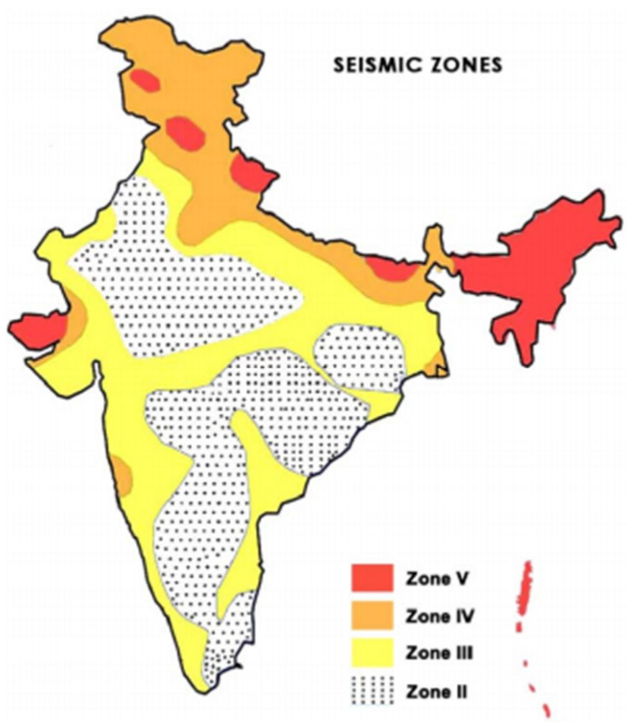

Fig.2 - Sketch of Seismic Zone Map of India as per IS: 1893 (Part 1) – 2007

II. MODELING

In all, four models were considered: Type-1: Regular model (Fig 3); Type-2: Heavy mass at 5th and 10th story (Fig 4); Type-3: Soft story at Base storey (Fig 5); and Type-4: Irregular geometry at plan as Re-entrant corners (Fig 6). Details of Buildings considered in this work are as follows:

- Type of structure: Residential Building
- Height of typical floor: 3.2m
- Column size: 300 mmX500 mm
- Beam size: 300 mmX500 mm

- Slab thickness: 150 mm
- Masonry wall thickness: 230 mm
- Live load: 2 KN/m^2
- Floor finish: 1 KN/m^2
- Earthquake loads are calculated as per IS 1893(Part 1): 2002 for the seismic zone II, zone III, zone IV, zone V.
- Soil types considered as type II – Medium soil.
- All the columns are assumed to be fixed at their base.
- Characteristic compressive strength of concrete, f_{ck}: 20 N/mm^2
- Grade of steel: 500N/mm^2
- Density of Concrete: 25N/mm^2
- Modulus elasticity of concrete: 2000N/mm^2
- Poison's ratio of concrete, µ: 0.3
- Density of brick masonry, ρ: 19.2 KN/m^3
- Modulus of elasticity of brick masonry: 14000 N/mm^2
- Poison's ratio of brick masonry: 0.2
- Damping ratio: 5%

Table 1 - Seismic Calculations for All Zones

Characteristics	**Zone 2**	**Zone 3**	**Zone 4**	**Zone 5**
Number of stories	16	16	16	16
Typical storey height, m	3.2	3.2	3.2	3.2
Seismic zone, Z	0.10	0.16	0.24	0.36
Response reduction factor, R	3	3	3	3
Importance factor, I	1	1	1	1
Soil type	II	II	II	II

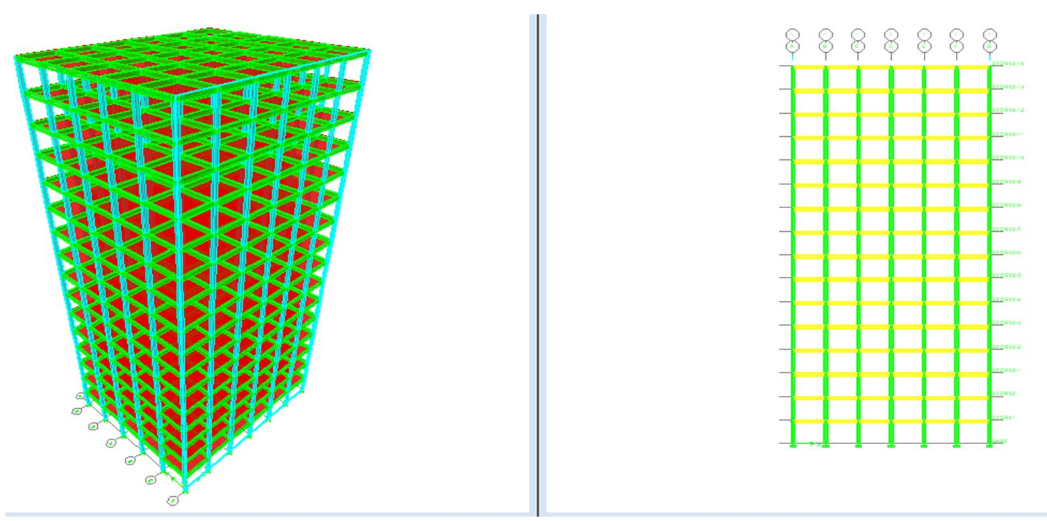

Fig. 3 - ETABS Model of a regular 16 Storied Building (Type-1)

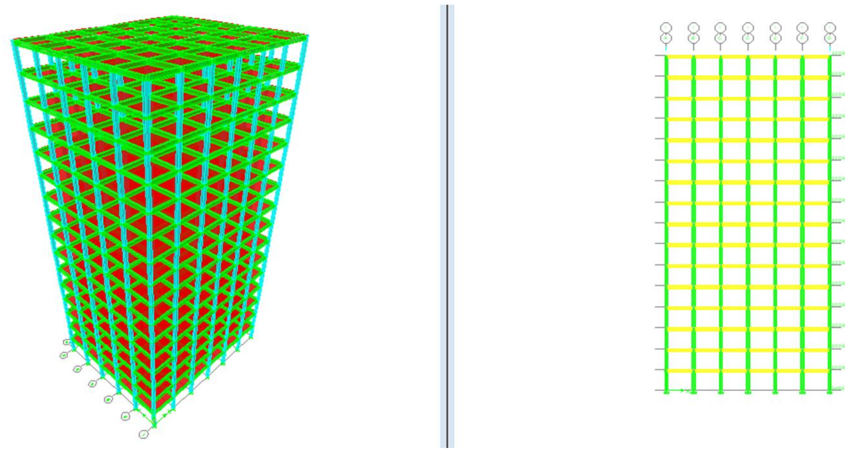

Fig. 4 - ETABS Model of an irregular 16 Storied Building (Type-2) in which an additional mass of 5 KN/m^2 is assigned at the fifth and tenth floors

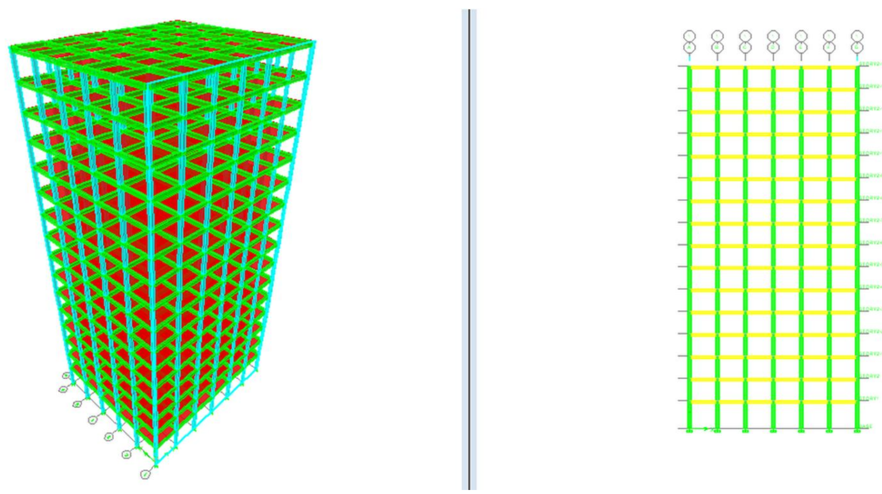

Fig. 5 - ETABS Model of an irregular 16 Storied Building (Type-2) in which the base storey is modelled as soft storey

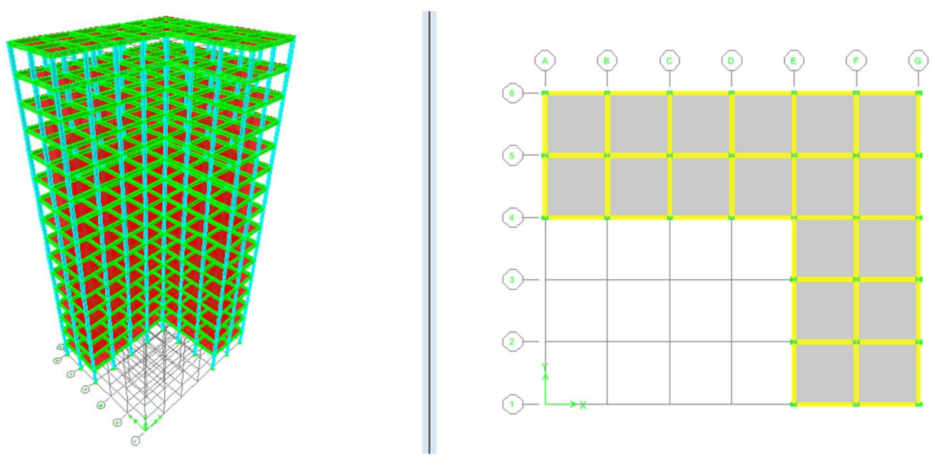

Fig. 6 - ETABS Model of an irregular 16 Storied Building (Type-2) in which the plan is irregular and is made as re-entrant corners

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III. RESULTS AND DISCUSSIONS

The seismic response of the four building models—regular and three types of irregular configurations—has been evaluated in terms of base shear, lateral displacement, storey drift, and natural time period across different seismic zones (Zone II to Zone V). The results clearly demonstrate the significant influence of structural irregularities on seismic performance.

Fig. 7 demonstrates the diagram of Zone v/s Base shear all things considered, it demonstrates that as the zone builds Base shear additionally increments, so the most extreme Base shear is in Sort 4 for example Re-participant corner in zone 5 which is the most powerless seismic zone of India.

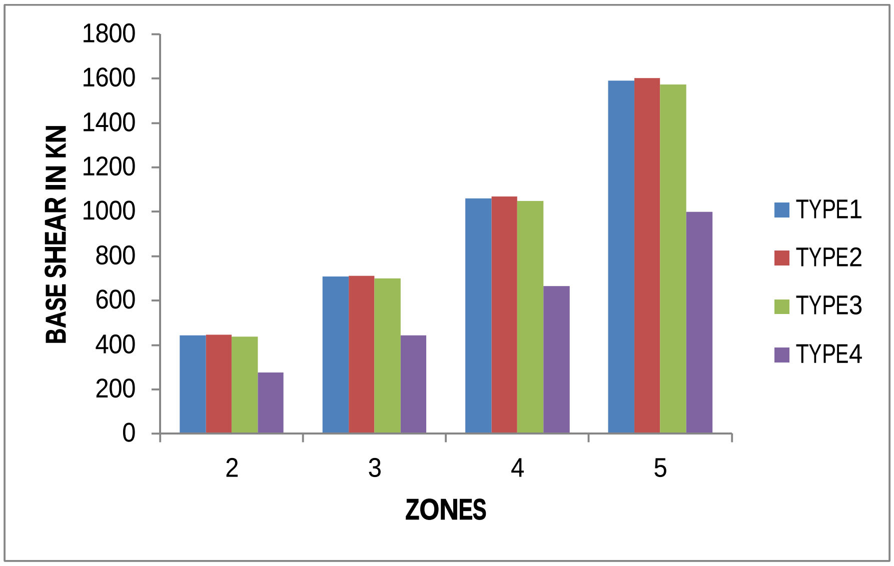


Fig.7 - Graph of Zone v/s Base shear for all type of models

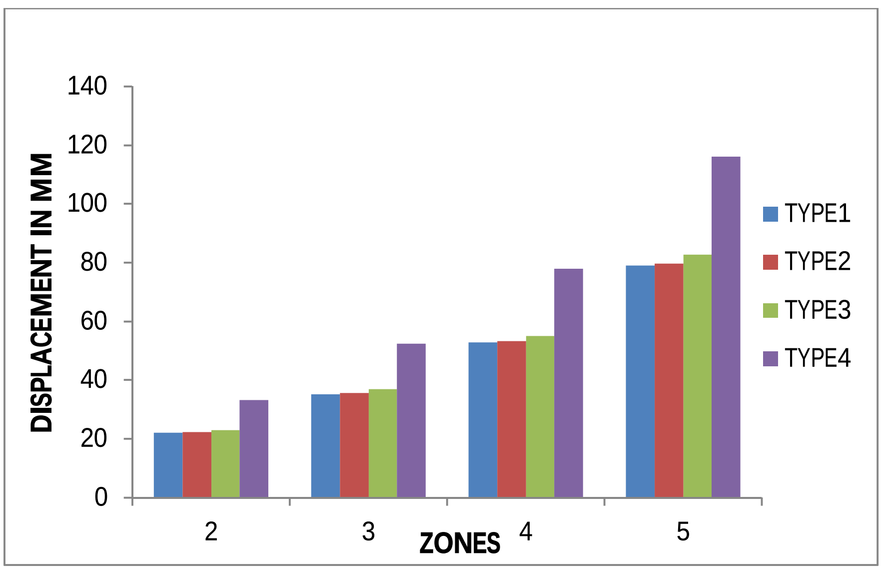


Fig 8. - Graph of Zone v/s Displacement for all type of models

Fig. 8 shows the graph of Zone v/s Displacement of all models, it shows that as the zone increases Displacement also increases, so the maximum Displacement is in Type 4 i.e. Re-entrant corner in zone 5 which is the most vulnerable seismic zone of India.

From Fig. 9, it can be observed that from base storey to 14thstorey the storey drift gradually increases but in 15th and 16thstorey it decreases because usually storey drift is maximum in middle portion of the structure.

Fig. 10 shows the graph of models v/s Time period of all models, it shows that in type 3 i.e. stiffness irregular (soft storey) model maximum time period is 3.13secs in mode 1.

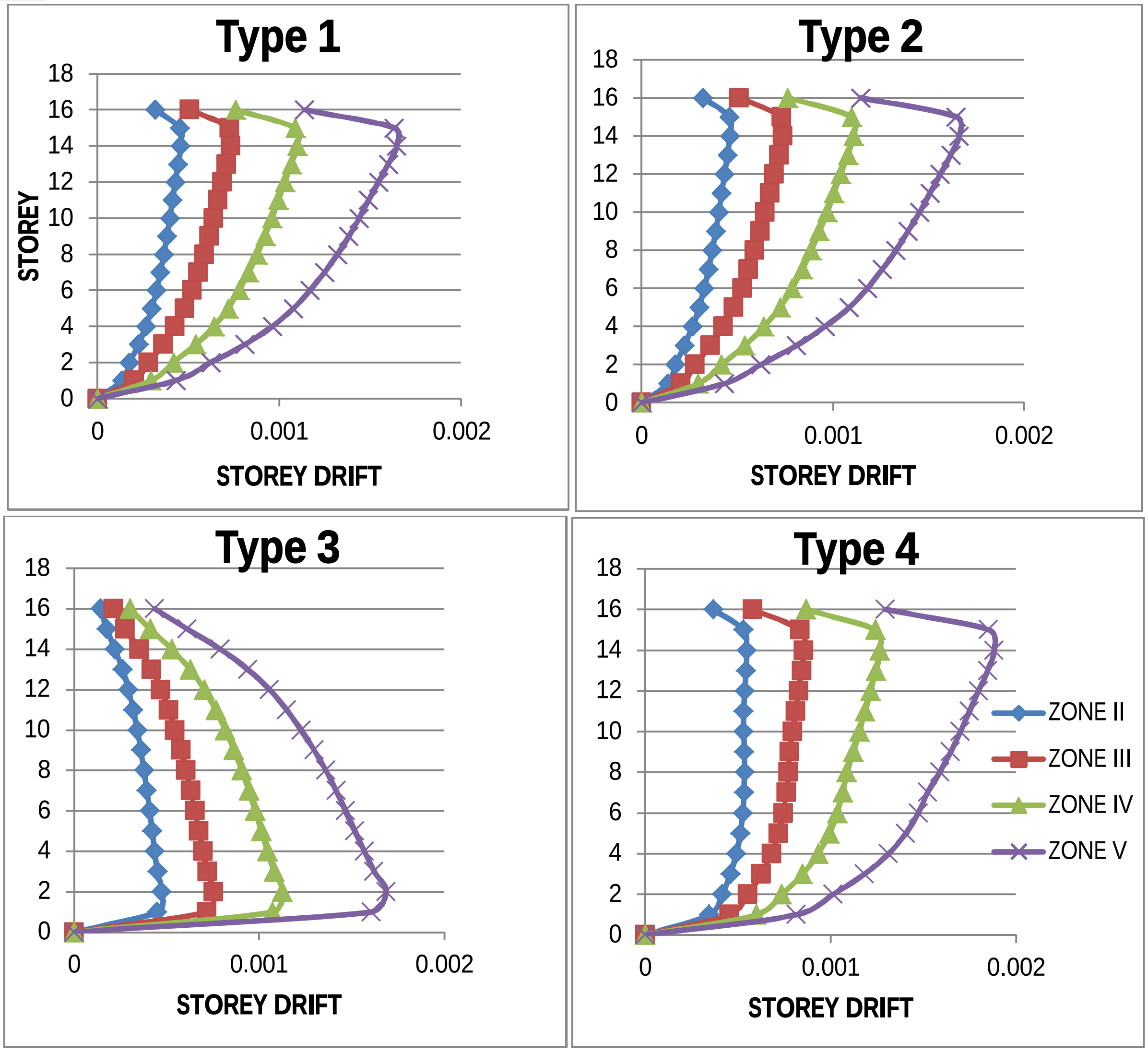


Fig.9 - Graph of Storeydriftsv/sStoreyall the models

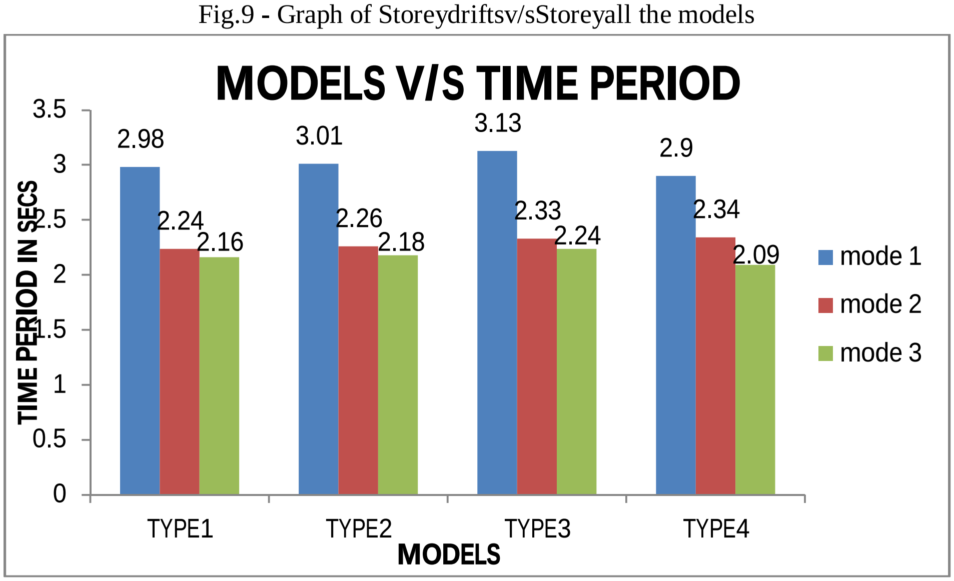


Fig. 10 - Graph of Time period v/s modes for all type of models

IV. SUMMARY AND CONCLUSIONS

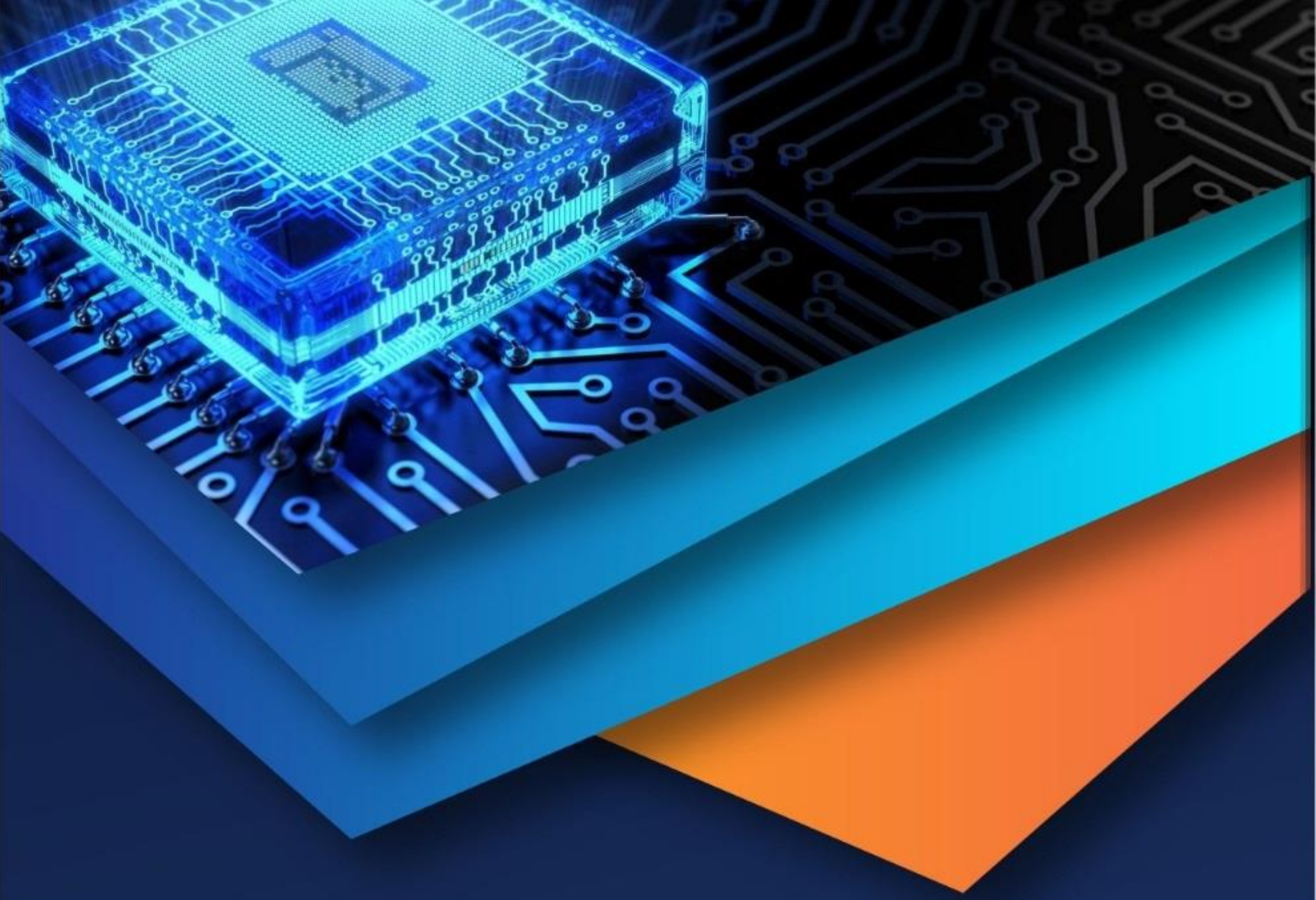
The present investigation tries to assess the impact of firmness on seismic reaction of a vertical sporadic structure on seismic zones II, III, IV, and V on medium soil. The investigation likewise stretches out to discover the impact of Base shear, horizontal uprooting of structures and major normal time of the customary and unpredictable models. The examination prompts the accompanying expansive ends. The following are the key observations of this study-

1) The Base shear and sidelong removals are progressively expanded with increment in zone factors for all models.
2) The horizontal uprooting is less in normal model contrast with vertical unpredictable models.
3) The sidelong dislodging is most extreme in model kind 4 for example the Re-participant corner model.
4) The sidelong dislodging is least in model sort 1 for example the customary model.The base shear is maximum in the model type-2i.e. mass irregularity, heavy mass in 5th and 10th floor.
5) The base shear is minimum in model type-4 i.e. Re-entrant corner model.
6) From the modal analysis, it shows that the natural time period is gradually increases with the type of irregularity.
7) The timespan from the outset mode is high in model sort 3 for example solidness abnormality and low in the model sort 4 for example Re-contestant model.The base shear and lateral displacement are gradually increased with increase in zone factor for all types of models and maximum for severe zone-5.
8) The vertical irregular models i.e. model-3 and model-4 shows the less base shear compare to other type of models.
9) The base shear is almost same in regular model, model type-2 and model type-3.
10) The regular model shows less displacement compare to irregular model, but the displacement is almost same in regular model and irregular model i.e. model type-2.
11) At the point when sporadic structures are examined utilizing direct comparable static examination and Reaction range investigation thinking about various seismic zones as indicated by code arrangements, the outcomes got features the significance of mass, firmness and geometry of the structure. Following wide ends can be made in this regard:
12) This study measures the impact of vertical abnormalities in mass and firmness on seismic requests.
13) From the general examination and perception it tends to be inferring that, Base shear and sidelong dislodging will increments as the seismic force increments from zone-2 to zone-5 which shows progressively seismic interest the structure should meet.
14) Base shear for mass inconsistency is discovered more contrasted with every single other abnormality since base shear relies upon seismic load of the structure.

REFERENCES

[1] GK Hafshejani, PF Dehkordi, R Ghaderi -Structures, 2025 Seismic response of neighboring irregular structures seated at different embedment depths considering soil-structure interaction https://doi.org/10.1016/j.istruc.2025.109298
[2] G Blasi, AS Scarlino, S Chirivì, D Perrone Published: 06 July 2024 Seismic response of irregular RC buildings designed for gravity and seismic loads Volume 22, pages 5231–5257
[3] S Tomer, M Bhandari - IOP Conference Series: Earth and …, 2023 Evaluation of seismic response of irregular buildings Citation Sahil IOP Conf. Ser.: Earth Environ. Sci. 1110 012012 DOI 10.1088/1755-1315/1110/1/012012
[4] H Jia, Y Song, X Chen, S Liu, B Zhang - Buildings, 2022 - mdpi.com Seismic performance evaluation of a high-rise building with structural irregularities Buildings 2022, 12(9), 1484; https://doi.org/10.3390/buildings12091484
[5] Submission received: 23 July 2022 / Revised: 11 September 2022 / Accepted: 14 September 2022 / Published: 18 September 2022
[6] Pannirselvam N, Sreelekshmi M (2022) Study on Irregular Tall RC Structure and Composite Structure by Pushover Analysis. Advances in Construction Management. Lecture Notes in Civil Engineering, 2022. 191
[7] Ravi Kumar C M and Babu Narayan K S. et al.“Effect of Irregular Configurations on Seismic Vulnerability of RC Buildings”, National Institute of Technology, Surathkal, Architecture Research 2017, 2(3): 20-26
[8] Devesh P. Soni and Bharath B. Mistry. “Qualitative review of seismic response of Vertically Irregular Building Frames”, ISET Journal of Earthquake Technology, Vol 43, No.4, December 2016, PP 121 – 132.
[9] Bhattacharya S.P and Chakra borty S, et al., “Estimation of storey shear of a building with Mass and Stiffness variation due to Seismic excitation”, International journal of civil and structural engineering, volume 1, no 3, 2018, Assistant Professor, Department of Architecture, Birla Institute of Technology, Mesra.
[10] George k. Georgoussis. “Simplified dynamic analysis of eccentric buildings with a setback the effect of stiffness irregularity”. Department of civil and construction engineering, school of pedagogical and technological education (aspete), Attica, Greece
[11] Misam Abidi, Mangulkar Madhuri. N. “Review on Shear Wall for Soft Story High-Rise Buildings”, International Journal of Engineering and Advanced Technology (IJEAT), ISSN: 2249 – 8958, Volume-1, Issue-6, August 201
[12] Al-Ali and Krawinkler. 2018, “Effect of vertical irregularity on seismic behaviour of building structures”, Department of civil & environmental engineering, Stanford university.
[13] Vinod Kota Sadashiva., (2011), “Quantifying structural irregularity effects for simple seismic design”, the department of civil and natural resources engineering, University of Canterbury Christchurch, New Zealand
[14] FEMA, Federal emergency management agency.

[15] ATC-40, Applied technology council, California seismic safety commission.
[16] IS: 1893 (Part 2): 2002 Criteria for Earthquake Resistant design of structures.
[17] Pankaj Agarwal and Manish Shirkhande. (2010), "Earthquake Resistant Design of Structures" Prentice – Hall of India Private Limited, New Delhi, India.
[18] Dr. S.K. Dubey, P.D. Sangamnerkar. "Seismic behaviour of asymmetric RC buildings", International Journal of Advanced Engineering Technology E-ISSN 0976-3945, Professor & Head Dept of Civil Engineering, MANIT, Bhopal.
[19] Thuat V. Dinh and Toshikatsu Ichinose. "Criterion for Preventing Formation of Story Mechanism in Vertically Irregular Wall Buildings", Journal of Advanced Concrete Technology Vol. 2, No. 3, 1-10, October 2004.
[20] Poonam, Anil kumar and Ashok k.Gupta. "Study of response of structurally irregular building frames to seismic excitations".
[21] M De Stefano, B Pintucchi "Seismic behaviour of irregular building structures". Bulletin of Earthquake Engineering 6(2), 285-308,2008
[22] Chatpan Chintanapakdee, Anil K Chopra "Seismic response of vertically irregular frames: response history and modal pushover analysis". Journal of Structural Engineering 130 (8), 1177-1185,2004
[23] Das, S. and Nau, J.M. (2003). "Seismic Design Aspects of Vertically Irregular Reinforced Concrete Buildings", Earthquake Spectra, Vol. 19, No. 3, pp. 455-477.
[24] Esteva, L. (1992). "Nonlinear Seismic Response of Soft-First-Story Buildings Subjected to Narrow-Band Accelerograms", Earthquake Spectra, Vol. 8, No. 3, pp. 373-389.
[25] Wood, S.L. (1992). "Seismic Response of R/C Frames with Irregular Profiles", Journal of Structural Engineering, ASCE, Vol. 118, No. 2, pp. 545-566.
[26] Valmundsson, E.V. and Nau, J.M. (1997). "Seismic Response of Building Frames with Vertical Structural Irregularities", Journal of Structural Engineering, ASCE, Vol. 123, No. 1, pp. 30-41.
[27] Shahrooz, B.M. and Moehle, J.P. (1990). "Seismic Response and Design of Setback Buildings", Journal of Structural Engineering, ASCE, Vol. 116, No. 5, pp. 1423-1439
[28] Moehle, J.P. and Alarcon, L.F. (1986). "Seismic Analysis Methods for Irregular Buildings", Journal of Structural Engineering, ASCE, Vol. 112, No. 1, pp. 35-52.



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