



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 6, June 2024

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

 9940 572 462

 6381 907 438

 ijirset@gmail.com

 www.ijirset.com

Study of High-Rise Structures by using Time History Analysis

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ABSTRACT: The practical response to the limited amount of land available is the construction of multi-story buildings, which are driven by the increasing demands of urbanisation and population expansion. Using time-history analysis, this work offers a distinctive and thorough comparison analysis that focuses on the seismic behaviour of high-rise structures with regular and variable story heights. Optimising the design of such structures to provide maximum safety, utility, and economic feasibility is the main goal. The process of design and analysis includes a nine-story residential high-rise building that includes a ground floor. Using the ETABS programme, the design is completed in strict accordance with Indian standards, namely IS 1893 Part 2:2016 for seismic loads and IS 456:2000 for the design of reinforced concrete. The research highlights the critical function of time history analysis in accurately predicting structural responses by capturing the non-linear behaviour seen in irregular structures. This research validates that time history analysis is a more accurate method for understanding the dynamic characteristics of high-rise buildings. A thorough analysis reveals their significant effects on important metrics such as storey drifts, base shear, and storey displacements. The study emphasises how crucial it is to take design flaws into account and make sure that lateral inertia forces are distributed appropriately in order to improve low-rise buildings' seismic performance. The knowledge gained from this study greatly expands the body of information already available on seismic evaluation and the planning of tall buildings. These results provide engineers and designers with important guidance for upcoming projects, enabling them to create structures that are more resilient, safer, and financially feasible while meeting the demands of seismic activity.

KEYWORDS: Time History Method, , ETABS , Time Period.

I. INTRODUCTION

Structural analysis involves determining the behaviour of structures to predict the response of various structural components under different load conditions. This project focuses on identifying bending and shear forces that occur due to different load conditions and aims to design appropriate sections to enhance the serviceability of a G+9 building. To achieve these objectives, the project utilises ETABS (Extended Three-Dimensional Analysis of Building Systems), software integrated with major analysis engines such as static, dynamic, linear, and non-linear analysis. ETABS is specifically designed for analysing and designing buildings, making it a valuable tool for this project.

Structural deformation of critical inelastic nature occurs during big earthquakes, and these changes are permanent in nature. Consequently, inelastic analytical techniques that take these dynamic behaviours into account are needed to assess a structure's performance. Among the techniques used to determine failure modes, evaluate the possibility of dynamic collapse, and comprehend the true behaviour of structures is inelastic time history analysis. While the distribution of mass and stiffness throughout the height of the structure dictates the seismic force distribution, the natural duration of the earthquake affects the seismic base shear that a building experiences. This project intends to shed light on the behaviour and performance of high-rise structures by investigating them critically using time-history analysis, with regular and irregular story heights.

Performing Time History Analysis: The project will utilise the ETABS software to conduct inelastic time history analysis on high-rise structures with both regular and irregular story heights. This analysis will consider the dynamic response of the buildings to seismic loads, including earthquakes, to evaluate their behaviour under extreme conditions. **Assessment of Bending and Shear Forces:** Under various load scenarios, the project will determine and examine the bending and shear forces that arise in the building's structural elements. Understanding the structural reaction and possible weaknesses of high-rise buildings with varying story heights will be made easier with the aid of this evaluation.

Design Optimisation for Serviceability: The project's goal is to suggest and create suitable structural components and sections to improve the G+9 building's serviceability. Ensuring the safety and comfort of passengers during seismic events, reducing deformations, and enhancing overall structural integrity will be the main goals of this optimisation.

Study of regular and irregular story heights: This project will compare high-rise buildings with regular and irregular story heights. We will evaluate the natural periodicity, stiffness, mass distribution, and seismic force distribution of these structures to determine how they behave dynamically. Understanding the benefits and drawbacks of various configurations of story height is the goal of this investigation. Throughout the analysis and design phases, the project will comply with all applicable Indian Standard (IS) norms and guidelines. By following recognised industry standards and best practices, this adherence guarantees that the project will operate in a way that promotes high-rise structures' safety and dependability.

Promotion of Safety and Resilience: Improving high-rise buildings' safety and resilience in India is the project's main goal. The research seeks to guide future design practices and aid in the creation of more resilient and disaster-resistant structures by improving our understanding of the seismic performance and structural behaviour of buildings with varying story heights. The project's main goal is to study how high-rise structures in Seismic Zone IV behave with regular and irregular story heights. Taking into account the unique features of this seismic event, the research will make use of the Bhuj earthquake data for time history analysis.

II. RELATED WORK

- S. Patil and P. D. Kumbhar, [1], The study finds that, for both models taken into consideration, time histories, and varied intensities (V to X), there are consistent patterns in the seismic responses (base shear, storey displacements, and storey drifts). The reactions' values rise from V to X as the earthquake intensities rise. With reference to intensities VI to X, in comparison to intensity V, the base shear, storey displacements, and storey drifts are notably larger (1.85, 3.56, 7.86, 15.1, and 17.15 times) for both X and Y directions, regardless of the presence of a soft story in the models. Crucially, since the realistic time history method accurately calculates seismic hazard and captures true dynamic behaviour, it is a more efficient way to assess the safety of structures built in compliance with the IS code.
- Mr. Gururaj B. Katti and Dr. Basavraj S. Balapgol, [2], The research implies that time history analysis is essential for capturing the non-linear behaviour of irregular structures. Comparatively speaking, equivalent static analysis overestimates displacements, but dynamic studies such as response spectrum and time history analysis accurately reflect movements. Because of the non-linear distribution of forces, irregular buildings need to be studied dynamically. The differences in base shear values amongst the various techniques underline the shortcomings of comparable static analysis and the benefits of time history analysis in terms of capturing non-linear effects and changing mass. Comparing comparable static analysis and reaction spectrum methodologies to time history analysis yields a more accurate and trustworthy assessment of structural safety overall.
- Bahadur Begheri [3], A building's highest displacements rise from the first to the last floor, with the exception of the sixteenth floor, exhibiting inconsistent patterns of displacement. Plan property differences result in smaller centre of mass displacements at the 16th floor compared to the 15th floor. During earthquakes, reaction spectrum assessments record the highest structural response.

III. OBJECTIVE

- To perform seismic analysis of G+9 building model using Etabs software.
- To Find Maximum Value of Global Response.
- To Find Maximum Value of Local Response.
- To check response of model for earthquake ground acceleration.

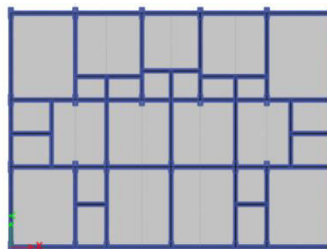
IV. METHODOLOGY

The G+9-story high-rise construction in Zone Iv, with regular and irregular storey height, is examined using the ETABS software and time history analysis based on BHUJ earthquake data, with a building size plan of 15.24mX21.33m

Sr No	Regular Structure	
1.	Types Of Structure	SMRF
2.	Length X Width	15.24mX21.33m
3.	No. Of Storey's	(G+9)
4.	Beam	230mmX450mm
5.	Columns	300mmX600mm
6.	Storey height	3.5m
7.	Slab Thickness	150
8.	Support Condition	Fixed
9.	Grade of Concrete	M30
10.	Grade of Steel	Fe415N/mm ²

Sr No	Irregular Structure	
1.	Types Of Structure	SMRF
2.	Length X Width	15.24mX21.33m
3.	No. Of Storey's	(G+9)
4.	Beam	230mmX450mm
5.	Columns	300mmX600mm
6.	Storey height	4m, 3.5m, 3m
7.	Slab Thickness	150
8.	Support Condition	Fixed
9.	Grade of Concrete	M30
10.	Grade of Steel	Fe415N/mm ²

Model of RCC frame of regular and irregular storey height of high-rise structure



Plan view of regular and irregular structure

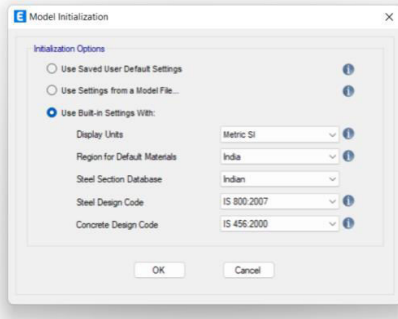
Modeling Steps

The analysis carried out on Etabs software is performed step by step with the following process

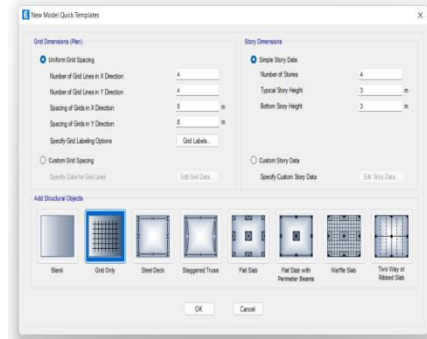
STEP – 1 A new model is selected after running the software, in model initialization Built-in settings with Metric SI units and Indian codes for concrete, steel are selected

Open → New Model → Model Initialization → Use Built-in Settings With →

→ OK → Custom Grid spacing →

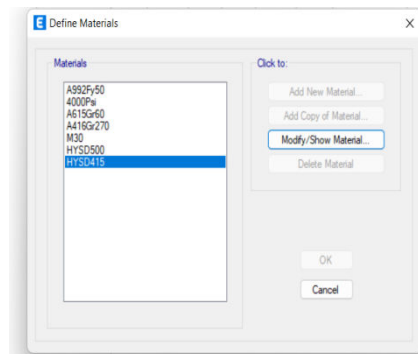
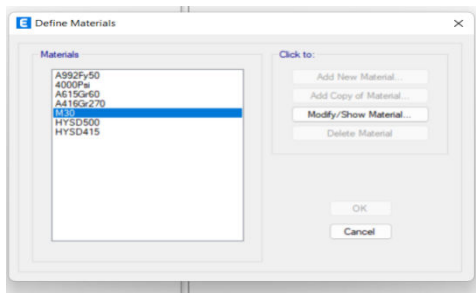


Model Initialization



Custom Grid spacing

STEP – 2 By using the Define menu, Material properties are added
Define → Material properties → Add New Material →

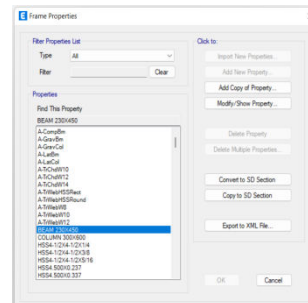
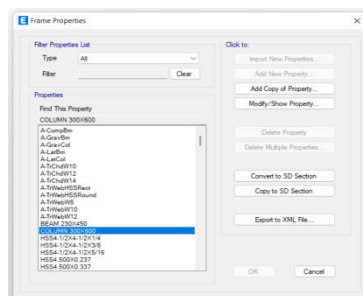


Material properties

STEP – 3 By using define menu section properties are added (Size, material, Clear cover)

*Define → Section Properties → Frame section → Beam 230x450 / Column 300x600 → Modify → Size & Show Rebar

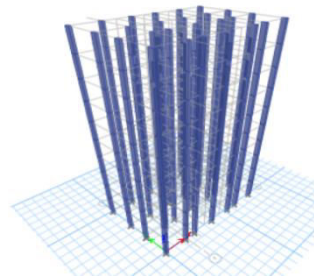
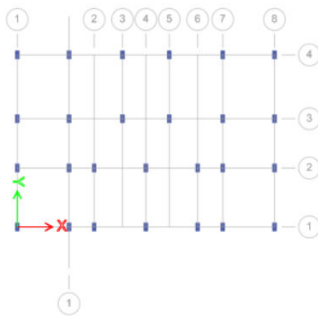
*Define → Section Properties → slab section →



Define Column and Beam

STEP 4 – By using Quick Draw - columns are placed at respective grid intersection points, keeping the worksheet as all story.

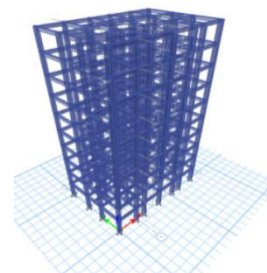
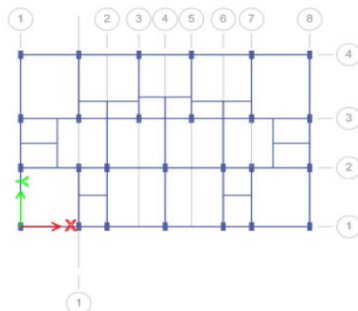
Quick draw column → property column 300x600



Quick draw column property

STEP 5 – By using Draw menu beams are placed

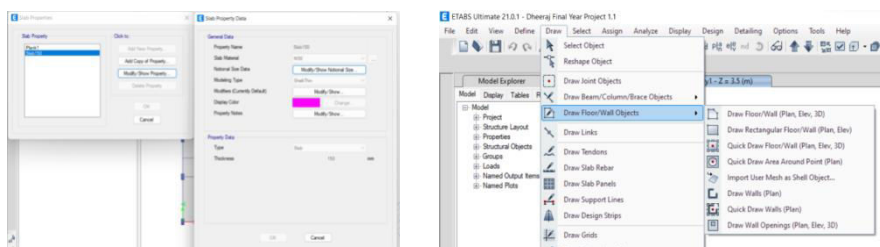
Quick draw Beam → property Beam 230x450

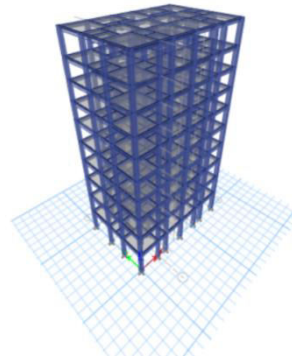
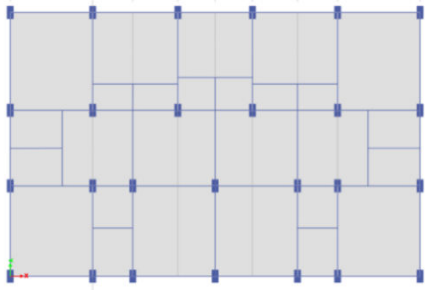


Quick draw Beam property

STEP 6 – By Using Draw menu thin shell slab are placed

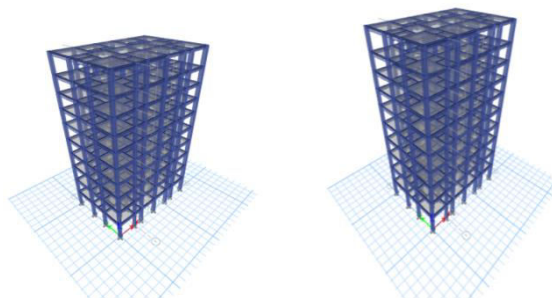
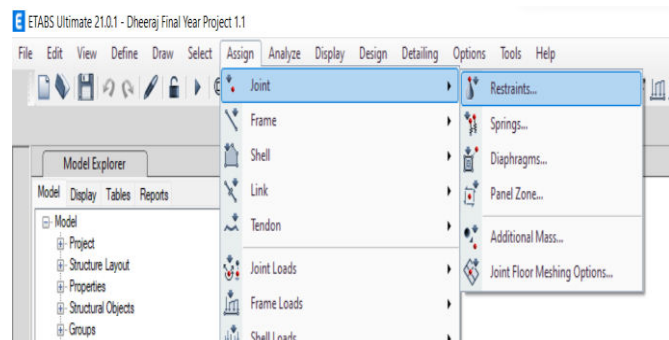
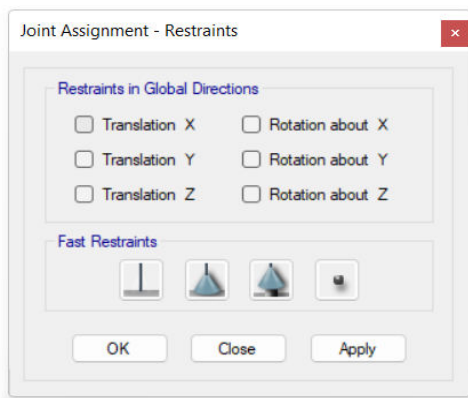
Draw → Draw rectangular floor → slab150





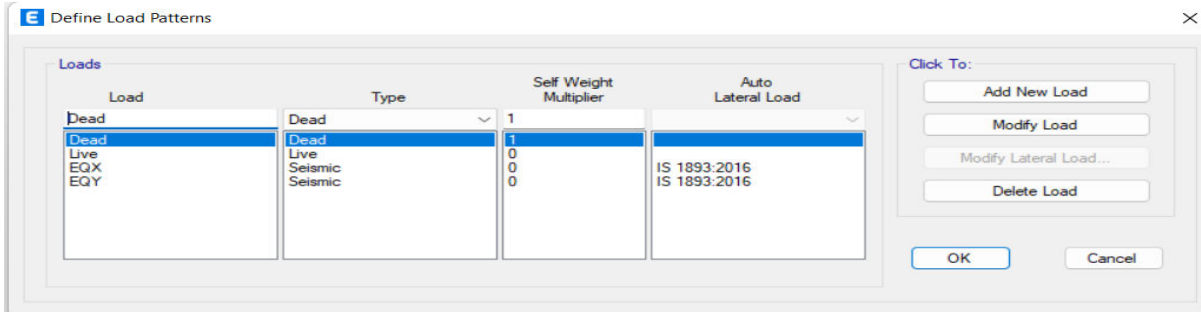
Define Slab150 property

Then add restrain by Assign → joints →restrains → fixed ok

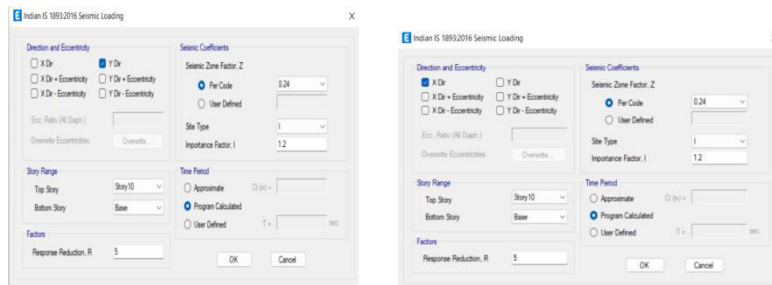


3D view of regular and irregular structure in ETABS

STEP 7 By using the Define menu Load Patterns → Load Case EQX and EQY For Type seismic → Auto Lateral Load IS 1893:2016 → Direction of Eccentricity → seismic Zone Factor IV, 0.24 → Importance Factor I, 1.2 → Response Reduction , R 5 → ok

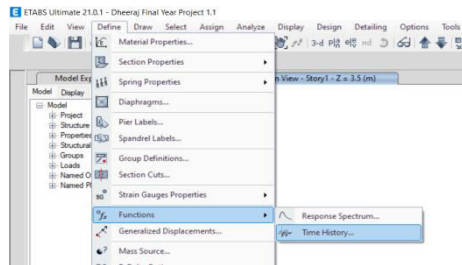


Define menu Load Patterns

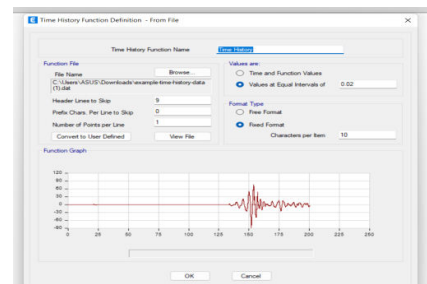


Load Case for EQX and EQY Direction

STEP 8 By using Define menu add time history functions Define → Functions → time history → from file → add new function → browse → define →



Define time history functions



Time history data file

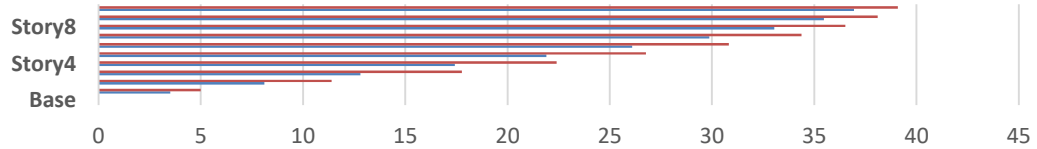
V. ANALYSIS OF RESULTS, GRAPHS AND DISCUSSIONS

Maximum Story Displacement in case of EQ-X-direction

Sr NO	Storey	Regular building			Irregular building		
		Elevation	Location	X -Direction On mm	Elevation	Location	X -Direction On mm
10	Story10	35	Top	36.94	35	Top	39.092
9	Story9	31.5	Top	35.468	32	Top	38.103
8	Story8	28	Top	33.052	29	Top	36.516
7	Story7	24.5	Top	29.866	26	Top	34.375

6	Story6	21	Top	26.094	22.5	Top	30.818
5	Story5	17.5	Top	21.901	19	Top	26.766
4	Story4	14	Top	17.43	15.5	Top	22.399
3	Story3	10.5	Top	12.802	12	Top	17.77
2	Story2	7	Top	8.118	8	Top	11.392
1	Story1	3.5	Top	3.512	4	Top	4.995
0	Base	0	Top	0	0	Top	0

Maximum Story Displacement



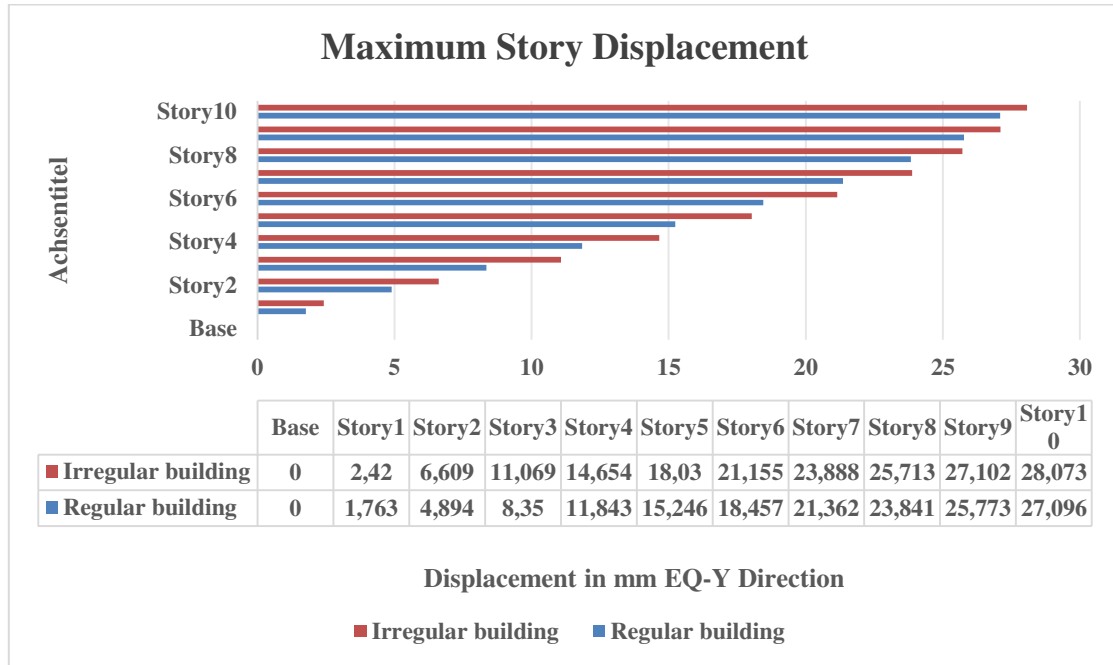
	Base	Story1	Story2	Story3	Story4	Story5	Story6	Story7	Story8	Story9	Story10
■ Irregular building	0	4,995	11,392	17,77	22,399	26,766	30,818	34,375	36,816	38,103	39,092
■ Regular building	0	3,512	8,118	12,802	17,43	21,901	26,094	29,866	33,052	35,468	36,94

Displacement in mm EQ-X Direction

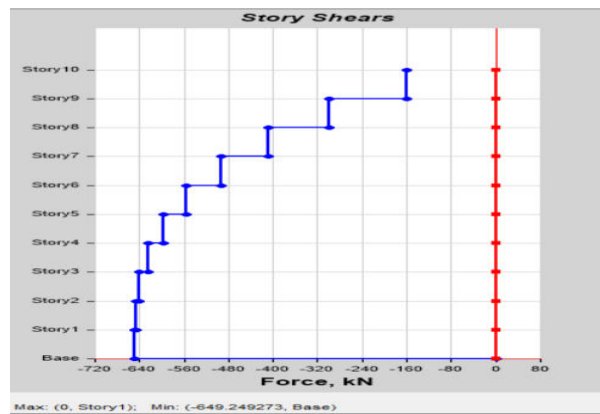
■ Irregular building ■ Regular building

Maximum Story Displacement in case of EQ-Y-direction

Sr NO	Regular building				Irregular building			
	Storey	Elevation	Location	Y - Direction On mm	Elevation	Location	Y - Direction On mm	
10	Story10	35	Top	27.096	35	Top	28.073	
9	Story9	31.5	Top	25.773	32	Top	27.102	
8	Story8	28	Top	23.841	29	Top	25.713	
7	Story7	24.5	Top	21.362	26	Top	23.888	
6	Story6	21	Top	18.457	22.5	Top	21.155	
5	Story5	17.5	Top	15.246	19	Top	18.03	
4	Story4	14	Top	11.843	15.5	Top	14.654	
3	Story3	10.5	Top	8.35	12	Top	11.069	
2	Story2	7	Top	4.894	8	Top	6.609	
1	Story1	3.5	Top	1.763	4	Top	2.42	
0	Base	0	Top	0	0	Top	0	



Maximum Story Shear in case of EQX-direction



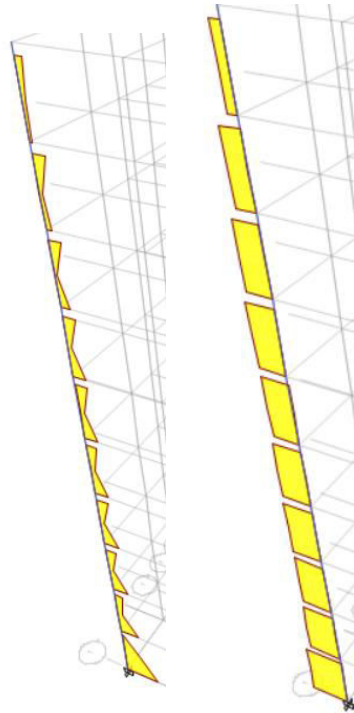
Overturning Moment in in case of EQX-direction



	Local Response Value For Column C1			
	Even building	Uneven building	Even building	Uneven building
	V2	V2	M3	M3
Story	kN	kN	kN-m	kN-m
Story10	0.7735	0.6267	2.1186	1.6437
Story9	1.5497	1.3264	3.3491	2.6387
Story8	2.0709	1.6695	3.4548	2.9431
Story7	2.334	1.9395	3.8988	3.3015
Story6	2.3271	1.8984	4.1085	3.4128
Story5	2.6104	2.1258	4.244	3.4187
Story4	2.7539	2.1512	4.9047	3.6102
Story3	2.7903	2.4455	5.2048	4.5602
Story2	3.0425	2.7779	6.102	5.9644
Story1	3.7302	3.4909	11.4735	11.6671

	Local Response Value For Beam B4			
	Regular building	Irregular building	Regular building	Irregular building
	V2	V2	M3	M3
Story	kN	kN	kN-m	kN-m
Story10	0.9606	0.758	1.5688	1.2052
Story9	1.7777	1.3657	3.0259	2.354
Story8	2.6409	1.9904	4.3974	3.5036
Story7	3.2474	2.5207	5.2022	4.4917
Story6	3.5187	2.8141	5.9769	4.9351
Story5	3.8254	3.1725	6.9521	5.7032
Story4	4.1262	3.4382	5.8383	4.7418
Story3	4.1363	3.5703	6.9865	5.9773
Story2	4.199	4.2713	5.9215	5.3231

Story1	3.6053	3.8878	5.0237	4.7887
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Shear force Bending moment

VI. CONCLUSION

- Both regular and irregular buildings show reduced displacements from top to base in both the EQ-X and EQ-Y, TH-X and TH-Y axes.
- Storey displacements of regular buildings is increasing in the X-direction (42.22%) and Y-direction (32.26%) as compared to irregular buildings.
- Storey drifts of regular buildings is increasing in the X-direction (30.96%) and Y-direction (20.03%) as compared to irregular buildings.
- The irregular building shows significantly maximum story displacement, indicating that of story height can impact the of displacement of stories.
- Local response of column in terms of story shear is found to be maximum in regular story high building .
- Local response of beam in terms of story Bending moment is found to be maximum in regular story high building.

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