SEISMIC PERFORMANCE ANALYSIS OF IRREGULAR STEEL BUILDING

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Abstract: The seismic performance of buildings is a critical concern in civil engineering, particularly in regions prone to earthquakes. Irregularities in steel building structures, such as asymmetries and discontinuities, pose unique challenges in predicting and mitigating seismic effects. This abstract focuses on the response spectrum performance analysis of irregular steel buildings within the Masters of Technological Engineering (MTech) stream of Civil Engineering in Structural Engineering (SE). The study aims to comprehensively investigate the dynamic behavior of various irregular steel structures under seismic loading, utilizing response spectrum analysis as a tool to provide detailed insights into the complex interplay between irregularities and structural response. The analysis employs advanced computational models and simulation techniques, as per the code IS 1893-2016 with a primary focus on response spectrum analysis. Response spectrum analysis is a widely accepted method for evaluating the dynamic response of structures to seismic forces. Realistic three-dimensional models of 4 different shape (Square shape, T-shape, L-shape, C-shape) are created with all wind load as per the code IS 875-2015 and different load combination as per Indian Standard code to capture the complexities of irregular structural geometry accurately. The outcomes of this research hold significant implications for civil engineering practices. The detailed understanding of response spectrum characteristics in irregular steel buildings can lead to refined design codes and guidelines. This, in turn, can contribute to designing structures that not only meet safety standards but also exhibit optimal performance under varying seismic conditions.

Index Terms – **Irregular steel building, Seismic performance, Response spectrum analysis.**

1. INTRODUCTION

The effect of seismic loads on steel buildings is a critical aspect of structural engineering, as seismic events can exert dynamic forces that significantly impact the integrity and performance of these structures. This explanation delves into the complex interactions between seismic loads and steel buildings, elucidating the challenges and considerations involved.

The selection of the installation process plays an important role in the basic plan of earthquake protection against ground vibrations. Seismicity analysis of the model confirmed that the irregular model was exposed to more hazards than the reference model. In this direction, conflict needs to be taken into account and limited to the unsustainable model in order to maintain the difference between rapid change of quality and challenges. Non uniform standards are registered in the Indian Standard Codes. Inconsistencies are divided into vertical irregularities and horizontal irregularities. Some of the irregularities are willingly used for the aesthetic purpose and for making structure attractive. Vertical discrepancy refers to the uneven distribution of power depending on the height of the structure or the difference in **size, stiffness, number and efficiency**. For the analysis of the structure, we prefer a horizontal irregularities of steel building with various types of shapes some of them are mentioned below

1. Square Shape
2. T-Shape
3. L-Shape
4. C-Shape.

For the various shape and parts, we use various **I-Shape** steel section for the beam and column as per the Indian Standards (ISHB, ISMB, ISWB, ISLB) using "trial and error method" to find an adequate section that counter with this load patterns. After all the theoretical experiments the point we clarify is the different results in various load, load patterns, structure shapes. compare all of them with each other to find out which structure among them give the weakest and the lowest performance towards the Response Spectrum Analysis on ETABS (software)

1.1 WHY WE PREFER STEEL BUILDING OVER RC BUILDING?

Design flexibility: Steel structures can be designed in a variety of shapes and sizes, and can be easily expanded and modified.
Durability: Steel is a durable material that can withstand significant impacts without breaking. It's also resistant to Mold, termites, and corrosion.
Maintenance: Steel buildings have low maintenance requirements and costs.
Construction: Steel buildings are quick and easy to install.
Strength-to-weight ratio: Steel has a better strength-to-weight ratio than concrete, which allows for lighter buildings with less expensive foundations.
Earthquake resistance: Most steel structural components are bolted, which allows for slight deformation during earthquakes Ease of Use

1.2 NEED OF RESEARCH

After a study the various research papers on response spectrum analysis of irregular steel buildings are crucial for understanding and mitigating potential seismic risks. This analysis helps engineers evaluate the dynamic behaviour of structures under earthquake loads, ensuring their safety and resilience. Irregularities in steel buildings, such as variations in mass or stiffness, can significantly impact their response to seismic forces.

The response spectrum analysis is a valuable tool in earthquake engineering, providing a graphical representation of a structure's response to varying ground motions at different frequencies. In the context of irregular steel buildings, this analysis becomes particularly essential due to the complexity introduced by irregularities in design and construction.

The horizontal irregularities in steel buildings may arise from asymmetrical mass distribution, eccentricities in lateral stiffness, or irregular floor plans. Investigating the effects of these irregularities through response spectrum analysis with a different type of shapes with a various I-steel section allows researchers to identify potential vulnerabilities and propose design modifications to enhance seismic performance.

Furthermore, the research delves into the significance of accurate modelling in ETABS software in response spectrum analysis. Developing precise mathematical models that represent the real-world behavior of irregular steel buildings with a different load and load combination as per the IS code is critical for obtaining reliable results. Advanced computational tools such as ETABS and simulation techniques play a pivotal role in achieving accurate representations of structural responses under seismic loads.

In conclusion, a comprehensive research paper on the response spectrum analysis of irregular steel buildings serves as a vital contribution to earthquake engineering. By examining the fundamental principles, modelling accuracy, real-world case studies, and implications on design standards, such research enhances our understanding of how these structures respond to seismic forces, ultimately leading to safer and more resilient buildings.

2. LITERATURE REVIEW

Radhika S. Patil, H. S. Jadhav: - The results have been withdrawn in terms of base shear, storey drift, storey displacement and time period. The seismic analysis of steel framed structure has been performed in this work. All the results withdrawal are based on the response spectrum analysis performed in the E Tabs. Obtained results shows that as the number of storeys increases the value of storey displacement increases similarly the value of time period increases as number of storeys increases. The base shear is more in shorter side of the building. The results obtained are within permissible limits.

Yash Chhatani, Dr. Prashant Y Pawade, Dr. Kuldeep R Dabhekar, Dr. Isha P Khedikar: - To design L-shaped building in ETABS study the seismic response demands of L shaped building and compare the L-shaped building plan with other shaped building plans of W shaped and I shaped, L shaped structures some of these marked out point: - L-shape buildings are safe if they are not high rise. And it is also safe if it is only constructed in ground floor. If we design the irregular building the semi rigid diaphragm is considered. Irregular buildings are more vulnerable because of the stress concentration in the re-entrant corner. It is observed that sporadic structures are more utilized in new architectural design. In these structures the torsion phenomenon can induce detrimental stresses especially in the case of a seismic movement. it was observed that there is still a lot of study required to make sure that the designing the L shaped building in high seismic prone areas are really safe as per earthquake point of view. It has been observed from almost all literature review the building structures are L-shaped seems to give better results if the code provisions are sufficient and should be amended. Hence, finally from the study it can be concluded that as far as possible, the designer should take all the specialized viewpoints to make the structure seismic tremor resistant and safe.

Yeshodhara T S, Pradeep A R, Dr. N Jayaramappa Professor: - The base shear was observed that maximum for Framed Building with Masonry Infills and reduced for Framed Building with Ferro-cement Panels and further reduced for Bare Framed Building. The maximum displacement was observed in Bare Framed Building for both equivalent static condition and response spectrum condition. Pushover analysis results shows that hinges formed in members at performance point are under immediate occupancy level in SAP2000 software. The maximum value of performance point for the structure having masonry infills and ISHB250–2 with Top and Bottom Plate of 320mm width and 25mm thick as a column is 4934.575 kN and 4044.360 kN along X and Y direction respectively. The results obtained from Framed Building with Masonry Infills and ISHB250–2 with Top and Bottom Plate of 320mm width and 25mm thick as a column gives the maximum displacement of 396.354mm at performance level.

M. T. Raagavi, Dr. S. Sidhardhan: - Comparison of base shear, maximum displacement, maximum moment, beam end forces, storey height vs displacement, storey height vs beam end forces, storey height vs moment. Irregularities in buildings causes eccentricity between the building mass and stiffness centers, give rise to damaging effect on building. Structures with plan irregularities quite often suffer severe damage in earthquake events. Response spectrum analysis is the generally used method for analysis and design of earthquake resistance structures. But Time history analysis is more eminent and precise than Response spectrum analysis. Plan regular structure and 'O' shaped structure suffered maximum displacement compared to other irregularities. Though the regular structure showed baser shear and displacement value, the load transfer was even throughout the structure, which is an important while considering a structures safety during an earthquake. The formation of re-entrant corners greatly affects the load path. The L shaped structure showed the least performance during an earthquake. The moment of inertia

has much importance in the stability of seismic resistant building which in turn clears the influence of mass of a structure. In high rise buildings the top stories are the one most affected if the structures are with irregularities.

3. OBJECTIVE

For the seismic performance analysis of irregular steel building the main objectives of response spectrum analysis is give a more accurate and effective as a mentioned below;

Analyse Seismic Performance: The main goal is to determine the building's seismic resistance. Response spectrum analysis is useful in comprehending the behaviour of a structure subjected to earthquake loading, as irregularities can give rise to intricate dynamic behaviour.

Determine the Vulnerable Zones: Certain areas of the building may experience a concentration of seismic stresses due to anomalies in mass or stiffness, such as discontinuous mass distribution or soft stories or torsional irregularities. Response spectrum analysis is useful in locating these weak points where structural reinforcement could be required.

Engineering purpose: Engineers can quantify the dynamic response of a structure, which includes maximum displacements, accelerations, and inter-storey drifts, by examining the response spectrum. For the purposes of design and retrofitting, this knowledge is essential.

Check for Code Compliance: Standards for evaluating irregular buildings under seismic loads are frequently included in building codes. Engineers can confirm if the building complies with these code standards or whether further steps are required for compliance using response spectrum analysis.

Optimize Design: In order to enhance seismic performance, structural design parameters may be optimized with the use of response spectrum analysis. In order to lessen the consequences of irregularities, engineers might modify structural components including damping systems, stiffness distributions, and bracing arrangements.

Predict structure reaction: Engineers can forecast the structure reaction to various seismic situations by entering the relevant ground motion recordings into the analysis. The capacity to foresee the future is crucial for evaluating risks and organizing emergencies.

Evaluate Retrofitting procedures: Response spectrum analysis is a useful tool for assessing the efficacy of retrofitting procedures intended to improve seismic performance in existing structures that have anomalies. To make sure that retrofitted structures fulfil intended performance goals, engineers can model how they will behave.

Boost Safety: In the end, response spectrum analysis in non-uniform multistorey steel buildings aims to reduce the chance of structural failure or damage to buildings during seismic events while also boosting occupant safety.

4. STRUCTURE DETAILS

Design a different shaped steel structures we use a ETABS software for their convenience and easy mode to prepare a model and analysis of different aspect of steel structure. For this model design we use an IS (Indian Standards) parameter. Making a model in ETABS software

Seismic performance analysis we make a different shaped horizontal irregular structure to analyses its behavior. There we make a 4 different types of structure model with

1. Square shape
2. C shape
3. T shape
4. L shape

This structure is individually divided in 3 different bays based on their storeys there for the,

1. 1 to 10 storey (Square 6*6 bay)
2. 11 to 15 storeys (Square, L shape, T shape, C shape)
3. 16 to 18 storey (Square 2*2 bay)

Table 3.1: - Structure Details

Plan Dimension	24m * 24m
Storey	18
Height of each storey	3m
Total height	54m
Steel design code	IS 800-2007
Concrete design code	IS 456-2000
Steel grade	Fe345
Concrete grade	M20
Frame section	Steel I/Wide flange
Slab thickness	125mm
Restrain	Fixed
Diaphragm	D1, Rigid
Dead load	2kN/m2
Live load	2.5kN/m2
Floor load	1kN/m2
Earthquake load	IS 1893:2016
Seismic zone factor Z	0.36
Silt type	II
Importance factor I	1
Wind load	IS 875:2015
Wind speed Vb	50m/s
Terrain category	2

Risk coefficient K1	1
Topography factor K3	1
Response spectrum	IS 1893:2016
Seismic zone	V
Soil type	II
Response reduction factor R	5

Table 3.2: - Section of Beam & Column

	Square model	L model	T model	C model
Storey 1-10	ISHB450-2	ISWB600-2	ISWB600-1	ISWB600-1
Storey 11-15	ISHB225-1	ISHB400-1	ISWB500	ISWB400
Storey 16-18	ISHB200-1	ISHB300	ISWB250	ISWB300
Beam	ISMB250	ISMB500	ISMB550	ISMB600
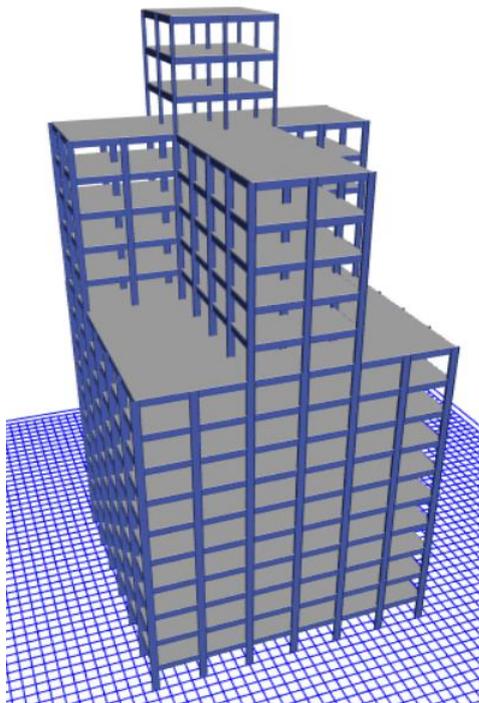
Fig. 3.1 T-model render view   Fig. 3.2 C-model design check
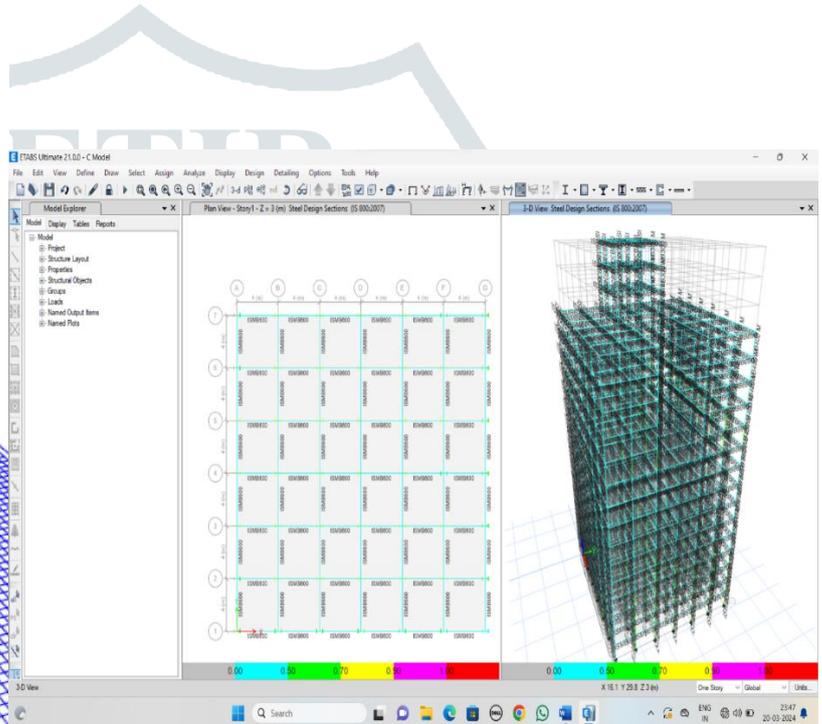
Special design a columns Seismic loading condition and Response Spectrum Analysis we made a special design of column section for a high rise building to a safe loading transfer and detailing of structure that can encounter all loading condition and load combinations. Special design of a column we make a thick steel plate attached with steel section flanges on both side and make it stronger and more durable to withstand loading conditions.

Design of plates: - Width of steel plate = Width of flange + 20 mm (10mm on both side)
Thickness of steel plate = 12 mm

This 10 mm space is made on both side for a welding purpose and this special design section is denoted by 'M' in column sections.

As per IS code 875:2015 (part V) and as per IS code 1893:2016 we define a load combination in linear add this loads and load combinations assign in an all-model structure as per mentioned below;

1. 1.5 Dead load + 1.5 Live load
2. 1.2 Dead load + 1.2 Live load + 1.2 Wind X
3. 1.2 Dead load + 1.2 Live load + 1.2 Wind Y
4. 1.2 Dead load + 1.2 Live load + 1.2 EQ X
5. 1.2 Dead load + 1.2 Live load + 1.2 EQ Y
6. 0.9 Dead load + 0.9 Live load + 0.9 Wind X
7. 0.9 Dead load + 0.9 Live load + 0.9 Wind Y
8. 0.9 Dead load + 0.9 Live load + 0.9 EQ X
9. 0.9 Dead load + 0.9 Live load + 0.9 EQ Y

5. COMPARATIVE ANALYSIS

After performance analysis of all 4 types of model C-shape, Square shape, L-shape, T-shape in a design forces of beams, design forces in column, maximum storey displacement, maximum storey drift now we do a comparison analysis of performance in beam, column, and response spectrum analysis in maximum storey displacement & maximum storey drift between of all 4

types model and discuss the result of which structure give a best performance and which give poor performance on a seismic loading conditions.

5.1 DESIGN FORCES IN BEAM

Design forces in beam we do a comparative performance analysis of all 4 types of models as per mentioned below;

1. Shear force V (kN) max.
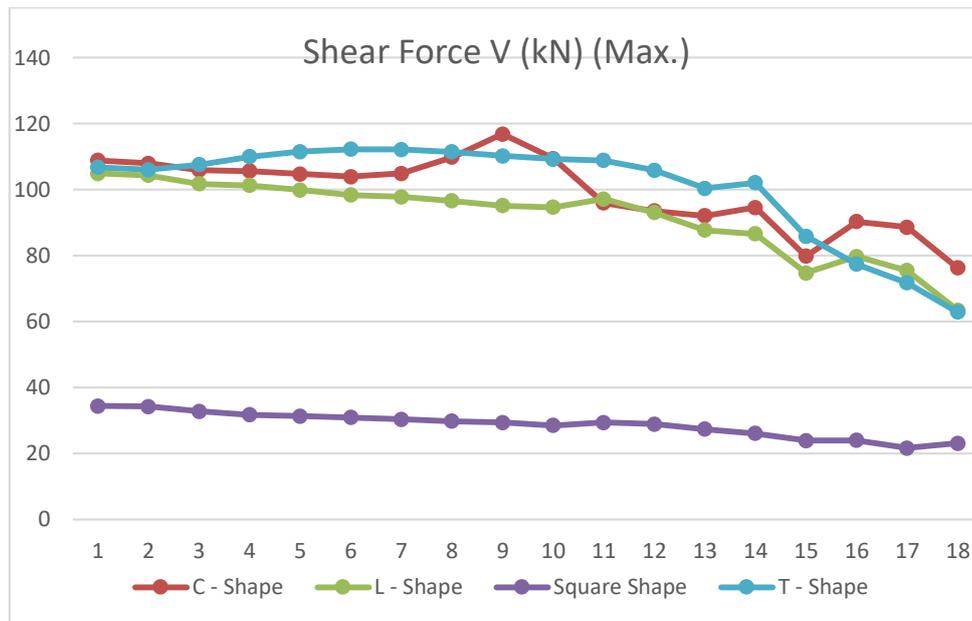2. Bending moment M (kN-m) max.
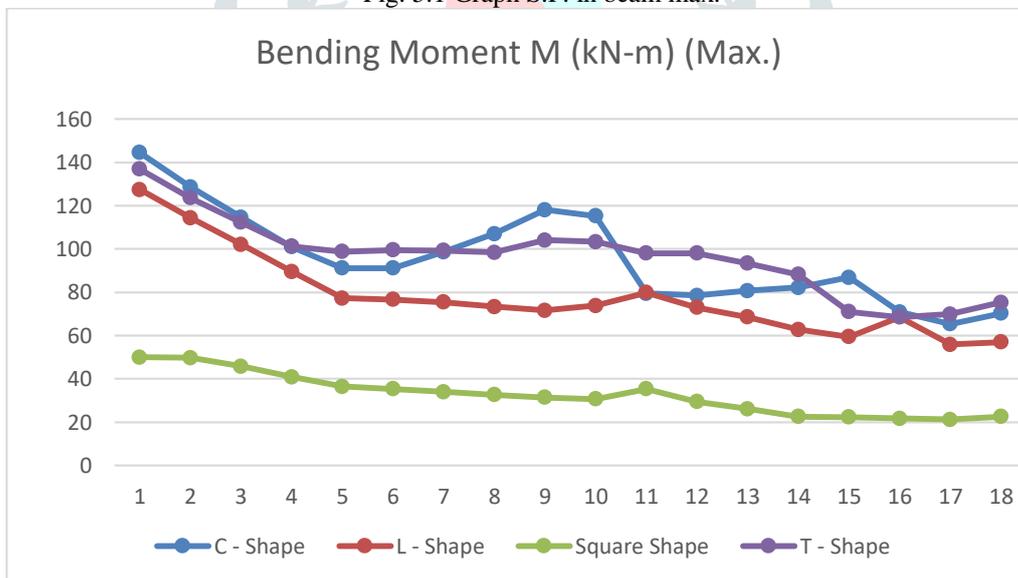

Fig. 5.1 Graph S.F. in beam max.
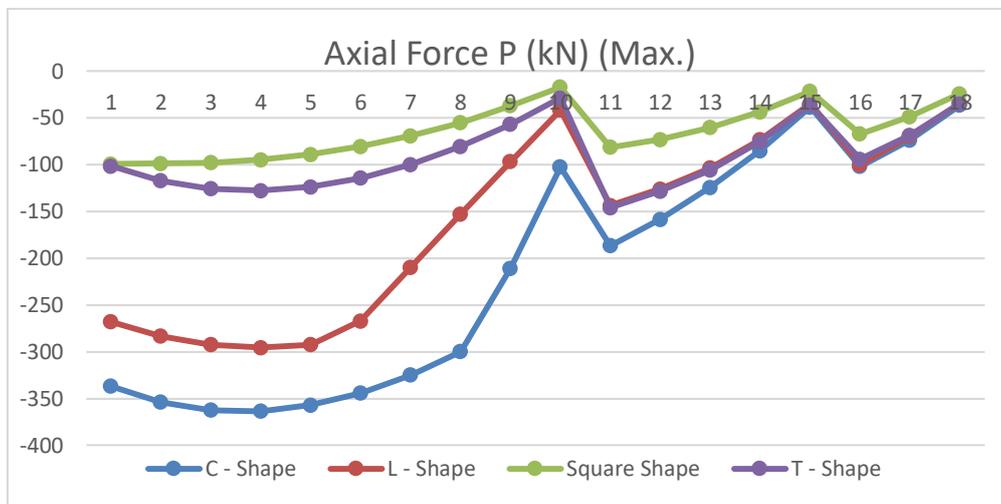

Fig. 5.2 Graph B.M. in beam max.

5.2 Design forces in column

Design forces in column we do a comparative performance analysis of all 4 types of models as per mentioned below;

1. Axial force P (kN) max.
2. Shear forces V (kN) max.
3. Bending moment M (kN-m) max.
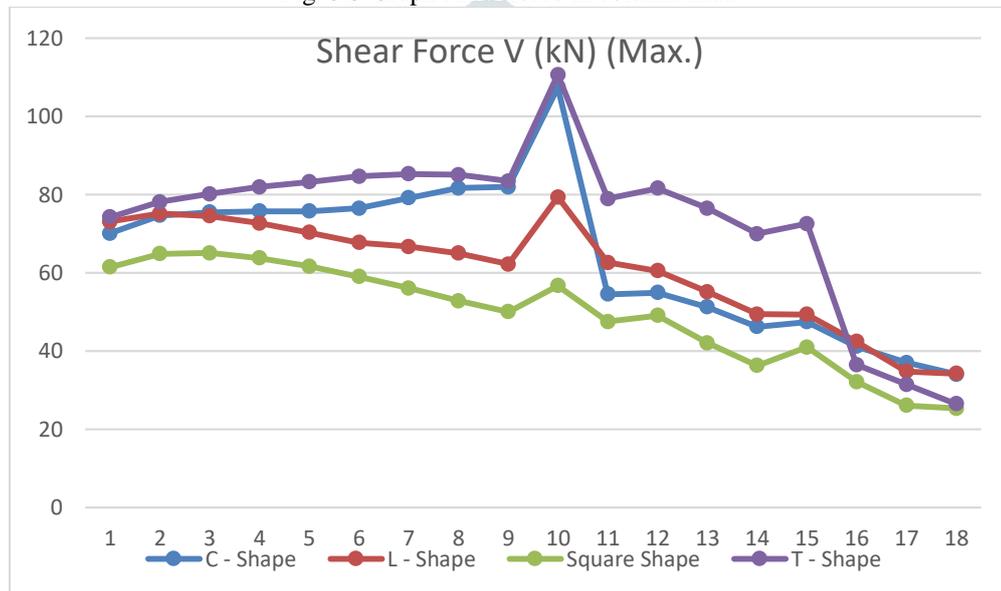
Fig. 5.3 Graph Axial force in column max.
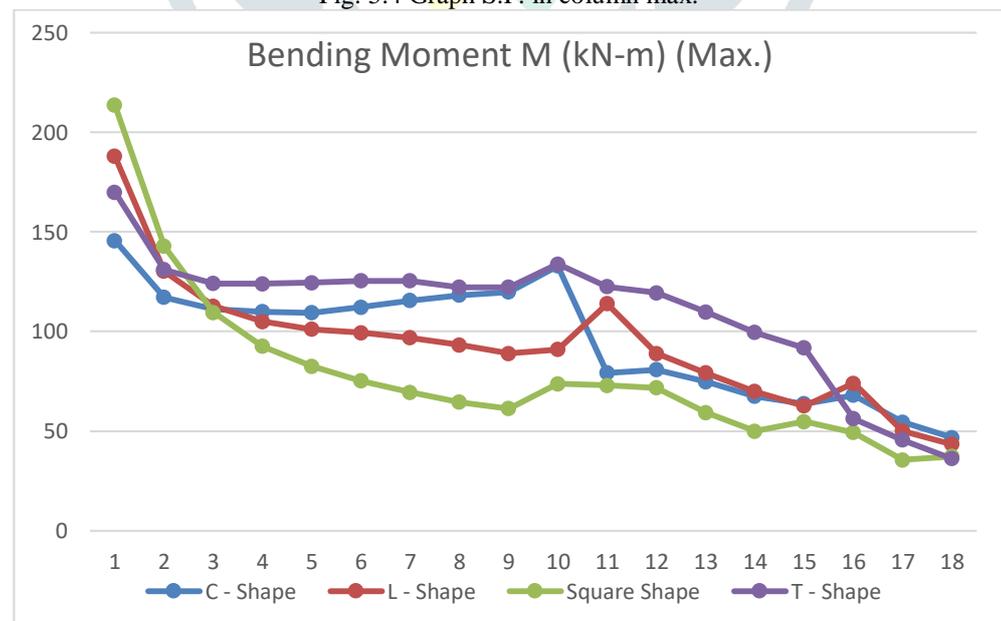

Fig. 5.4 Graph S.F. in column max.

Fig. 5.5 Graph B.M. in column max.

5.3 Response spectrum analysis

   Comparatively performance analysis of all 4-shape model in a response spectrum analysis considers as per mentioned below;

1. Maximum storey displacement RSA-X (mm)
2. Maximum storey displacement RSA-Y (mm)
3. Maximum storey drift RSA-X
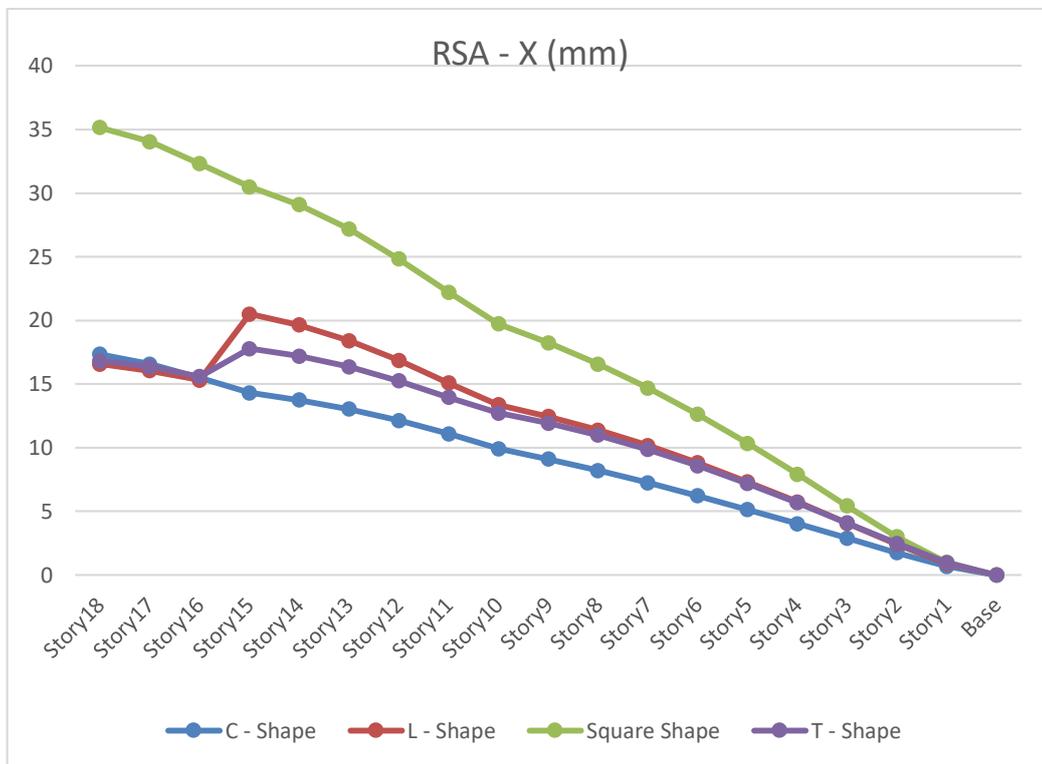4. Maximum storey drift RSA-Y
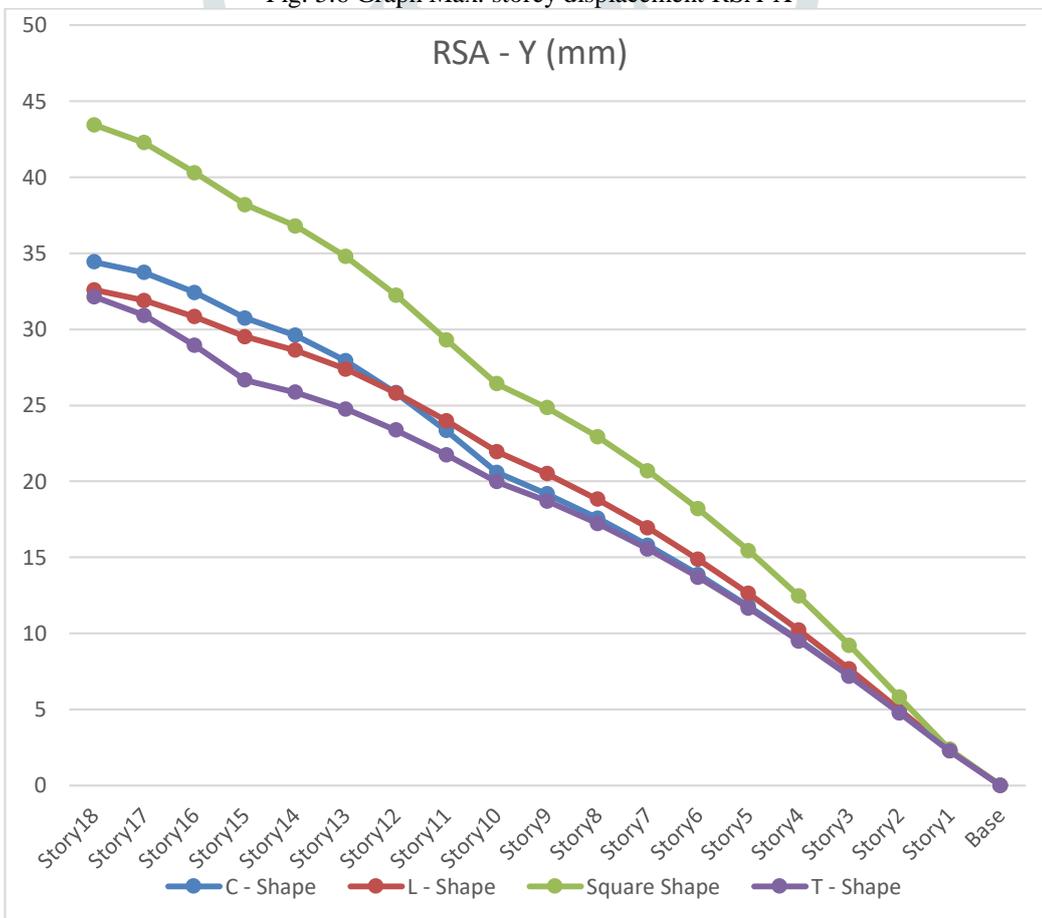
Fig. 5.6 Graph Max. storey displacement RSA-X

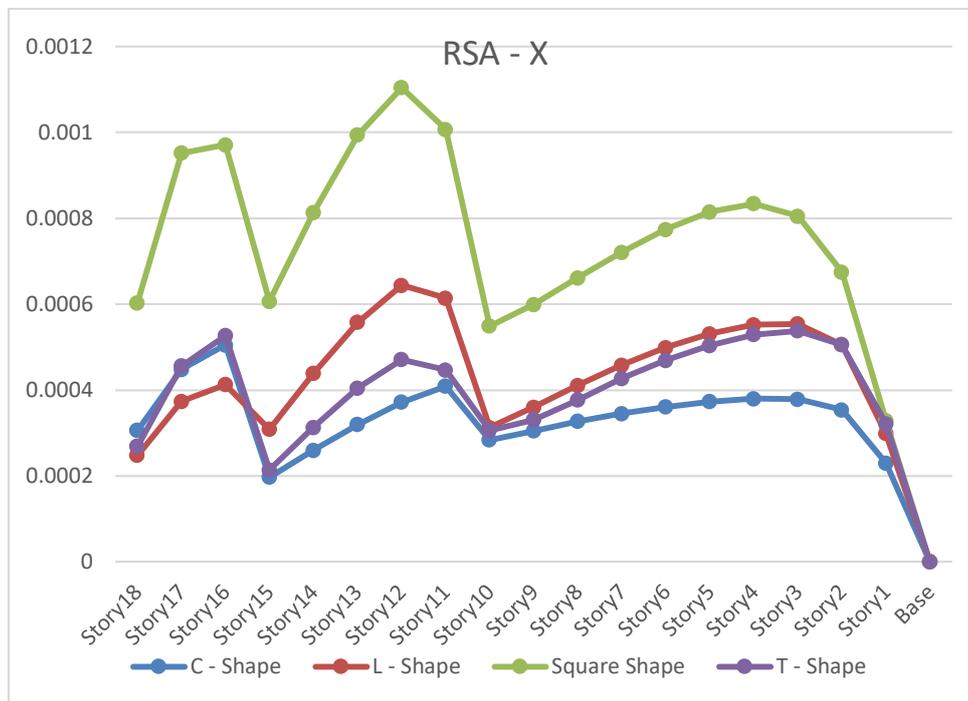Fig. 5.7 Graph Max. storey displacement RSA-Y
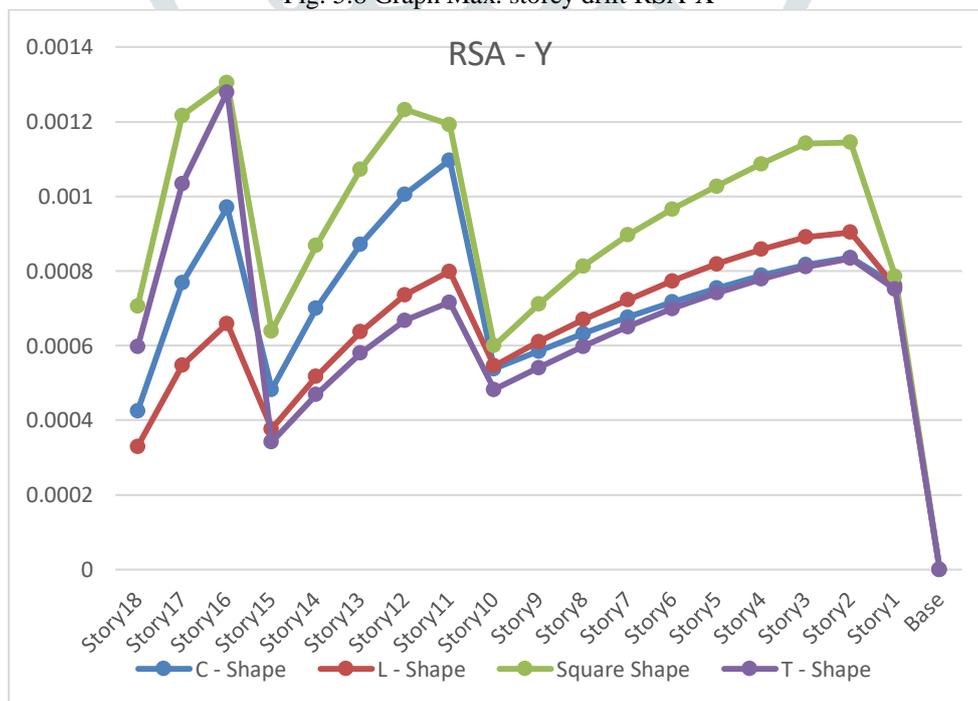
Fig. 5.8 Graph Max. storey drift RSA-X

Fig. 5.9 Graph Max. storey drift RSA-Y

6. CONCLUSION

Design a square shape, L-shape, T-shape, C-shape models of 18 storey steel frame in ETABS software and assign a load and load combinations as per IS code provisions and seismic conditions and analyze its performance in loading condition and give an overview of comparative analysis of an all models the conclusion are as mentioned below;

1. **C-shape: -**

Best Performance: -	Maximum storey displacement in RSA-X
	Maximum storey drift in RSA-X
Poor performance: -	Shear force in beams maximum
	Shear force in beams minimum
	Bending moment in beams maximum
	Bending moment in beams minimum
	Axial force in column maximum
Average performance: -	Axial force in column minimum
	Shear force in column maximum
	Shear force in column minimum
	Bending moment in column maximum
	Bending moment in column minimum
	Maximum storey displacement in RSA-Y
	Maximum storey drift in RSA-Y

2. **L-shape: -**

Average performance: - Maximum storey displacement in RSA-X
Maximum storey drift in RSA-X
Shear force in beams maximum
Shear force in beams minimum
Bending moment in beams maximum
Bending moment in beams minimum
Axial force in column maximum
Axial force in column minimum
Shear force in column maximum
Shear force in column minimum
Bending moment in column maximum
Bending moment in column minimum
Maximum storey displacement in RSA-Y
Maximum storey drift in RSA-Y

It's a noticeable that L-shape give an average performance in all of load and load conditions.

3. **Square shape: -**

Best Performance: - Shear force in beams maximum
Shear force in beams minimum
Bending moment in beams maximum
Bending moment in beams minimum
Axial force in column maximum
Shear force in column maximum
Shear force in column minimum
Bending moment in column maximum

Poor performance: - Axial force in column minimum
Maximum storey displacement in RSA-X
Maximum storey displacement in RSA-Y
Maximum storey drift in RSA-X
Maximum storey drift in RSA-Y

Average performance: - Bending moment in column minimum

We can see that square shape give a best performance in beams and columns but give a poor performance in response spectrum analysis.

4. **T-shape: -**

Best Performance: - Maximum storey displacement in RSA-Y
Maximum storey drift in RSA-Y

Poor performance: - Shear force in column maximum
Shear force in column minimum
Bending moment in column maximum
Bending moment in column minimum

Average performance: - Shear force in beams maximum
Shear force in beams minimum
Bending moment in beams maximum
Bending moment in beams minimum
Axial force in column maximum
Axial force in column minimum
Maximum storey displacement in RSA-X
Maximum storey displacement in RSA-Y
Maximum storey drift in RSA-X
Maximum storey drift in RSA-Y

As above details we can clarify that for shear forces and bending moments square shape model can withstand with safe and securely but have a poor performance in a response spectrum analysis & T-shape, C-shape give a good performance against a response spectrum analysis and overall L-shape give an average performance in all models.

7. FUTURE SCOPE

The present study shows comparative performance of different shapes steel building and that work can extend to a give a solution to poor performance building with using different types bracing systems.

This study gives only response spectrum analysis but for further we can use dynamic and static other methods like time history analysis.

This study is for a steel framed design and but we can use a RC building with other irregularities.

We can use the location of the bracings could be changed to visualize the effect due to change in location and give a comparative analysis.

Comparison between the systems could also be done when the building is slender to see the behaviour of the systems for slender buildings.

Comparison between RC and steel building under static and dynamic with consider liner and non-liner analysis.

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