Comparative Study of Seismic Analysis of RC Frame Structure with and without Belt Truss and Outrigger Truss

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Abstract - *A comprehensive three-dimensional model of the RC buildings, including all structural and architectural details, is first created as part of the investigation. In order to find out how the structure reacts dynamically to seismic stimulation, ETABS software is used to do the response spectrum analysis. The response spectra that correlate to the site's location and the seismic hazard level that has been established are used in the study.*

The use of belt and outrigger trusses improves the structural performance. These supplementary systems for lateral load resistance are positioned at appropriate heights throughout the building. The trusses improve the building's stability by reducing inter-story drift, redistributing lateral pressures, and supporting the structure.

Material qualities, seismic characteristics, and code requirements are just a few of the design aspects that are considered during the process. By analysing the structure's response spectra, one may learn about its dynamic properties, such as its basic period, mode shapes, and spectral accelerations.

Base Shear, Natural Period, Storey Stiffness, Maximum Storey Displacement, and Storey Drift are terms that come out of the study. The efficiency of the extra lateral load-resisting devices is evaluated by comparing the structures with and without the belt and outrigger trusses. Incorporating such truss systems improves structural performance under seismic loads, as shown in the research.

Key Words: G+30, reinforced concrete (RC) structure, belt truss, outrigger truss, response spectrum analysis, ETABS, seismic loads.

1. INTRODUCTION

Tall buildings have been around for a long time because people have always been interested in building things that reach new heights. An enduring example of the awe-inspiring towering buildings built by ancient civilizations like the Mayans and Egyptians is the Great Pyramid of Giza. Impressive heights were shown by monumental and religious buildings in mediaeval Europe, such Gothic cathedrals. Nevertheless, the idea of skyscrapers came into existence in the 19th century, propelled by advancements in technology and the expansion of metropolitan areas. The Home Insurance Building in Chicago is widely recognised as the pioneering skyscraper, setting the stage for other renowned landmarks such as the Eiffel Tower, the Empire State Building, and the Chrysler Building. The construction of record-breaking structures such as Taipei 101 and the Petronas Towers has been made possible by advancements in structural engineering. As the highest building in the world right now, the Burj Khalifa is a symbol of how far humans are willing to go in their quest for architectural perfection.

Figure 01: High Rise RC Frame Structure.

1.1. Increase Performance of High-Rise Structure

To enhance the performance of a high-rise structure, several key considerations should be addressed. Firstly, implementing advanced structural analysis techniques and materials is crucial to ensure optimal load distribution and resistance to external forces. This involves employing cutting-edge engineering technologies and materials with high strength-to-weight ratios. Additionally, incorporating intelligent design features such as damping systems and tuned mass dampers can effectively mitigate vibrations and sway, improving overall stability. Moreover, the integration of energy-efficient systems and sustainable technologies not only reduces operational costs but also aligns the structure with environmental standards. Regular maintenance and monitoring protocols should be established to identify and address any potential issues promptly. Collaboration between architects, engineers, and construction teams throughout the project lifecycle is essential to optimize performance and ensure the longevity of the high-rise structure. By incorporating these measures, the structure can achieve heightened resilience, efficiency, and sustainability in the face of dynamic external factors.

1.2. REGULAR STRUCTURE

In the context of a regular frame structure, compliance with IS 1893 Part 1:2016 involves a systematic approach to earthquake-resistant design. This includes selecting appropriate materials with specified strength characteristics, determining seismic forces and their distribution, and incorporating design features to enhance the structure's ability to withstand seismic events.

The standard emphasizes the importance of properly proportioning structural elements, considering the lateral load-resisting system, and incorporating ductility in the design to allow for controlled deformation during earthquakes. The detailing of reinforcement and connections is also addressed to ensure the integrity of the structure under seismic forces.

It is essential for structural engineers and architects to thoroughly familiarize themselves with the provisions of IS 1893 Part 1:2016 and integrate these guidelines into the design and construction processes to enhance the earthquake resistance of regular frame structures. This comprehensive approach helps in creating structures that are better equipped to withstand the dynamic forces associated with seismic events, thus prioritizing the safety and resilience of the built environment.

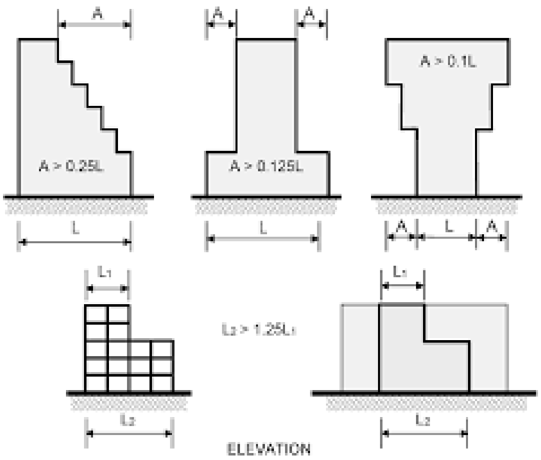


Figure 02: Irregular Frame Structure.

2. METHODOLOGY

This part of the approach will teach us all the tricks we need to know to build models and then analyse them. The Indian standard code, model load, model view, load combination, and analysis technique for all models will also be covered in this study.

2.1. Software

ETABS (Extended Three-Dimensional Analysis of Building Systems) is a widely-used structural analysis and design software for buildings. Developed by Computers and Structures, Inc. (CSI), ETABS offers advanced modeling and analytical tools to assess the behavior of structures under various conditions. It enables engineers to perform linear and nonlinear static and dynamic analyses, making it a valuable tool for designing and optimizing complex structures, including high-rise buildings. ETABS facilitates efficient and accurate structural engineering solutions, streamlining the design process.

2.2. Method Used for Analysis

Response Spectrum Analysis, as per IS 1893 Part 1:2016, is a seismic analysis method used in structural engineering to evaluate a structure's response to earthquake forces. The standard provides guidelines for determining site-specific response spectra, representing the maximum response of a structure at varying natural frequencies. Engineers use this analysis to assess the dynamic behavior of structures and design them to withstand seismic events effectively. IS 1893 Part 1:2016 outlines procedures and factors to ensure structures meet earthquake-resistant criteria in India.

2.3. Seismic Parameter

IS 1893 Part 1:2016, the Indian Standard for earthquake-resistant design, defines seismic parameters crucial for structural analysis and design in seismic-prone regions. These parameters encompass seismic zone factors, site-specific response spectra, and design ground acceleration values. Seismic zones categorize regions based on their seismic vulnerability, with associated factors indicating the seismicity level. Engineers utilize these parameters to calculate and apply seismic forces during the design process, ensuring structures are resilient to potential earthquakes. Compliance with these specifications is essential for constructing buildings that meet Indian seismic safety standards.

2.4. Details of Model

In this section, we have studied the geometry of the model, load on the model, seismic parameters on the model, material of models, etc.

2.4.1. Material Parameters

In this section of the material parameter, we will know the details of the grade of the concrete, grade of the steel, etc are given below in the form of the table:

Table-1: Material Parameters

Serial Number	Name of the Material	Grade
1	Concrete	M30
2	Mild Steel Bar	Fe250
3	HYSD Bar	Fe500
4	Belt and Outrigger	Mild Steel

2.4.2. Dimension of Belt and Outrigger Truss

The cross-section of the belt and outrigger truss is an I section which is made of mild steel and the dimensions of the belt and outrigger truss are given below

Table-2: Dimension of Belt and Outrigger Truss

S.No	Name of Properties	Value
1	The top width of Flange	125 mm
2	The bottom width of Flange	125 mm
3	Top and Bottom Thickness of the Flange	20 mm
4	Thickness of the web	20 mm
5	The total depth of the section	250 mm

The cross-section of the belt and outrigger truss is given below:

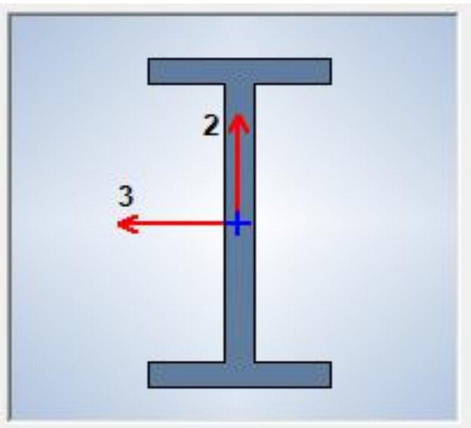


Figure 03: Cross section of the Belt and Outrigger Truss.

2.4.3. Load on Models

The load of the models is given below in the form of the table, which is used in these all models.

Table-3: Load on Models

S.No	Name of Load	Value
1	Deal Load	As Per IS Code 875 Part 1
2	Live Load	4 KN/m3
3	Finishing Load	1.5 KN/m3
4	Seismic Load	As per IS Code 1893 Part-1:2016

2.4.4. Seismic Load Parameter

All parameter of the seismic load is given below in the form of the table which is used in all three models:

Table-4: Seismic Load Parameter

S.No	Seismic Parameter	Value
1	Seismic Zone	0.24
2	Importance Factor	1.50
3	Soil Type	Second
4	Response Reduction Factor	3

2.4.5. Building Geometry

The parameter of the building geometry is given below in the form of the table:

Table-5: Building Geometry

S.No	Parameter of Building	Values
1	Cross section of Beam	400mm * 600mm
2	Cross section of Column.	750mm * 400mm
3	The thickness of the Slab.	150.00mm
4	Length of Beam.	3000 mm
5	Height of G+30	93000mm
6	Floor Height	3000 mm
7	Plan Area	21m*15m

2.5. Name of Models

In this thesis work, we have created three models with the help of the ETABS software, the details of the models are given below:

1. Model-01: G+ 30 RCC Regular Structures.
2. Model-02: G+30 RCC Regular Structure with Belt Truss.
3. Model-03: G+ 30 RCC Regular Structures with Outrigger.

2.5.1. Details View of Model-01

The plan, elevation, and 3D View of Model-01 are given below:

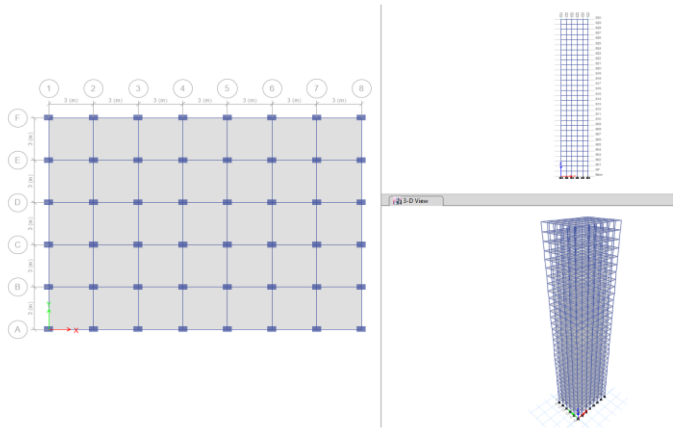


Figure-04: Plan, elevation, and 3D View of the Model-01

2.5.2. Details View of Model-02

The plan, elevation, and 3D View of Model-02 are given below:

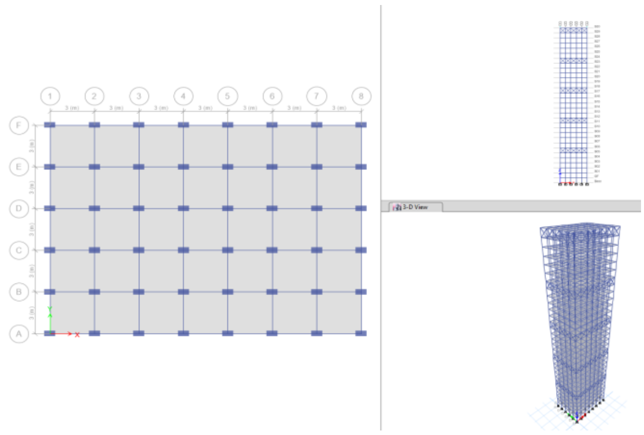


Figure-05: Plan, elevation, and 3D View of the Model-02.

2.5.3. Details View of Model-03

The plan, elevation, and 3D View of Model-03 are given below:

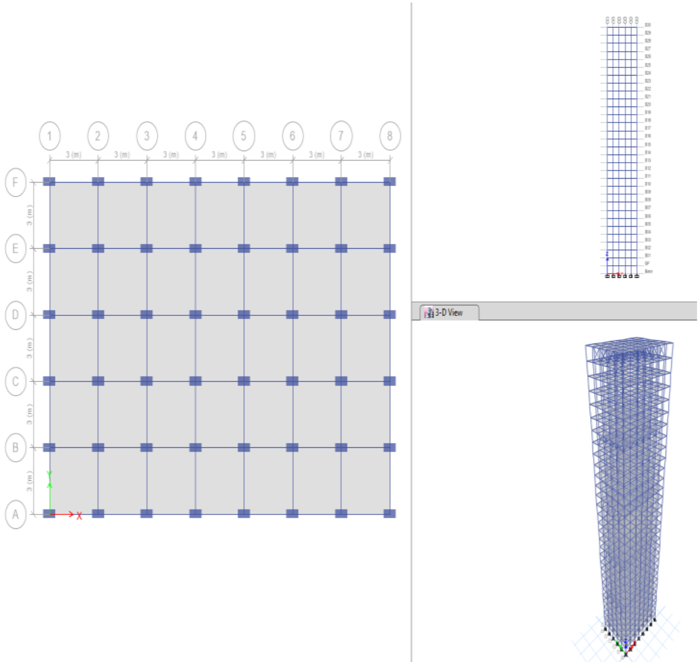


Figure-06: Plan, elevation, and 3D View of the Model-03.

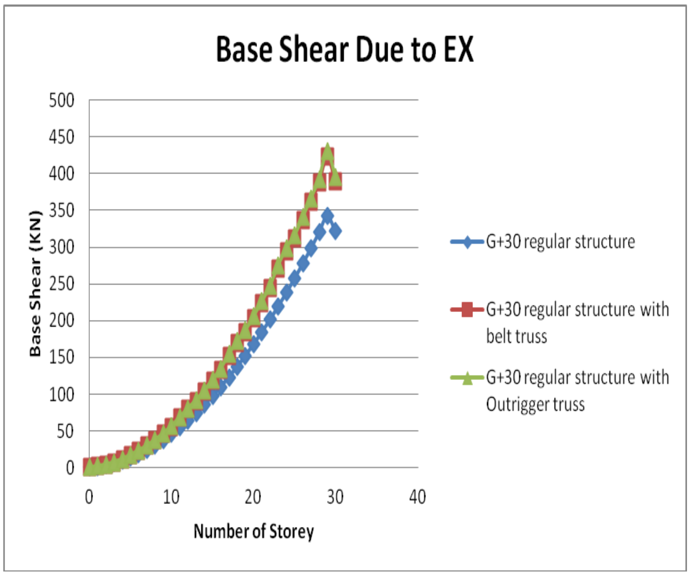
3. RESULT AND ANALYSIS

Here we will examine the outcomes of all three models that were developed using the ETABS programme. Response Spectral Analysis is used to examine all of these models. In order to evaluate the models, we have settled on the following seven seismic parameters:

1. Base shear due to EX
2. Natural period,
3. Maximum Storey Displacement,
4. Maximum storey drift,

3.1. Base Shear

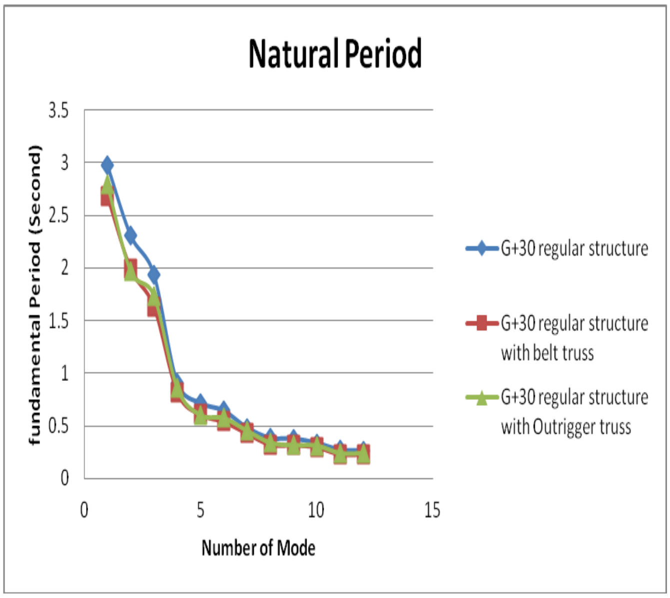
Base Shear, as defined by IS 1893 Part 1:2016, is a fundamental seismic force used in earthquake-resistant design of structures in India. It represents the total lateral force applied at the base of a structure during an earthquake. The standard provides specific formulas and coefficients to calculate the base shear, considering factors such as seismic zone, importance of the structure, and soil characteristics. Engineers use this parameter to design structures capable of withstanding seismic forces and ensuring compliance with Indian seismic safety standards.



Graph 01: Base Shear.

3.2. Natural Period

The Natural Period, as outlined in IS 1893 Part 1:2016, is a crucial parameter in seismic analysis and design. It represents the time taken for a structure to complete one full cycle of oscillation in response to an applied lateral force. The standard provides guidelines for estimating the natural period based on the structural characteristics and dynamic properties. Engineers use this information to assess the dynamic behavior of structures, aiding in the development of earthquake-resistant designs that align with Indian seismic safety standards.

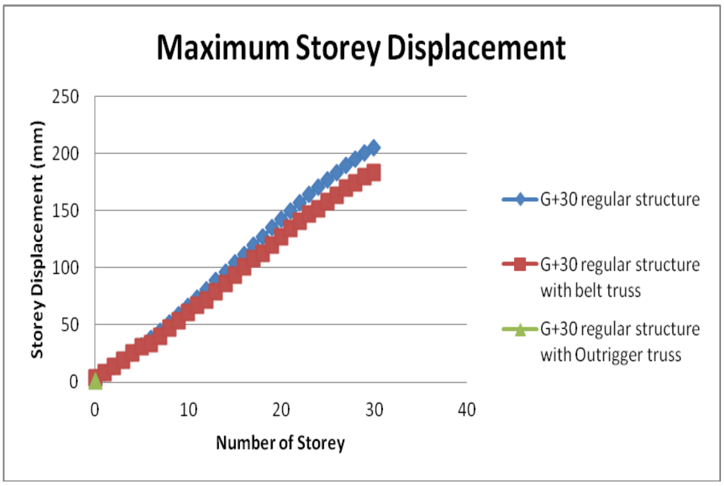


Graph 02: Natural Period.

3.3. Maximum Storey Displacement

The seismic zone and building type determine the maximum permitted storey displacement, as stated in IS 1893 (Part 1): 2016. Different values are provided by the code for structures that have ductile detailing and those that do not.

The maximum value of the storey displacement, as per IS Code 1893 part-1: 2016, shall not exceed H/250, where H is the overall height of the building in mm.

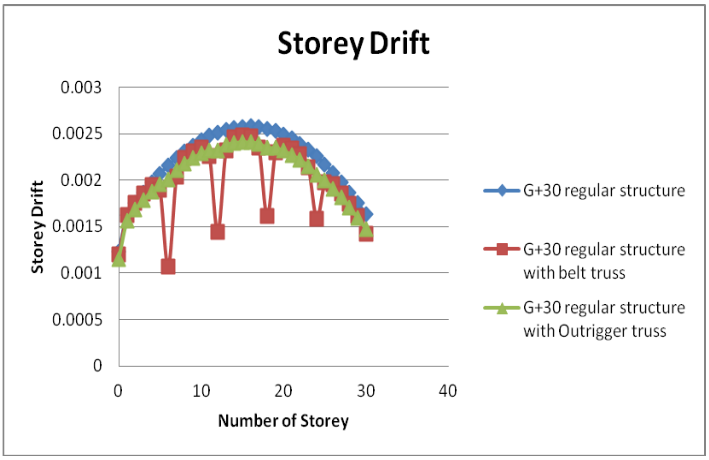


Graph 03: Maximum Storey Displacement.

3.4. Maximum Storey Drift

One of the crucial factors taken into account by seismic designers when evaluating the lateral displacement of a building's storeys during an earthquake is the maximum storey drift. A number of variables, including the seismic zone, structural system, occupant type, and design goals, determine the maximum permissible storey drift.

At load scenario 0.9DL+1.5EY, the maximum storey drift is shown below in the table and graph.



Graph 04: Maximum Storey Drift.

4. CONCLUSION

Based on our research into these three models, we know that their natural periods all fall somewhere within 3.0 seconds; model 02, which includes a belt truss, has the shortest natural period, while model 01, which does not, has the longest.

According to the Indian standard code 1893 part1:2016, as long as all the seismic factors (seismic zone factor, importance factor, soil type, response reduction factor, etc.) stay constant, the base shear value grows as the structure's self-weight does. Based on these results, we may deduce that model-03, which includes the outrigger truss, has a growing base shear value, whereas model-01, which does not, has a minimal base shear value.

According to the results of the maximum story displacement and maximum storey drift, the models without belt truss or outrigger truss (model-01) and with them had the highest values for these variables, while the ones with belt truss had the lowest.

Our research shows that belt trusses are better suitable for use in high-rise buildings than outrigger trusses.

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