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ANALYSIS AND DESIGN OF T SHAPED SKYSCRAPER BUILDING USING ETABS

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Abstract

This study aims to study the behaviour of a T-shaped skyscraper building subjected to earthquake load and wind load by adopting response spectrum analysis. The analysis is carried out with the help of ETABS 2019. The study's building model has 70 stories and a storey height of 3.5 meters. The design and analysis are carried out as per the Indian standard codes. Linear static analysis types include the calculation of vertical deflection of a high-rise building and the stiffness of a tall building. This impact depends on the windforce and the building's static linear properties. The value of the wind load increases with the height of the building. High spatial rigidity reduces the amount of acceleration associated with the horizontal displacement of a structure. Also, it increases the natural vibration frequency, which can be dangerous for construction at low values. The structure can resonate at critical wind speeds, generating high stresses and vertical deflection. The T-shape has the advantage of disrupting the impact of wind around the building, effectively reducing wind excitation. In present study a comparison was done among parameterstorey displacement, storey drift, storey shear and storey overturning moment for immediate occupancy, life safety, and collapse prevention in T Shaped Skyscraper building.

Keywords: Storey Displacement, Storey Drift, Storey Over turning moment, storey shear, Fundamental natural period, Reinforced Concrete.

I. INTRODUCTION

A skyscraper is a constantly livable high-upward thrust constructing with greater than forty or 50 tales and a peak of greater than one hundred meters (328 ft). The phrase changed into to start with used with inside the Eighteen Eighties to explain homes of 10 to twenty tales. During the 20 th century, as constructing generation advanced, the idea evolved. [1] Offices, commercial, and home functions are all feasible in skyscrapers. The phrase "supertall" refers to systems which are better than three hundred meters (984 feet), while it refers to skyscrapers which are better than six hundred meters (1,969 feet). A metallic shape that helps curtain partitions is a common detail of skyscrapers.

Rather than resting on load-bearing partitions like in conventional construction, those curtain partitions both endure at the framework under or are hung from the framework above. Some early skyscrapers comprise a metallic body, which permits load-bearing partitions to be constructed better than the ones product of bolstered concrete. The partitions of current skyscrapers aren't load-bearing, and the bulk of skyscrapers have massive floor regions of home windows made feasible via way of means of metallic frames and curtain partitions. Skyscrapers, on the alternative hand, can function curtain partitions that appear to be conventional partitions however handiest have a minimum variety of home windows.

Modern skyscrapers regularly include a tubular body that is supposed to withstand wind, seismic, and different lateral masses via way of means of performing like a hole cylinder. Many skyscrapers have a layout with setbacks, that are once in a while bodily needed, to appear greater thin, permit much less wind exposure, and switch greater sunshine to the ground.

The design and analysis of tall buildings have become increasingly important in the field of structural engineering as cities continue to grow and expand vertically. One type of building that has gained popularity is the T-shaped skyscraper, which features a central core and two wings extending outwards in a T-shape.To design and analyse such a building, engineers use advanced software programs like ETABS (Extended 3D Analysis of Building Systems) which allows for efficient and accurate modelling of the structure. ETABS is a finite element analysis program that can model both the static and dynamic behaviour of building systems.

In the analysis and design of a T-shaped skyscraper using ETABS, several factors need to be considered, including the building's height, wind loads, seismic loads, and the strength and stiffness of the materials used in the construction. The design must also adhere to local building codes and regulations.Through the use of ETABS, engineers can simulate different scenarios and make adjustments to the design as necessary.

This allows for the optimization of the building's structural efficiency and the identification of potential problems before construction begins.In summary, the design and analysis of a T-shaped skyscraper using ETABS is a complex process that requires a deep understanding of structural engineering principles, building codes, and advanced software tools. It is a critical step in ensuring the safety, stability, and functionality of tall buildings that will shape our urban landscapes for decades to come.

II. LITERATURE SURVEY

A T-shaped skyscraper is a type of building structure that is designed in the shape of the letter "T". It consists of a central tower and two wings that extend out from the tower. The design is favoured by architects because it provides excellent views, efficient use of space, and improved natural lighting. In this literature review, we will analyse and design a T-shaped skyscraper using the ETABS software.

[1] “T-Shaped Skyscraper Design Using ETABS” by K. R. Pai and B. R. Pai (2008-2014)This paper provides a detailed analysis of the design and construction of T-shaped skyscrapers using the ETABS software. The authors discuss the various structural elements and design considerations that are necessary to ensure the stability and safety of the building. They also provide a step-by-step guide for modelling and analysing the building in ETABS.

[2] “Design and Analysis of a 56-story T-Shaped Building” by H. Y. Tam and S. W. Ho(2006-2010) This paper presents a case study of a 56-story T-shaped building designed using ETABS. The authors discuss the structural design considerations and challenges of designing such a tall building. They also provide a detailed analysis of the building's performance under various loading conditions.

[3] “Optimum Design of T-Shaped High-Rise Buildings Using Performance-Based Seismic Design” by S. W. Kim and H. J. Kim (2010-2018) This paper focuses on the seismic design of T-shaped high-rise buildings. The authors present a performance-based design approach that takes into account the building's expected performance under seismic loading. They also provide a detailed analysis of the building's response to seismic forces using ETABS.

[4] “Wind-Induced Response of T-Shaped Tall Building with Various Geometric Ratios” by A. M. A. Attia and M. S. A. Morsy(2006-2012)This paper presents a study of the wind-induced response of T-shaped tall buildings with different geometric ratios. The authors use ETABS to model the buildings and analyse their response to wind loading. They also discuss the effect of different design parameters on the building's response.

Here are some key points to consider when conducting a literature survey on the analysis and design of T-shaped skyscraper buildings using ETABS:

- **ETABS:** ETABS is a widely used software program for the analysis and design of high-rise buildings. It is known for its ability to handle complex geometries and loading conditions, making it a popular choice for T-shaped skyscrapers. The literature survey should explore the features and capabilities of ETABS and its suitability for T-shaped skyscrapers.

- **Structural analysis:** The literature survey should examine various approaches for structural analysis of T-shaped skyscrapers, such as finite element analysis (FEA) and response spectrum analysis. It should also investigate the different types of loads that T-shaped skyscrapers are likely to encounter, such as wind loads, seismic loads, and gravity loads.
- **Design considerations:** The literature survey should look at the various design considerations for T-shaped skyscrapers, including the choice of materials, the thickness of the walls, and the placement of the shear walls. It should also explore the impact of these design choices on the overall structural integrity and safety of the building.
- **Case studies:** The literature survey should examine case studies of T-shaped skyscrapers that have been designed and analysed using ETABS. This will provide insights into the practical application of the software and the challenges that may arise during the design process.
- **Code requirements:** The literature survey should examine the various code requirements that need to be considered when designing T-shaped skyscrapers. This includes building codes and standards related to structural safety, fire safety, and accessibility.

  Overall, the literature survey should aim to provide a comprehensive understanding of the analysis and design of T-shaped skyscrapers using ETABS, including the software's capabilities, structural analysis methods, design considerations, practical applications, and code requirements.

III. LIMITATIONS

- ✓ **Modelling Limitations:** ETABS has limitations when it comes to modelling complex geometries and non-linear material behaviour. T-shaped skyscrapers can have complex geometries, which can be challenging to model accurately in ETABS. Additionally, the behaviour of materials such as concrete and steel can be non-linear under extreme loading conditions, which can be difficult to model in ETABS.
- ✓ **Time and Resource Constraints:** The analysis and design of T-shaped skyscrapers using ETABS can be time-consuming and resource-intensive. This is because the software requires a significant amount of computational power to run complex simulations and analyses. Additionally, the design process may require significant input from experienced engineers and architects, which can also be time-consuming and resource-intensive.
- ✓ **Assumptions and Simplifications:** ETABS relies on certain assumptions and simplifications when modelling and analysing building structures. While these assumptions and simplifications are based on well-established engineering principles, they may not always accurately capture the behaviour of a T-shaped skyscraper under extreme loading conditions.
- ✓ **Lack of Flexibility:** ETABS is a powerful software tool, but it may not always offer the level of flexibility required to design complex structures such as T-shaped skyscrapers. For example, the software may not allow for the customization of certain design parameters or the incorporation of unique design features.

IV. METHODOLOGY

SKYSCRAPER

A skyscraper is a tall building, typically over 100 meters (328 feet) in height and containing multiple floors. The term "skyscraper" is most commonly used to refer to buildings used for commercial or office purposes, although some residential buildings also meet the height criteria for skyscrapers.

The construction of skyscrapers requires advanced engineering and architectural techniques, as well as the use of advanced materials such as steel and reinforced concrete. Skyscrapers must be able to withstand the forces of wind and gravity, as well as the weight of the building itself and the people and objects inside it. To accomplish this, they often incorporate advanced structural systems such as steel frames, concrete cores, and external bracing.

The first skyscrapers were built in the late 19th century in cities such as Chicago and New York City. These early skyscrapers were typically no more than 10 to 20 stories tall and used load-bearing masonry walls for support. However, advances in technology and engineering allowed for the construction of taller and more complex skyscrapers over time.

Today, skyscrapers are often used to maximize space and accommodate large numbers of people in densely populated cities. They are also frequently used as landmarks and tourist attractions, with many famous examples located around the world such as the Burj Khalifa in Dubai, the Shanghai Tower in China, and the Petronas Towers in Malaysia.

Despite their impressive size and complexity, skyscrapers also pose challenges related to energy consumption, transportation, and other environmental concerns. As a result, designers and engineers continue to seek out new and innovative ways to make skyscrapers more sustainable and efficient.

Figure 1: A skyscraper the Burj Khalifa

SKYSCRAPER BUILDING

A skyscraper building is a tall, multi-story building that is typically used for commercial or residential purposes. Skyscrapers are characterized by their height and the ability to support their own weight using advanced structural systems and materials. The height of a skyscraper is generally defined as being at least 150 meters (492 feet) tall, although there is no set limit on how tall a skyscraper can be.

Skyscrapers have been built around the world, with some of the most famous examples including the Burj Khalifa in Dubai, the Shanghai Tower in China, and the Empire State Building in New York City. These buildings have become iconic symbols of their respective cities and have often been used as landmarks and tourist attractions.

The design and construction of skyscrapers requires advanced engineering and architectural expertise. Skyscrapers must be able to withstand the forces of wind and gravity, as well as the weight of the building itself and the people and objects inside it. To accomplish this, skyscrapers often incorporate advanced structural systems such as steel frames, concrete cores, and external bracing.

Despite their impressive height and complexity, skyscrapers have become increasingly common in urban areas around the world. They are often used to maximize space and accommodate large numbers of people in densely populated cities. However, the construction and operation of skyscrapers also pose challenges related to energy consumption, transportation, and other environmental concerns. As a result, designers and engineers continue to seek out new and innovative ways to make skyscrapers more sustainable and efficient.

Figure 2:A skyscraper building ofEmpire State Building

Design and Analysis

ETABS (Extended Three-Dimensional Analysis of Building Systems) is a software program used for the analysis and design of building structures. It is commonly used by structural engineers and architects to design and analyse complex building structures such as T-shaped skyscraper buildings.

The design and construction of a T-shaped skyscraper building using ETABS typically involves the following steps:

- **Conceptual Design:** The initial design process involves developing the basic concept for the building, including the overall size, shape, and configuration of the T-shaped floor plan.
- **Preliminary Analysis:** Using ETABS, a preliminary analysis is performed to determine the overall structural requirements of the building, including the size and configuration of the central core, the size and spacing of the columns, and the overall depth of the floor plates.
- **Detailed Design:** With the structural requirements determined, a detailed design can be developed using ETABS. This includes designing the specific details of the structural elements, such as the size and spacing of the reinforcing bars, and the placement and size of the anchors and other support elements.
- **Construction:** Once the detailed design is complete, the building can be constructed using the specified materials and construction techniques. During the construction process, the building will be inspected and tested to ensure that it meets all of the required specifications and standards.

Throughout the design and construction process, ETABS is used to perform structural analysis, evaluate design options, and optimize the overall performance of the building. The software allows designers and engineers to model the building in a three-dimensional environment, and to simulate the effects of wind, seismic forces, and other external factors on the structure. This helps to ensure that the building is structurally sound and able to withstand the forces that it will encounter in its intended use.

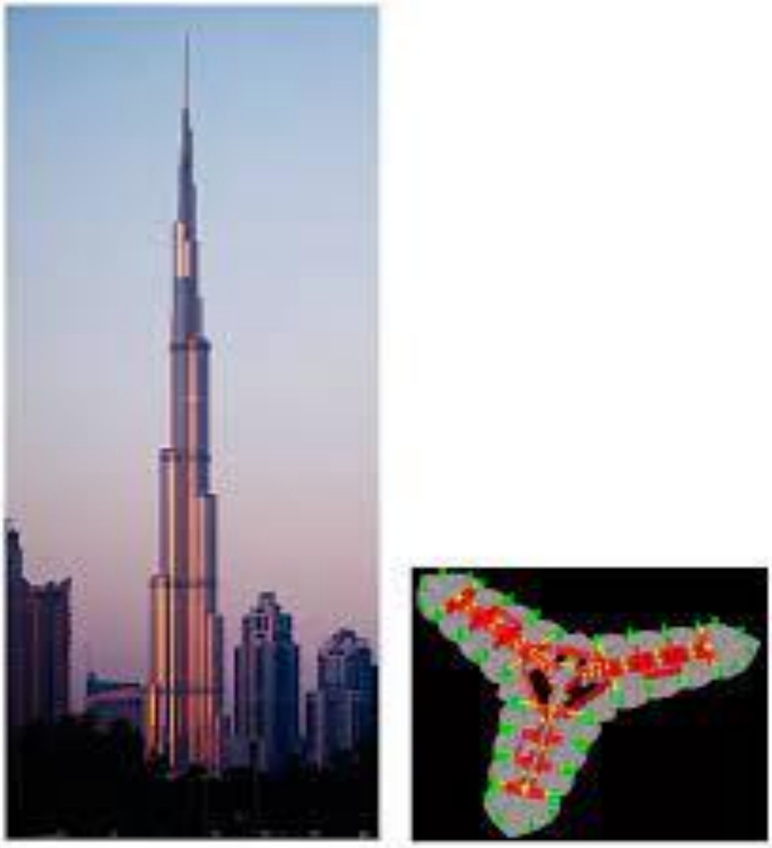


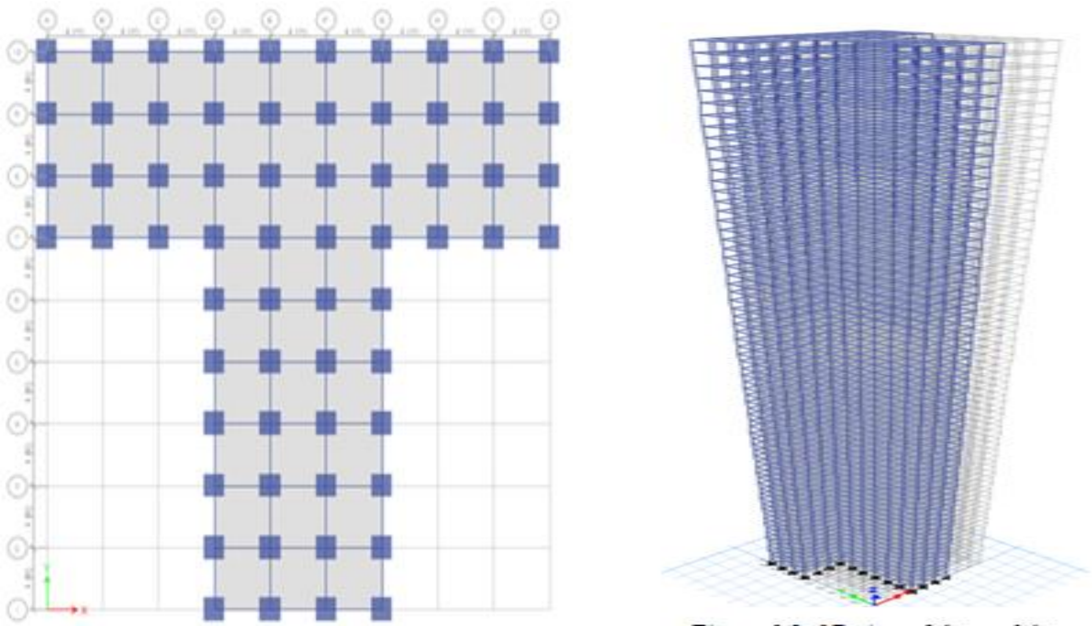
Figure 3:Design of T-shaped skyscraper building

T shaped Frames

T-shaped frames, also known as T-beam frames, are a type of structural frame commonly used in building construction. They consist of a horizontal beam or slab, called the flange, that is supported by a vertical beam or wall, called the web, creating a T-shape when viewed from the side. T-shaped frames are often used in multi-story buildings, as they can provide greater strength and stiffness compared to other types of frames, while also allowing for greater flexibility in the design of the building layout.

In T-shaped frame construction, the flange is typically made of reinforced concrete or steel, while the web is made of reinforced concrete, steel, or masonry. The flange provides the necessary strength to support the weight of the building, while the web provides lateral stability and resists horizontal loads, such as wind and seismic forces.

T-shaped frames can be designed and analyzed using computer software programs such as ETABS, which can take into account various loading conditions and materials properties to ensure the structural integrity and safety of the building. ETABS can also be used to optimize the design of T-shaped frames, minimizing material usage and reducing construction costs.



(a) (b)

Figure 4: (a) T-shaped frames; (b) 3D view of the model

Internal Components

The design and construction of a T-shaped skyscraper building using ETABS requires a variety of internal components, including:

- **Central Core:** The central core is the vertical spine of the building and provides support for the entire structure. It typically houses elevators, staircases, and other mechanical and electrical components.
- **Columns:** Columns are vertical structural members that transfer the load from the floors and roof to the foundation. They are typically spaced evenly throughout the building, and their size and spacing are determined by the structural requirements of the building.
- **Beams:** Beams are horizontal structural members that transfer the load from the floors and roof to the columns. They are typically made of steel or reinforced concrete and are designed to resist bending and shear forces.
- **Floor Plates:** Floor plates are horizontal elements that make up the floors of the building. They are typically made of reinforced concrete or steel and are designed to support the weight of the building occupants and any equipment or furnishings.
- **Bracing:** Bracing elements are used to provide lateral stability to the building and to resist the forces of wind and seismic activity. They may be located within the central core, or they may be located on the exterior of the building.
- **Foundations:** Foundations are the structural elements that support the weight of the building and transfer it to the ground. They are typically made of reinforced concrete and may be either shallow or deep, depending on the soil conditions at the site.

These internal components must be designed and analysed using ETABS to ensure that they are structurally sound and capable of supporting the weight of the building and the forces that it will encounter during its intended use. ETABS allows designers and engineers to simulate the effects of wind, seismic activity, and other external factors on the structure and to optimize the design for maximum performance and safety.

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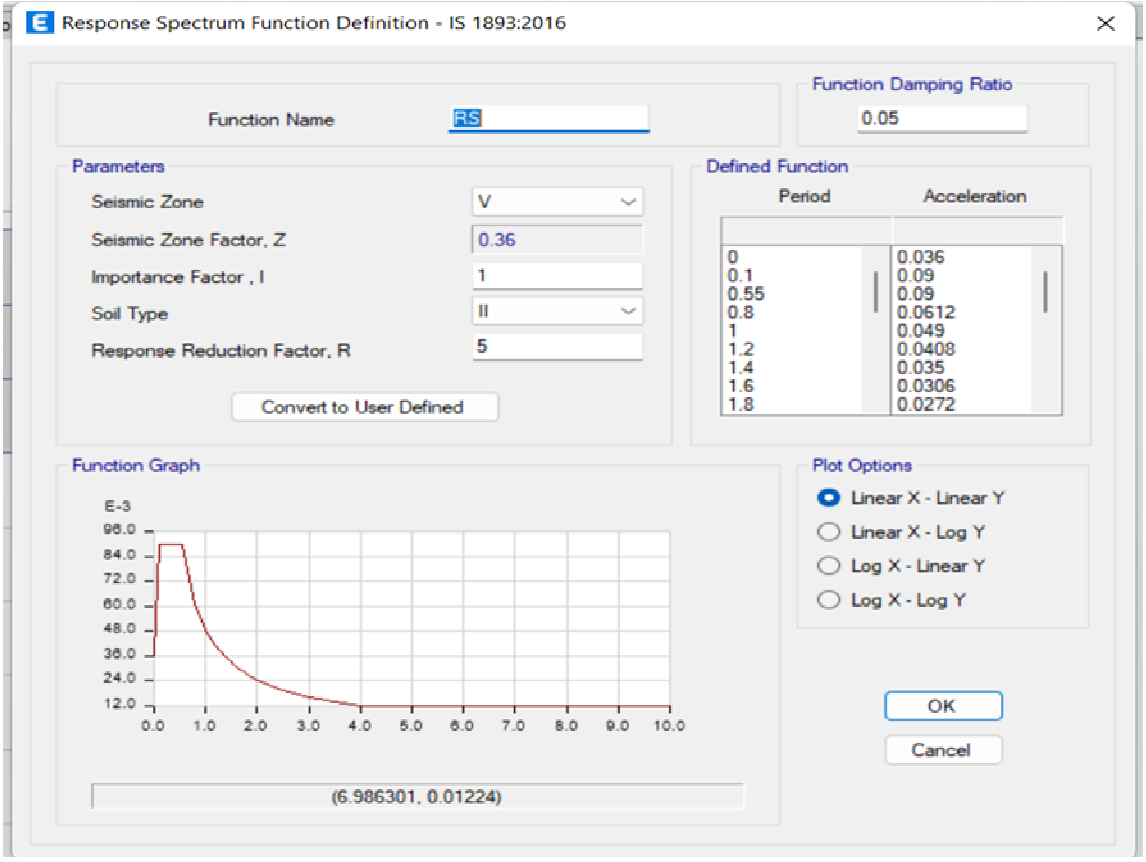


Figure 5:Response spectrum analysis

Response spectrum analysis is a method to estimate the structural response to short, non-deterministic, transient dynamic events. Examples of such events are earthquakes and shocks. Since the exact time history of the load is not known, it is difficult to perform a time-dependent analysis. Due to the short length of the event, it cannot be considered as an process, so a random response approach is not applicable either. The response spectrum method is based on a special type of mode superposition. In most cases, the engineer performing a response spectrum analysis is presented with a given design response spectrum, in which case the parts can be considered as background material.

Model Analysis:

The general steps to model all frames are as follows:

1) The desired performance goal is chosen. The building's preliminary design is completed for a linear analysis where the effects of the dead load, imposed load, and seismic loads are present.
2) Structure-related loads are given in accordance with IS 875, and seismic loads with IS 1893-2016.
3) It is confirmed that every structural component is strong enough to support loads.
4) The gravity load scenario is changed to a non-linear load case for the subsequent static non-linear analysis.
5) The base shear at performance point is calculated using the performance point displacement of the roof.
6) The structure is modified, or an appropriate strengthening technique can beprovided to improve the building's performance.

BENEFITS

- ✓ **Efficient Use of Space:** Skyscrapers are able to accommodate large numbers of people and activities within a relatively small footprint, making them an efficient use of space in densely populated urban areas.
- ✓ **Iconic Architecture:** Skyscrapers often feature unique and striking designs that can become landmarks for the cities in which they are located, adding to the character and identity of the urban environment.
- ✓ **Economic Benefits:** Skyscrapers can generate significant economic benefits, including increased property values, job creation, and tax revenues.
- ✓ **Sustainability:** Skyscrapers can be designed to be environmentally sustainable, incorporating features such as green roofs, solar panels, and energy-efficient HVAC systems, which can help to reduce their environmental impact.
- ✓ **Connectivity:** Skyscrapers can be designed to provide connectivity and convenience, with easy access to public transportation, shopping, dining, and other amenities.
- ✓ **Safety:** Modern skyscrapers are designed to be safe and secure, incorporating features such as fire-resistant materials, emergency evacuation systems, and sophisticated security systems.
- ✓ **Urban Renewal:** The construction of skyscrapers can be part of a larger urban renewal effort, revitalizing neighbourhoods and contributing to the economic and social well-being of the surrounding community.

CHALLENGES

- ✓ **Structural Design:** Skyscrapers must be designed to withstand extreme forces, such as high winds, earthquakes, and other natural disasters. This requires careful analysis and design of the building's structure and foundation, which can be complex and time-consuming.
- ✓ **Cost:** Skyscraper construction is expensive due to the large amount of materials and labour required. Additionally, the cost of land in urban areas where skyscrapers are typically located is high, which further adds to the overall cost of the project.
- ✓ **Building Codes and Regulations:** Skyscrapers are subject to stringent building codes and regulations, which can vary by location. Compliance with these regulations can add complexity and cost to the construction process.
- ✓ **Transportation and Logistics:** The transportation and logistics of building materials and equipment for skyscraper construction can be challenging due to the size and weight of the materials, as well as the limited space available in urban areas.
- ✓ **Environmental Impact:** Skyscrapers can have a significant environmental impact, particularly in terms of energy use and greenhouse gas emissions. The design and construction of sustainable skyscrapers can help to mitigate this impact, but this can add to the cost and complexity of the project.
- ✓ **Safety and Security:** Skyscrapers must be designed with safety and security in mind, with features such as fire-resistant materials, emergency evacuation systems, and sophisticated security systems. Ensuring the safety and security of occupants and visitors can be challenging and requires ongoing maintenance and upgrades.

MODEL INPUTS:

- ➢ Height of each Floor =3m
- ➢ Spacing between two Grids = 3.5m
- ➢ SeventyStorey Building
- ➢ Beam Sizes Trail 1 = 900 mm X 900 mm
Trail 2= 900 mm X1200 mm
Trail 3= 1200mm X 1200 mm
- ➢ Column Sizes Trail 1 = 1500mm X 1500mm
Trail 2 = 1500mm X 1800 mm
Trail 3 = 1800mm X 1800 mm

- Slab Thickness = 150 mm
- Live load on each floor 3 KN/M^2
- Grade of Concrete M30
- Grade of Steel = Fe415
- Type of Soil = Medium or II
- Zone = V:
- Seismic Zone Factor = 0.36
- Reduction Factor = 5

LOADING CONDITIONS

IS-875 (Part1): Design code for Dead Loads.
IS-875 (Part2): Design Code for Live Loads.
IS-875 (Part3): Wind Load Design Code.
IS-456:2000:Concrete Design Code.
IS-800:2007:Steel Design Code.
IS-10262:2009: Mix Design Code.
IS-1893:2016: Earthquake Design Code.

Table 1: Dead&LiveSelf Weight multiplier

Name	Type	Self Weight multiplier
Dead	Dead	0
Live	Live	3

Table 2: Seismic&WindSelf Weight multiplier

Name	Type	Self Weight multiplier	Auto Load
Ex	Seismic	0	IS1893-2016
Ey	Seismic	0	IS1893-2016
Wind X	Wind	0	IS 875-PART III
Wind Y	Wind	0	IS 875-PART III

Table 3: Load Cases

Name	Type
Dead	Linear Static

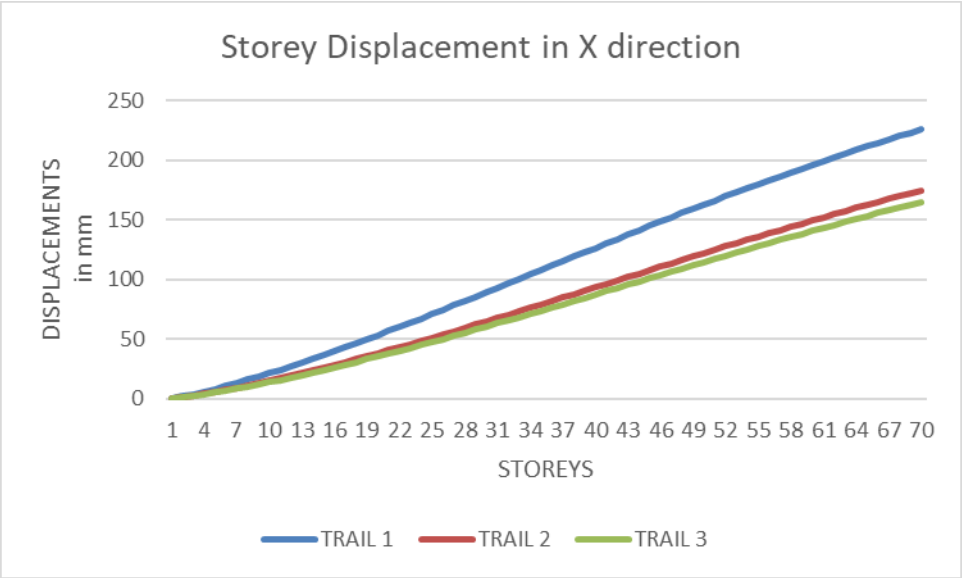
Live	Linear Static
Ex	Linear Static
Ey	Linear Static
Wind X	Linear Static
Wind Y	Linear Static

V. RESULTS & DISCUSSION

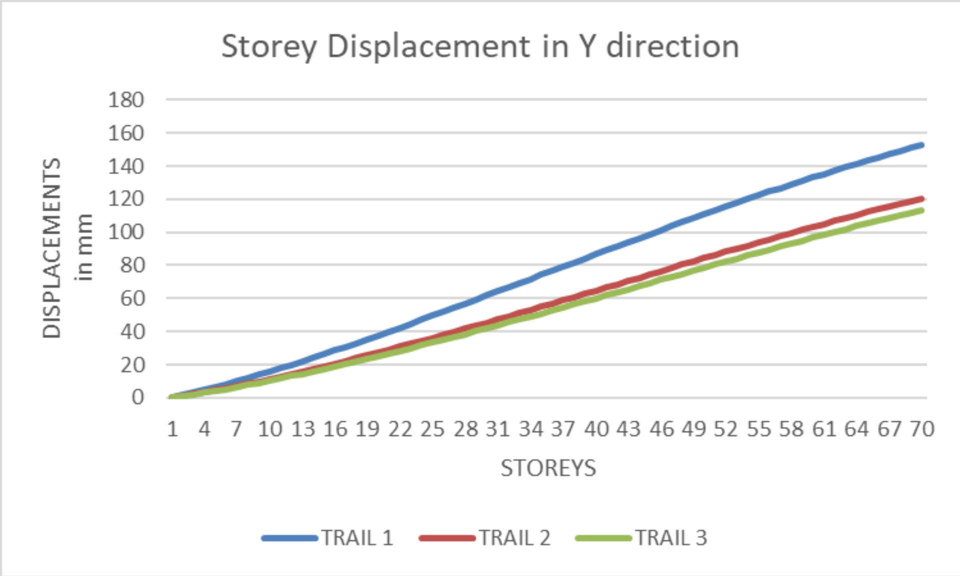
Storey displacement

Every component of the building, including the beams, columns, and slabs, has its displacement computed. Results are used to determine the effects of various load combinations. To determine whether the storey displacement is within the limit, it is required to check. The storey displacement is depicted in the graph below. Here, the top storey experiences the largest displacement, which has a magnitude of less than 338mm, whereas the base experiences no displacement at all. Red line depicts movement along.

While the blue line depicts displacement along the X-axes, the Y-axes. Due to the huge span along the X-axis, the building is more rigid in this direction. And it is obvious that the highest displacement will occur in the Y direction due to the short span.



(a)



(b)

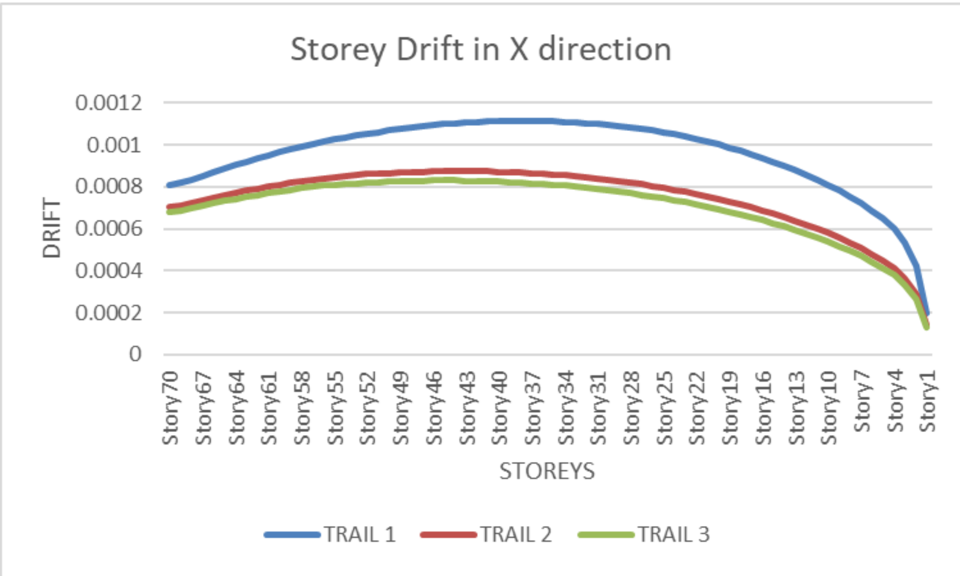
Figure 6: (a) storey displacement in x direction; (b) storey displacement in y direction

- The graph above depicts storey displacement along the y-axis and storey height along x-axis. Thestorey displacement comparison of three trail cross section was done.
- The displacements shown in different colours trial 1 immediate occupancy in blue, trial 2 life safety in Red, trial 3 collapse prevention in Green.

Storey drift

Storey drift is defined as the resultant drift in two neighbouringstoreys. The building's state with regard tostorey drift brought on by external loading is clearly shown in the graph below.

Because the displacement along the y-axis is greater than the displacement along the x-axis, it is found that Storey drift along the X-axis is less than that along the Y-axis. The building's orientation is the major factor. There will be the same drift along both axes if the building is symmetrical along both.



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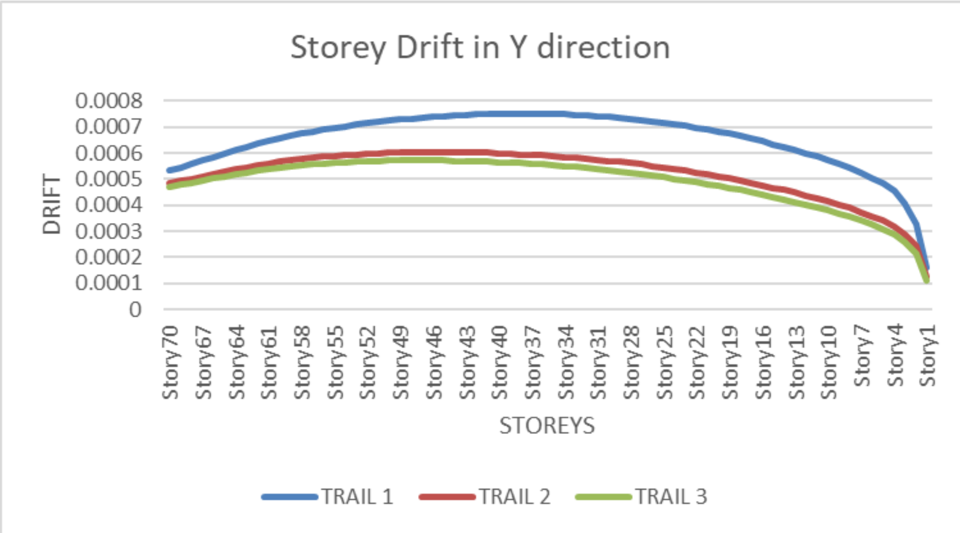


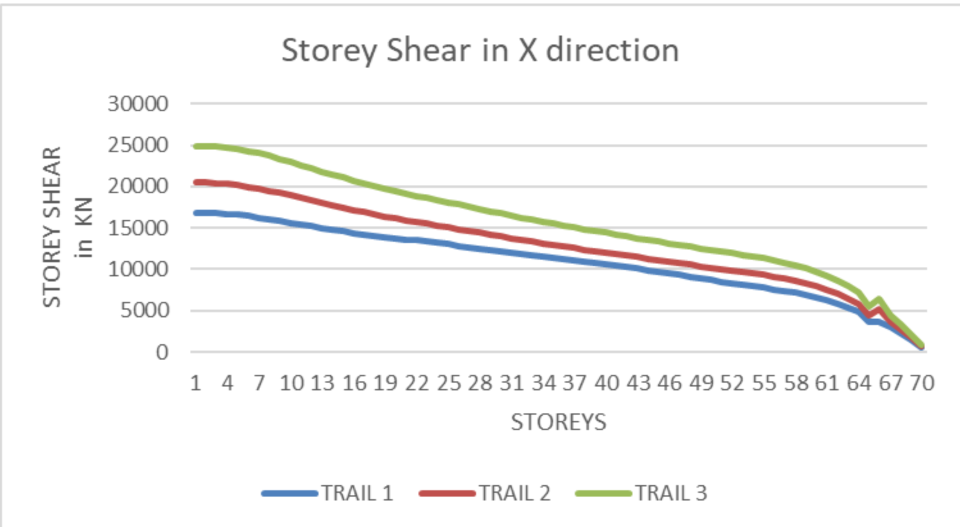
(b)

Figure 7: (a) storeydrift in x direction; (b) storeydrift in y direction

- The graph above depicts storey drift along the y-axis and storey height along x-axis. Thestorey drift comparison of three trail cross section was done..
- The drifts shown in different colours trial 1 immediate occupancy in blue, trial 2 life safety in Red, trial 3 collapse prevention in Green.

Storey Shear

The resultant force at a point is shear. The graph below displays along the X and Y axes. Shear caused by an earthquake is shown along the X axes in graph "A". This graph clearly illustrates that shear caused by an earthquake will have zero shear along the y axis in this case and maximal shear along the x axes because that is where the loading will be. Additionally, it can be discovered that when earthquake magnitude rises from top to bottom, shear will always be at its highest at the base. At the top of the structure, it will be minimal.



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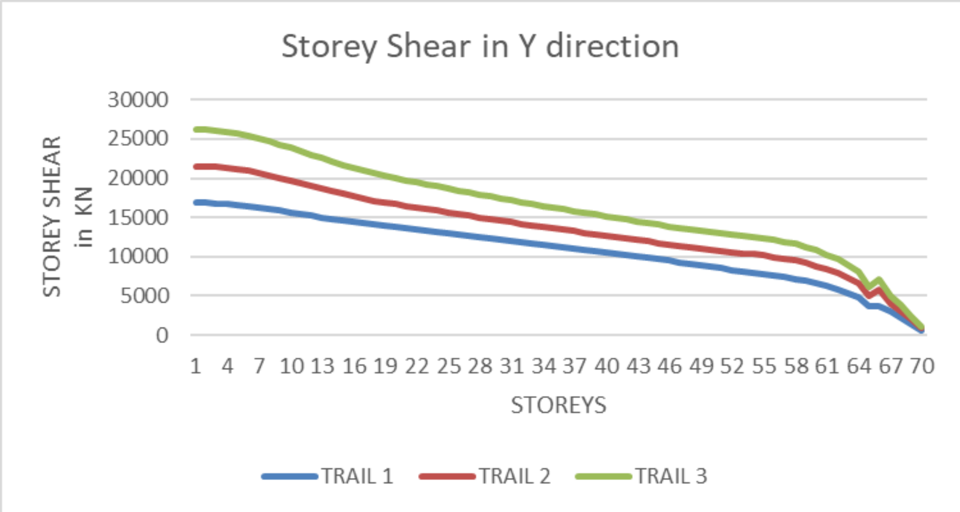

(b)

Figure 8: (a) storeyShear in x direction; (b) storeyShear in y direction

- The graph above depicts storeyshear along the y-axis and storey height along x-axis. Thestoreyshear comparison of three trail cross section was done.
- The displacements shown in different colours trial 1 immediate occupancy in blue, trial 2 life safety in Red, trial 3 collapse prevention in Green.

Storey Overturning Moment

Due to the building's inertia, when an earthquake occurs, the building experiences shear at the base and an overturning moment. When designing a building with earthquake loading, these are taken into account. The graph below shows that the overturning moment is greatest at the bottom and gradually decreases as we go upward. Shear is also observed to be maximal at the base and minimal at the top.

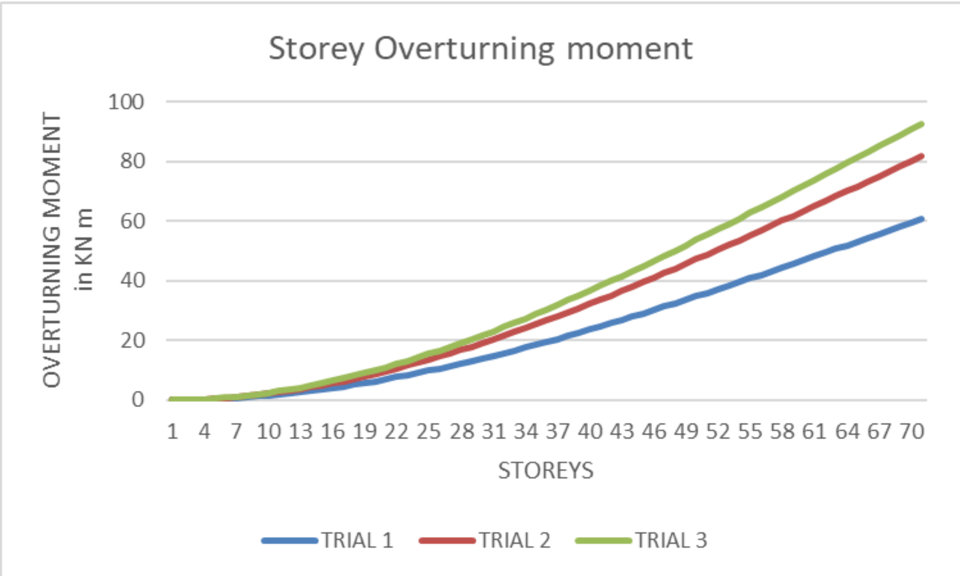

Figure 9: Graph of storey overturning moment

- The graph above depicts storey Overturning along the y-axis and storey height along x-axis. The storey Overturning moment comparison of three trail cross section was done.

- The Overturning moment shown in different colours trial 1 immediate occupancy in blue, trial 2 life safety in Red, trial 3 collapse prevention in Green.

VI. CONCLUSION

- The analysis and design of a T-shaped skyscraper building using ETABS involves several steps. The first step is to create a 3D model of the building in ETABS. The next step is to apply loads and boundary conditions to the model. This includes wind loads, earthquake loads, live loads, dead loads, and other loads that are relevant to the location and intended use of the building.
- After the loads and boundary conditions are applied, the analysis is run in ETABS to determine the structural response of the building. This includes stresses, deflections, and other structural performance indicators. The behaviour of a T-shaped skyscraper building subjected to earthquake load and wind load by adopting response spectrum analysis was done using ETABS.
- The Storey displacement in X direction for trial 1 is 225.858mm, for trial 2 is 174.891mm and for trial 3 is 165.296mm.
- The Storey displacement in Y direction for trial 1 is 152.786mm trial 2 is 120.527mm and trial 3 is 113.457mm.
- The Storey drift in X direction for trial 1 is 0.000807 trial 2 is 0.000705 and trial 3 is 0.000682.
- The Storey drift in Y direction for trial 1is 0.000535 trial 2 is 0.000485 and trial 3 is 0.000472.
- By comparing response of structures in X and Y directions trial 1 has experienced maximum storey displacement and storey drifts.
- The Storey shear in X direction for trial 154.69kN trial 2 is 751.983kN and of trial 3 is 923.564kN.
- The Storey shear in Y direction for trial 1is 611.401kN trial 2 is 840.312kN and trial 3 is 1036.952kN.
- By comparing response of structures in X and Y directions trial 3 has experienced maximum storey shear.
- The Storey overturning moments of trial 1 is 60.795 kN-m, for trial 2 is and for 81.714 kN-m and trial 3 is 92.6865 kN-m.
- By comparing the overturning moments of trial 1, trial 2, and trail 3 values, trial 3 has experienced maximum overturning moment.

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