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Seismic and Wind Resillence Study of a 15 Story High-Rise Building with Floating Columns in Seismic Zones II & V

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ABSTRACT

The use of floating columns in the construction of high-rise buildings, specifically in the context of G+15 structures in metropolitan cities, as per Indian standards. The structural design of a building is crucial for its durability, strength, stability, and lifespan. Floating columns play a significant role in transferring loads from the floors to the beams, affecting the overall stability of the building.Several factors impact the structural design, including bending moments, shear forces, torsion, and deflection. Due to the growing population in metropolitan areas, there is a need for high-rise buildings that can accommodate both commercial and residential spaces on a single platform.

Commercial and residential floors have different load requirements. Therefore, floating columns are specifically used for residential floors to address these varying load demands. The structural analysis considers seismic and wind forces as per Indian standards (IS 1893-2016 for seismic analysis and IS 875-2015 for wind analysis) for different seismic zones (Zone- Ⅱ, Ⅲ, Ⅳ, and Ⅴ). The materials used in the construction include concrete with a grade of M40 and steel with a grade of Fe550. These material grades are commonly used in construction for their respective strength properties. The floor height for residential floors is 3 meters, while commercial floors have a height of 4 meters. This distinction in floor height is considered in the structural design. The design of high-rise buildings, especially in seismic-prone regions, requires a thorough understanding of structural engineering principles and adherence to local building codes and standards to ensure the safety and stability of the structure. The use of floating columns can be a part of a structural design strategy to address varying load requirements in different parts of the building.Safety is paramount in the design and construction of high-rise buildings, particularly in areas susceptible to seismic activity and strong winds.

INTRODUCTION

The Design and Construction of High-rise buildings demand meticulous analysis and consideration of various factors to ensure structural integrity, safety, and resilienceparticularly in regions prone to seismic activity and varying wind speeds. This study delves into the analysis of a high-rise building with 16 stories (G+15) utilizing a unique structural feature using floating columns. The Primary focus is on assessing the building's response to seismic forces and different wind speeds, aiming to enhance our understanding of the structural behaviour and performance under these dynamic conditions.

Seismic zones present a significant challenge for engineers and architects, as ground movements during an earthquake can exert substantial forces on a structure. By incorporating floating columns, this research explores an innovative approach to mitigate the impact of seismic forces. Floating columns, which are designed to uplift during seismic events, can potentially reduce the transmission of lateral forces to the structure and improve overall seismic resilience.

Moreover, the study considers the influence of varying wind speeds on the high-rise building. Wind loads pose another critical aspect in the design and analysis of tall structures, influencing both lateral and torsional responses. Examining the building's behaviour under different wind speeds is crucial for ensuring its stability and performance throughout its operational life.

Through advanced structural analysis techniques, including finite element methods and dynamic analysis, this research aims to provide valuable insights into the performance of the high-rise building. The findings may contribute to refining design practices, optimizing structural configurations, and enhancing the overall safety and durability of tall structures in seismic zones with different wind speed scenarios.

In essence, this investigation seeks to bridge the gap between theoretical knowledge and practical application by exploring the feasibility and effectiveness of floating columns in a high-rise building subjected to seismic forces and varying wind speeds. The Outcomes of this analysis can significantly inform future design considerations, building codes, and engineering practices for tall structures in regions facing the challenges of seismic activity and dynamic wind conditions.

Structural engineering is a branch of civil engineering that focuses on the design and analysis of structures to ensure they can withstand various loads and environmental conditions. The primary goal of structural engineering is to ensure the safety, stability, and durability of structures such as buildings, bridges, dams, towers, and other infrastructure. Structural engineers use principles of physics and mathematics to design structures that can resist forces and loads, including gravity, wind, seismic activity, and other external factors.

LITERATURE REVIEW

STATIC ANALYSIS

N.M. NEWMARK CONSULTING SERVICES (1973) AND J.A. BLUME AND ASSOCIATES, ENGINEERS (1973) developed for defining site independent earthquake response spectra that are applicable to most sites. The only exceptions are the sites, which are relatively close to the Epicenter of a postulated earthquake or sites, which have physical characteristics (e.g. foundation deposits with well-defined frequency filtering characteristics) that could significantly enhance the spectral characteristics of ground motion in a portion of the spectral band of interest.

The very first response spectrum was proposed by Benioff in 1934 and again in 1943 by**MABIOT (WALTER W.HAYS, 1980)** proposed it as a different method for determining theMaximum amplitudes of response of ensemble of simple damped harmonic oscillators, whenExited by a given ground motion time history.

G.W.HOUSNER, father of earthquake engineering, accepted the concept of M.A.Biot, as a means of characterizing ground motion and their efforts on structures, the site independent method was first introduced by G.W.Housner, and he derived smooth normalized acceleration and velocity response spectra from the two horizontal components of ground acceleration recorded at four large earthquakes in the western United States, The earthquakes were (1) 1934 imperial valley, California (m 6.5); (2) 1940 imperial valley, California (m 7.9); (3) 1952 kern county, California (m 7.7) and (4) 1949 Puget Sound, Washington (m-7.1), The empirical distance ranged from 8 to 56 km. the recording sites were scaled by a factor based on the spectrum intensity rather than the peak ground acceleration. G.W. Housner used electrical analogy technique. But now the availability of digital computer in the calculation of spectra.

‘**CARR,(1994)** Under seismic actions, however, it is important that the distribution of ‘member forces be based on the realistic stiffness values applying close to member yield forces, as this will ensure that the hierarchy of formation of member yield conforms to assumed distributions The structural deformations due to seismic loading will generally be associated with high stresses. The estimation of deflections for the purpose of determining period of vibrations and inter-story drifts will be more realistic if an allowance for the effect of cracking the stiffness of the member is made. A more details recommendations for stiffness modelling of beam and columns are available.

M.ADAM, (1995) Earthquakes, caused by movements on the earth surface, result in different levels of ground shaking leading to damage and collapse of building and civil infra structure, landslides in the case of loose slopes, and liquefaction of sandy soil. Seismic analysis of a multi-story RC frame in Khartoum city was analyzed under moderate earthquake loads as an application of seismic hazard, and in accordance with the seismic provisions proposed for Sudan to investigate the performance of existing building if exposed to seismic loads, bending moments in beams and columns due to seismic excitation showed much larger values compared to that due to static loads.

IN1999, NEWMARK AND HALL (CHOPRA.KCANIL, 2001)proposed a new technique for estimating site independent spectra. Their technique as based on the fact that the response spectrum over certain frequency ranges is related by an amplification factor to peak values of ground acceleration, velocity and displacement. The amplification factor were statically determined from response spectra derived from the accelogram recorded at EI Centro from the 1940 imperial valley California earthquake and are a log-normal distribution. In this method, the estimation values of peak ground acceleration; velocity and displacement for the site are plotted on tripartite logarithmic papers. Using the amplification factors that correspond to the desired percentage of critical damping, the peak ground motion values are amplified to give a smooth design response spectrum for the site.

'SUDHIR KUMAR JAIN (2005) intended the importance and need for earthquake resistant construction in seismic active areas. He presented that for most ordinary buildings, it is sufficient to provide earthquake resistance in the building by means of a static analysis with suitable building code. However there are buildings that have some special characteristics which make it difficult to model their dynamic behavior satisfactorily by a code type static analysis, He concludes that such buildings warrant detailed dynamic analysis for satisfactory answers to question concerning the behavior during earthquakes included in the category is rise buildings, buildings With vertical setbacks, soft first-story buildings or buildings with high other unusual characteristics and hence requires special consideration,

NDIRANGU, J.G., NDERU, J.N., MAINA, C.M., MUHIA, A.M, this paper proposes a Fuzzy Logic Controller for Maximum Power Point Tracking of a case study wind energy conversion system (WECS).The system consists of a standalone fixed pitch, variable speed wind turbine directly coupled to a permanent magnet synchronous generator (PMSG), an uncontrolled diode rectifier, a dc-dc boost converter, a fuzzy logic based controller and a load. For a given wind speed, there is an optimum speed of rotation that gives maximum power. The aim of the maximum power point tracking controller is to drive the WECS at the optimum speed that corresponds to maximum power at any wind speed. The designed Fuzzy Logic Controller determines the duty cycle D that yields optimum speed for maximum power extraction from the WECS for various wind speeds. It then applies this D to the DC-DC boost converter to control the speed of rotation of the PMSG to track maximum power point curve. Simulation results show that the designed system is able to extract maximum power for varying wind speeds.

ARVINDY. VYAVAHARE1, GODBOLE. P. N2, TRUPTINIKOSE3, 2012,As author study that Tall buildings are slender flexible structures in nature and require to be examine to settle on the significance of wind speed induced excitation along and across the path of wind in specific zone. The Indian codal provision of practice for wind load on any buildings and structures (code IS-875 Part-3 1987) gives a procedure to determine along wind response of tall structures, while the across wind response and intervention effect are not included in the code at present. A article 'Review of Indian Wind Co de IS 875 (Part 3) 1987' has been set by IIT Kanpur under GSDMA project gives recommendations to gain across wind reaction of tall buildings and structure as per process given in Australian/New Zealand standard 'Structural Design Actions – Part 2 Wind Action (AS/NZS 1170-2 : 2002) In the Australian codal provision to obtain the cross wind response it is necessary to compute the coefficient (Cfs) for which figures and expressions are specified for selected (h:b:d) ratios. In this paper use of ArtificialNeural Network (ANN) has been made to generalize the above process from the limited available data, so that across wind response can be obtained for a building with given (h:b:d) ratio.

SHAIKH MUFFASSIR [1], L.G. KALURKAR [2], 2016, this studyshows thehigh-rise structure or building is the necessity of metro cities. The multi-story high rise RC building islargerand less elastic in nature as judge against tocompound structures. Thisstudy investigates thesimilarity or comparison between RCC and compositestructure under the effect of wind, additional to it compound structure also includes unlike plan configurations. This study has total 15 number of building model are arranged and analysis for wind load by using ETABS 2015software. The various softwareis workon wind and earthquake analysis but we go for software ETABS 2015.The wind analysis is performed for unlike heights such 20m, 50m and 80m respectively. In addingtogether, the comparative study concludes that the compound structure is bigger elastic in nature and more at risk as compare to RCC structure and the compound option is better than RCC for multi-story structure. Whole study is observed in software analysis. In addition, thecomparison of unlike plan configuration shows that the response of parameter such as story displacement, story stiffness, base reaction and time period under effect of wind. The reason of this analysis is to conclude the most efficient shape of construction in horizontal zone.

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SUKUMAR BAHERAin this paper involve stiffness balance of first storey and the storey above are studied to reduce irregularity occurs due to presence floating column. To study response of structures under different earthquake excitation having different frequency content keeping the PGA and time duration factor constant theydevelop FEM codes for 2D frames with and without floating column. The behavior of building frame with and without floating column is studied under static load, free vibration and forced vibration condition. The finite element code has been developed in MATLAB platform. The time history of floor displacement, inter storey drift, base shear, overturning moment are computed for both the frames with and without floating column. The dynamic analysis of frame is studied by varying the column dimension. It is concluded that with increase in ground floor column the maximum displacement, inter storey drift values are reducing. The base shear and overturning moment vary with the change in column dimension.

SREEKANTH GANDLA NANABALA1*, PRADEEP KUMAR.In this paper find whether structure is safe or unsafe with floating column when built in seismically activeareas and also find floating column building is economical or uneconomical. For that purpose, analysis of G+5 storey normal building and floating column building are done for external lateral forces. this analysis done by using sap2000.external lateral load are calculated manually. Using equivalent static method for analysis created 2D model model,model1,model2,model3.model1is a normal building with same dimension f beam and column.model2 is floating column building without changing dimensions.model3 is floating column building with changing dimension of beam and column. And compare the both building based on displacement due to lateral load in terms of model1, model2.model3.also based on stiffness, and based on time history analysis. To check economy of both building compares steel and concrete quantity in terms of model, model2, model3.

FLOATING COLUMN

Floating columns refer to structural columns that are supported by beams or slabs at both ends, rather than being directly anchored to the ground or foundation below. These columns appear to "float" above the ground or lower floors because they lack traditional support from the ground level. Floating columns are also known as "hanging columns" or "cantilevered columns." Floating columns are often used in architectural designs to create open and spacious areas without the obstruction of traditional columns on the ground floor. They can be employed in various types of buildings, including commercial, residential, and institutional structures. There are several reasons why floating columns may be used in building construction:

However, it's important to note that the design and implementation of floating columns require careful consideration of structural integrity, load distribution, and safety. Engineering calculations and structural analysis are crucial to ensure that the columns can support the intended loads and meet building code requirements.Designing structures with floating columns requires careful analysis and consideration of various factors such as load distribution, stability, deflection, and seismic performance. Engineers must ensure that the columns can safely support the loads imposed on them while maintaining structural stability. The choice of materials for floating columns depends on several factors including structural requirements, architectural aesthetics, and budget constraints.

LOADS AND COMBINATION

- **TYPES OF LOADS:**

  Generally, a structure may be subjected to following types of loads:

  - Dead loads
  - Imposed loads
  - Impact loads
  - Seismic loads
  - Wind loads

- **Dead loads:**

  Dead loads are permanent or stationary loads which are transferred to structure throughout the life span. Dead load is primarily due self-weight of structural members, permanent partition walls, fixed permanent equipment and weight of different materials.

- **Imposed or Live Load:**

  Live loads are either movable or moving loads without any acceleration or impact. They are assumed to be produced by the intended use or occupancy of the building including weights of movable partition or furniture etc. Since it is unlikely that any one particular time all floors will not be simultaneously carry maximum loading, the

- **Impact Load:**

  Impact load is caused by vibration or impact or acceleration. Thus, impact load is equal to imposed load incremental by some percentage called impact factors or impact allowance depending upon the intensity of impact.

- **Seismic Load:**

  Seismic loads are external forces applied to building structure as a result of earthquake generated agitation IS-1893-2016 gives details for earthquake resistant design of structures. By historical observations India for the first time in 1962 was divided into 4 zones (zone-2). However, the seismic means least and zone 5 means maximum earthquake prone area probabilistic ground accelerations cannot be predicted accurately either or deterministic or basis. Tectonic movements and geological aspects are very complex in nature intensity; durability etc. can ever be predicted accurately. Seismic zones maps are revised from time to time from geological and collected seismo-tectonicaldata. Now 4 zones are considered.Seismic loads result from the ground motion and shaking caused by earthquakes or seismic events.Seismic loads vary based on factors such as earthquake magnitude, duration, frequency, soil conditions, and building response characteristics.Designing structures to resist seismic loads involves seismic analysis and the implementation of seismic-resistant design principles and structural systems.

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- **Wind Load:**

Wind loads result from the pressure and suction forces exerted by wind on the surfaces of buildings and structures.Wind loads vary depending on factors such as wind speed, direction, building height, shape, and geographical location.Wind loads can significantly influence the design of structures, particularly tall buildings, bridges, and other exposed or aerodynamically sensitive elements.Wind load refers to the force exerted by the movement of air or wind on structures such as buildings, bridges, towers, and other exposed elements. Wind loads are a significant design consideration in structural engineering, particularly for tall or slender structures, coastal regions, and areas prone to strong winds.Wind loads result from the pressure and suction forces exerted by the wind as it flows around and over the surfaces of structures. The pressure difference between the windward and leeward sides of a structure creates wind-induced forces that act perpendicular to the surface.

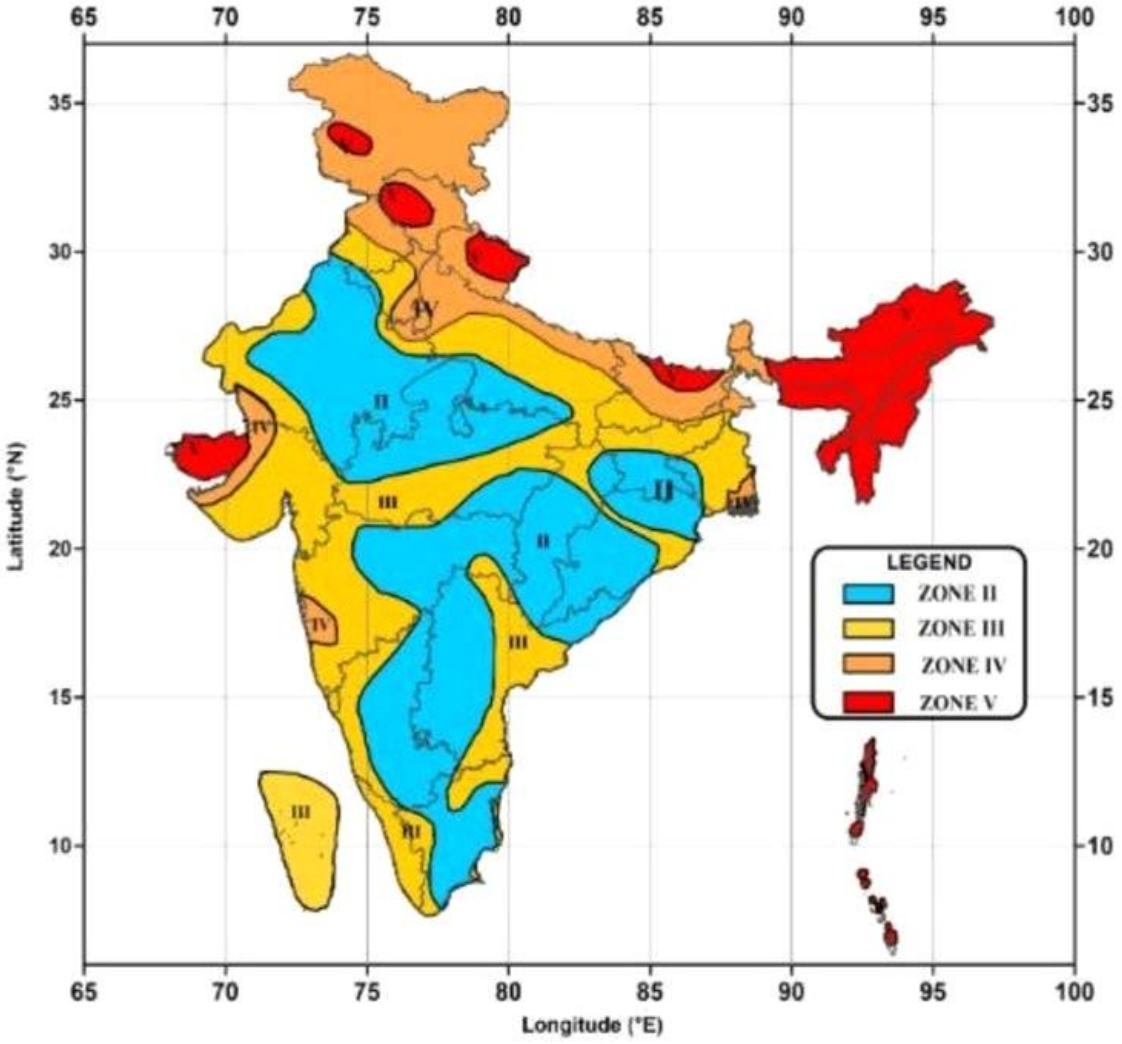

Fig-9 Seismic Zones in India

- **LOAD COMBINATIONS:**

A load combinations results when more than one load type acts on the structure. ETABS can generate loads combinations depending on the code selected. The various load combinations applied on the structure are shown below:

LOAD COMBINATIONS	
S.No	Load combinations
1.	1.5(D.L+L.L)
2.	1.2(D.L+L.L+EQ(X))
3.	1.2(D.L+L.L+EQ(-X))
4.	1.5(DL+EQ(X))
5.	1.5(DL+EQ(-X))
6.	0.9D.L+1.5EQ(X)
7.	0.9D.L+1.5EQ(-X)
8.	1.2(D.L+L.L+EQ(Y))
9.	1.2(D.L+L.L+EQ(-Y))
10.	1.5(D.L+EQ(Y))
11.	1.5(D.L+EQ(-Y))
12.	0.9D.L+1.5EQ(Y)
13.	0.9D.L+1.5EQ(-Y)

TABLE – 6.5

EQ(X) = Earthquake in X-direction

EQ(Y) = Earthquake in Y-direction

DL = Dead load

LL = Live load

METHODOLOGY

ETABS stands for Extended Three-Dimensional Analysis of Building System. It is a structural analysis and design computer program originally developed by Ashraf Habibullah. It is a computer program based on the theory of finite elements (FEA) dedicated to the analysis and design of structural sentences of buildings exclusively. His design began in 1963, when the first version was produced at Berkeley University in California, USA, in 1984.It's a software application used for structural analysis and design of buildings. ETABS is particularly known for its capability to handle complex geometries and load conditions, making it a popular choice for structural engineers working on high-rise buildings and structures with intricate designs.It performs various types of structural analysis, such as static, dynamic, linear, and nonlinear analyses, to evaluate the behavior of the structure under different load conditions.The software provides visualization tools to display analysis results, including deformations, stresses, and displacements, helping users understand the structural response intuitively.

ETABS can integrate with other engineering software applications like AutoCAD and Revit, allowing seamless data exchange and collaboration between different tools.It generates detailed reports and documentation of analysis and design results, which are crucial for project documentation and communication with stakeholders.

ETABS in present days leading design software in the market. Many design companies use this software for their project design purpose. The innovative and revolutionary ETABS is ultimate integrated software.

METHOD OF ANALYSIS:

LINEAR STATIC METHOD:

A linear static analysis in an analysis where a linear relation holds between applied forces and displacements. In practice, this is applicable to structural problems where stresses remain in the linear elastic range of the used material. In a linear static analysis the model's stiffness matrix is constant, and the solving process is relatively short compared to a nonlinear analysis on the same model. Therefore, for a first estimate, the linear static analysis is often used prior to performing a full nonlinear analysis.

MODELLING AND ANALYSIS:

For the analysis of G+ 15 building following dimensions are considered which are elaborated below. In the current study main goal is to compare the linear static values for bending moment and shear force of a G+ 15 building of different earthquake zones and their wind speed.

- **Define Geometry**: Start by creating the basic geometry of your building in ETABS. This includes defining the structural elements such as beams, columns, slabs, walls, and any other components that make up your building.
- **Assign Properties**: Once the geometry is defined, assign appropriate properties to each structural element. This includes material properties such as concrete or steel for beams and columns, as well as section properties such as dimensions and reinforcement details.
- **Define Loads**: Specify the loads acting on the building. This includes dead loads (self-weight of structural elements), live loads (occupant loads, furniture, etc.), and any other applicable loads such as wind, seismic, or snow loads based on the location and building codes.
- **Create Supports**: Define the support conditions for your building. This includes fixing the base of the building to represent the foundation and any other support conditions such as hinges or rollers at specific locations.
- **Meshing**: Generate the finite element mesh for your model. ETABS uses finite element analysis (FEA) to simulate the behavior of the structure, and meshing divides the structure into smaller elements for analysis.
- **Apply Constraints**: Apply any additional constraints or boundary conditions as needed. This may include constraints on displacements, rotations, or other behaviors based on the structural design requirements.
- **Run Analysis**: Once your model is fully defined with geometry, properties, loads, supports, and constraints, you can run the analysis in ETABS. The software will calculate the structural response of the building under the specified loads and conditions.
- **Review Results**: After the analysis is complete, review the results to evaluate the structural performance of the building. This includes checking deflections, stresses, member forces, displacements, and other relevant output data.

- **Generate Reports**: Finally, generate reports and documentation summarizing the modeling process, analysis results, design optimizations, and any other relevant information for project documentation and communication with stakeholders.

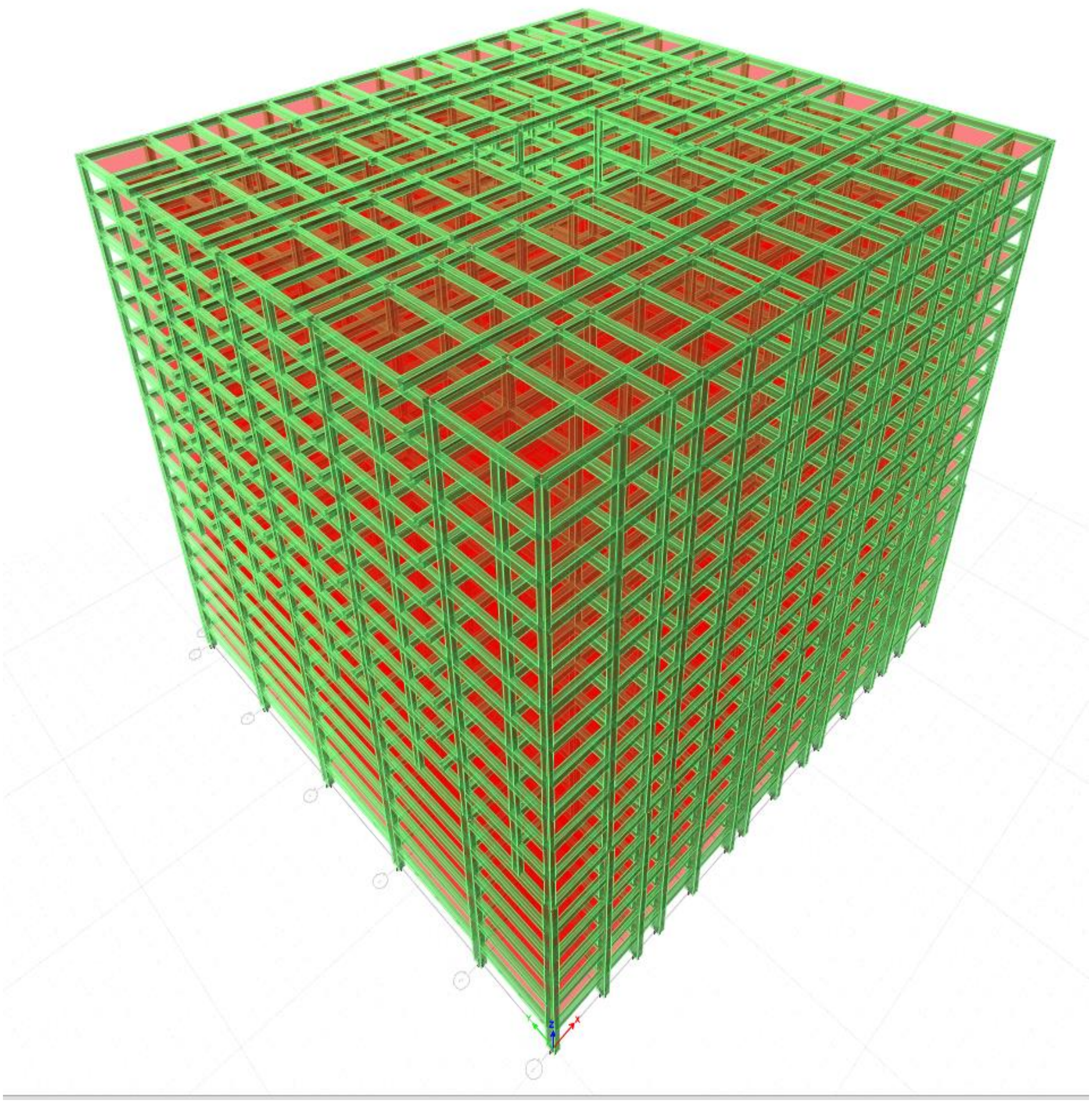

Fig-29 3-D View of Structure

8.4 DETAILS OF MODEL:

S.No	Particulars	Dimensions/Size/Value
1.	Model	G+ 15
2.	Floor Height	3m
3.	Plan size	55.54mx59.84m
4.	Size of columns	0.9x0.6m (G+ 5), 0.3x0.6m(5-15)
5	Size of beam	0.45x0.3m & 0.6x0.23m
6.	Walls	External Walls – 0.23m Internal Walls – 0.115m
7.	Thickness of slab	150mm & 115mm
8.	Type of soil	Type-II, Medium to well-graded sandy clays as per 1893
9.	Material used	Concrete
10.	Static analysis	Linear static Analysis
11.	Software used	ETABS

Table 6.6

CONCLUSIONS

The resulting data are presented as tables and graphs for seismic and wind data, according to IS: 1893-2016 and IS: 875-2015, respectively. Seismic zones II and V are taken into consideration, and wind speeds are calculated as 44 m/s and 39 m/s. The ETABS software is used to model and analyze any structure. Considered in this project's work structure are

- Hence, the structure in the Zone-V have higher Bending Moment and Shear Forces than the Structure in the Zone-II.
- According to the project study, the data collected support the idea that, when comparing the structure in Zone V to that in Zone II, the former has higher Bending Moment and Shear Force values utilizing specific wind speeds. Therefore, in order to construct such structures, we must take specific measurements.
- Zone-V buildings are more susceptible to damage during earthquakes compared to those in Zone-II. Therefore, there is generally less preference for high-rise buildings in Zone-V due to safety concerns.

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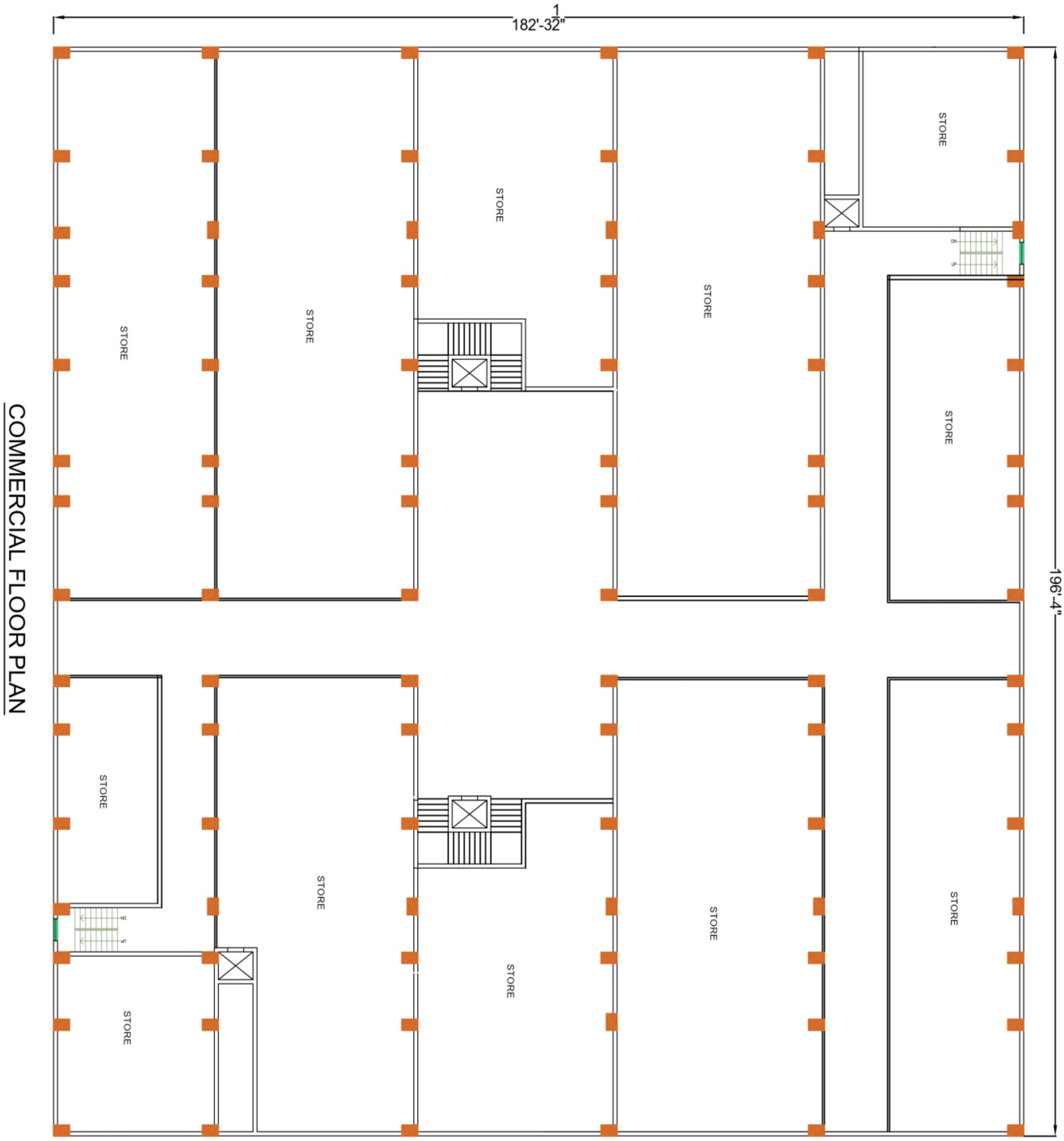

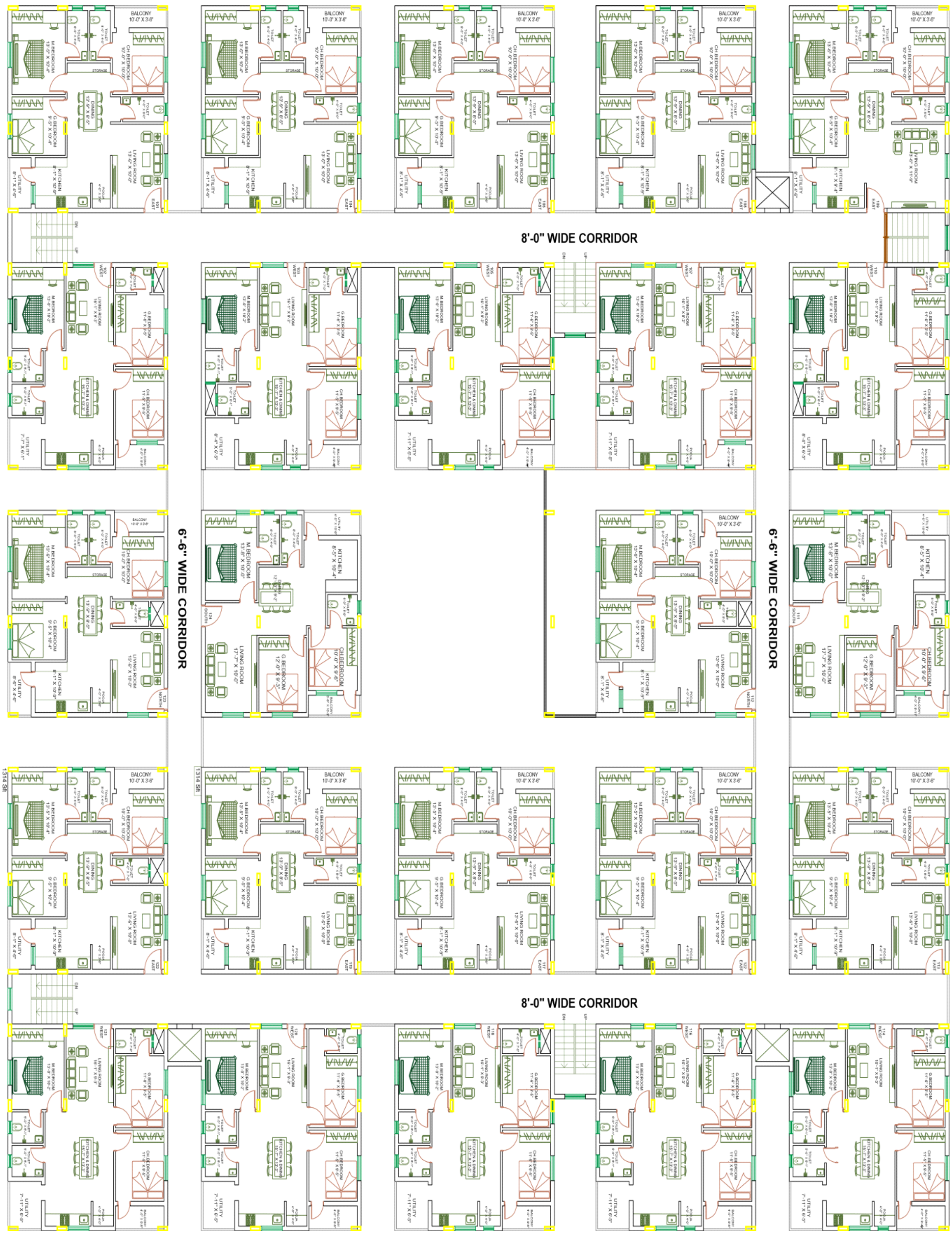

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