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Influenced Of Building Height And Seismic Zone On Foundation Design In Soft Soil

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Abstract: The increasing demand for vertical expansion in urban areas has led to the proliferation of mid-rise and high-rise buildings, especially in regions where land availability is limited. In countries like India, which lies in a seismically active zone, the safety and stability of such structures under earthquake loading is of paramount importance. Among the critical aspects of structural safety is the design and performance of the foundation system, particularly when the building is situated on soft soil.

Foundation systems in such environments must be carefully engineered to resist both static and dynamic loads while minimizing differential settlement and tilt. Another important factor influencing seismic response is building height. Tall buildings (e.g., G+15) tend to have higher flexibility and longer natural time periods, making them more susceptible to resonance with certain seismic wave frequencies. This increased flexibility can result in larger story drifts and greater base shears during an earthquake. Conversely, low-rise buildings (e.g., G+6) are stiffer and may respond differently under similar seismic conditions.

This study presents the development of a STAAD Pro. Model for G+6 and G+15 buildings in seismic zones III and V with soft soil conditions requires a detailed approach focusing on seismic design and soil structure interaction. The increased height (G+15) and higher seismicity (Zone V) combined with soft soil demand and design approach, particularly a Dyanamic Analysis Method like Response Spectrum Analysis.Model the beams and columns as frame members. The G+15 building will require greater precision in modeling due to its height. Assign appropriate material properties and section properties. Model the supports as fixed initially.However,since the soil is soft, the supports as spring supports initially. The seismic load varies significantly between the specified zones and building heights.Sesmic zone factor for Zone II -0.16 and Zone V -0.36.For G+15 zone V, using a Special Moment Resisting Frame with Response Reduction Factor R-5 is strongly recommended to ensure ductility and better seismic performance.

Keywords: Seismic zone, Response Reduction Factor, Soft soil, Dyanamic Analysis, STAAD PRO software, SAFE software.

1. Introduction

The foundation design of a building on soft soil is significantly influenced by both the building's height and the seismic zone it is located in. These two factors are deeply interconnected through a phenomenon known as Soil-Structure Interaction (SSI).Taller buildings are more flexible and have a longer natural vibration period. When a building is on soft soil, the flexibility of the soil further lengthens the system's natural period. This is a critical consideration in seismic design because if the natural period of the building foundation soil system is close to predominant period of the ground motion during an earthquake, a phenomenon called resonance can occur. Resonance can dramatically amplify the building's vibrations, leading to severe damage or even collapse.

Taller buildings have a greater mass and are more susceptible to lateral forces from wind and earthquakes. These forces, in turn, generate significant overturning moments at the base of the structure. The design must account for these large forces and moments to ensure the foundation can safely transfer them to the ground. The weight of a tall building is substantial and increases non-linearly with height. This vertical load must be distributed effectively over the soft soil. Shallow foundations may not be suitable, and engineers often need to use deeps foundations like piles, pile-rafts, or rafts to transfer the load to a stronger soil layer or bedrock at a greater depth.

The seismic zone of a region dictates the expected intensity and frequency of earthquakes. It is a primary factor in determining the design seismic forces and the required level of resilience for a structure. Structures in higher seismic zones must be designed to withstand greater lateral forces, including base shear and overturning moments. This directly impacts the foundation, which must be able to resist these forces and transfer them to the ground without failure. Building codes for seismic zones specify design criteria, material requirements and construction practices to ensure earthquake resistance. In seismic zones, the foundation must not only be strong but ductile. Ductility allows the foundation to deform without a sudden, brittle failure, which helps in dissipating seismic energy. The design should ensure that the superstructure fails before the foundation to prevent catastrophic collapse and to allow for repair.

The seismic behavior of a structure is not solely governed by its superstructure; the interaction between the structure, its foundation, and the underlying soil—commonly referred to as Soil-Structure Interaction (SSI) plays a pivotal role, especially during seismic events. Soft soils, which typically include clay, silt, and loose sand deposits, present significant geotechnical challenges due to their low bearing capacity, high compressibility, and susceptibility to large settlements and liquefaction. These soils amplify ground motions during earthquakes and can cause substantial differential settlements, leading to severe structural damage or even collapse if not properly accounted for in the design phase.

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Another important factor influencing seismic response is building height. Tall buildings (e.g., G+15) tend to have higher flexibility and longer natural time periods, making them more susceptible to resonance with certain seismic wave frequencies. This increased flexibility can result in larger story drifts and greater base shears during an earthquake. Conversely, low-rise buildings (e.g., G+6) are stiffer and may respond differently under similar seismic conditions. As the height increases, so do the demands on both the lateral and vertical load-resisting systems and the foundation.

Seismic zoning is a classification that represents the severity of earthquake forces expected in a region. India is divided into four seismic zones (III to V) as per IS 1893:2016, with Zone III being the least and Zone V being the most seismically active.

Buildings in higher seismic zones are subjected to greater seismic forces and hence must be designed with enhanced safety considerations. This includes the need for deeper or more robust foundation systems, especially when combined with the challenges of soft soil conditions.

In this context, the objective of this study is to conduct a comparative analysis of foundation behavior for buildings of varying heights (G+5 and G+12) in different seismic zones (Zone II and Zone V) founded on soft soils. Using STAAD PRO software, structural models were developed and analyzed according to the latest Indian standards, namely IS 1893:2016 for seismic design and IS 456:2000 for structural concrete. The Four configurations studied are:

1. G+6 building in Zone III on soft soil
2. G+15 building in Zone III on soft soil
3. G+6 building in Zone V on soft soil
4. G+15 building in Zone V on soft soil

The key structural parameters analyzed include story drift, base shear, and building weight. In addition, the study evaluates the suitability of different foundation types under these varying conditions by assessing the settlement behavior in soft soils. These findings are intended to guide engineers and designers in selecting appropriate foundation systems that ensure safety, serviceability, and cost-effectiveness for structures of different heights located in seismic-prone areas with problematic soils. [2]

By understanding how seismic zone classification and building height collectively influence foundation performance, this research contributes valuable insights into integrated seismic design and soil-structure interaction modeling, which are crucial for safe urban infrastructure development in developing countries like India.

2. Literature Review-

1) "Soil-structure interaction effects on seismic response of open ground storey buildings" (2021) , G V Rama Rao1, J C Sunil1 And R Vijaya.

Bhuj earthquake in India, 2001 had witnessed spectacular failures of a class of reinforced concrete multi-storied buildings termed as Open Ground Storey (OGS) buildings, necessitated by a functional demand to provide a parking space within a building plan. Due to the absence of brick-in filled walls at the ground floor, a sudden reduction in the storey stiffness can cause enormous seismic displacement demand in the ground storey itself. Further, the column-side sway mechanism is developed due to the presence of soft storey between the stiff upper storey and rigid base by assuming the soil support is stiff enough. The present study focuses on the effect of soil flexibility on the seismic response of open ground storey buildings. Analytical studies on typical open ground storey building models considering the soil flexibility have been carried out in SAP2000 software and static nonlinear analysis (pushover analysis) has been used to study the lateral response. Variation in boundary conditions are incorporated by simulating three different soil conditions hard, medium and soft, classified as mentioned in IS 1893 (Part 1) 2016.

It is observed from the present study that the soil flexibility increases the lateral displacement and secondary forces associated with the P-Delta effect. Further, a parametric study is carried out to study the influence of soil flexibility in OGS buildings of various slenderness ratios. The importance of considering the influence of soil-structure interaction has been highlighted for obtaining a realistic performance point of the building. In addition, for preliminary and quick seismic assessment of huge stock of existing OGS buildings in Indian urban regions, a simplified methodology for estimating the lateral behavior of a flexible base open ground storey building has been developed. This methodology is useful to segregate the highly vulnerable OGS buildings that undergo a detailed assessment prior to retrofit. The developed methodology is validated with the detailed analytical studies made on open ground storey buildings.

Open ground storied building frames with fixed and flexible base have been analyzed for different boundary conditions using pushover analysis. Variation in boundary conditions are incorporated by simulating three different soil conditions hard or rock, medium and soft, classified as mentioned in IS 1893 (Part 1) 2016. The soil characteristics are modelled as translational and rotational springs. In addition, the study also includes two other cases of boundary conditions, i.e., fixed and hinged supports at the base for comparison purposes. The seismic response of the building frames such as lateral deflection and time period are compared. Further, a parametric study is carried out to study the influence of soil flexibility in OGS buildings of various slenderness ratios.

The performance point obtained for various cases by verifying the seismic demand with the seismic capacity. From the SSI of open ground storey building study and parametric study the following observations are made: The natural period of the OGS building appreciably alter by considering the soil-structure interaction. The flexible base increases the time period, thus a slight change in the seismic force. Neglecting the soil flexibility in the modeling of OGS buildings, the drift in the ground storey columns can be underestimated. Variation in the base shear of the building models with boundary conditions as hard, medium and soft soil is observed to be marginal. A slight reduction in the soft storey deflected profile is observed due to an increase in the soil flexibility, however, it is observed only at the initial yield hinge formation stage.

The percentage increase of natural time period from fixed support condition to hard, medium and soft soil support conditions has increased as the slenderness ratio increases. But in cases of the hinged condition, a decreasing trend is observed. Therefore, neglecting soil-structure interaction in higher slenderness ratio cases can lead to erroneous results. The influence of soil-structure interaction on lateral behavior is more significant in frames with a higher slenderness ratio.

2) **"A Seismic Study On Lateral Load Resisting Systems At Variables Heights Considering Different Soil Conditions."(2022), Syed Mujtaba Ali Firas, Prof. Nadeem Pasha.**

Civil engineering deals with constructing different types of structures with ensuring safety, durability and serviceability. Now days "earthquake "is phenomena that affects the structures with their safety and serviceability. The amount of damage that earthquake can done to structures is depend on Type of building, Type of soil, Technology used for earthquake resistance, and last but not the least Location of building. An effect of earthquake is largely depend on type of soil in which foundation of building is done because earthquake changes the motion of ground that results the failure foundation. So it is important to study the behavior of different soil at the time of construction of structures. Also earthquake can resisted by various technologies used in building, one of these are shear wall.

It improves the structural performance of building subjected to lateral forces due to earthquake excitation. This study focuses on behavior of different types of soil at the time of earthquake occurrence with bracing and shear wall impact on structures for G+5 RCC building and G+11 RCC building and comparing the result of displacement, storey drift, base shear, and time period. The displacement is maximum for bare frame model (G+5). As the shear wall is placed the displacement decreases. Similarly displacement is maximum for bare frame model (G+13).

As the shear wall is placed the displacement decreases. The storey drift is minimum for bare frame model. The storey drift increases as the shear wall increases Provision of shear wall is more effective if we placed SW at middle along X and Y direction for reducing displacement. Provision of bracing is also effective for reducing displacement. The provision of shear wall at centre is more effective than placing of shear wall at corners. Also provision of bracing at middle is more effective than placing of bracing at corners. Hence it can conclude that placing of SW at centre is more effective than placing at corners.

3) **"Study of Lateral Load Resisting Systems of Variable Heights In All Soil Types of High Seismic Zone" (2024) , Abhijeet Vidyadhar Baikerikar.**

From the ancient time we know earthquake is a disaster causing event. Recent days structures are becoming more and more slender and more susceptible to sway and hence dangerous in the earthquake. Researchers and engineers have worked out in the past to make the structures as earthquake resistant. After many practical studies it has shown that use of lateral load resisting systems in the building configuration has tremendously improved the performance of the structure in earthquake.

In present research we have used square grid of 20m in each direction of 5m bay in each direction, software used is ETABS, the work has been carried out for the different cases using shear wall and bracings for the different heights, and maximum height considered for the present study is 75m. The modeling is done to examine the effect of different cases along with different heights on seismic parameters like base shear, lateral displacements and lateral drifts. The study has been carried out for the Zone V and all types of soils as specified in IS 1893-2002.As the building height increases Lateral displacements and drift increases.

Compared to all other cases Case 1(Bare Frame) produces larger lateral displacements and drifts. Lateral displacements and drift is significantly lower after inserting shear wall and bracings in the bare frame. One of the important conclusions that can be made from the above study is that as the soil changes from hard to soft there is massive increase in base shear, lateral displacements and lateral drifts. Extreme care should be taken in soft soil. Time Period increases as the height of the building increases because mass of the overall building increases as time period is directly proportional to the mass. From the study it is clear that CASE 2 (Shear Wall in Middle) is performing better and more efficient than all other cases. Base Shear is decreased as the time period increases. Time period is significantly lowered after placing shear walls and bracings.

4) **"Study of Lateral Load Resisting Systems of Variable Heights In All Soil Types of High Seismic Zone" (2022) , Abdul Shakeel, K.LovaRaju.**

A natural hazard like Earthquake causes damage to or collapse of buildings if not designed for lateral loads resulting due to Earthquake. Hence for seismic resistance for high rise structures it is important to provide exclusive Lateral Load Resisting System (LLRS) which will supplement the behavior of moment resisting frames in resisting the lateral load. The dual structural system consisting of special moment resisting frame (SMRF) and concrete shear wall has better seismic performance due to improved lateral stiffness and lateral strength. A well designed system of shear walls in a building frame improves its seismic performance significantly. Steel bracings are also one of the successful lateral load resisting system.

The use of steel bracing systems for strengthening or retrofitting seismically inadequate reinforced concrete frames is a viable solution for enhancing earthquake resistance. In the present study, we have used square grid of 20m in each direction of 5m bay in each direction, software used for the analysis is ETABS 7.0, and the work has been carried out for the different cases using shear wall and bracings for the different heights, maximum height considered for the present study is 75m. The modeling is done to examine the effect of different cases along with different heights on seismic parameters like base shear, lateral displacements and lateral drifts. The study also has been carried out for the different zones and different soil as specified in IS 1893-2002. Response of buildings with different heights is presented in table and graphs. Such a study may help to provide guidelines to assess more accurately the seismic vulnerability of building frames and may be useful for seismic design.

5) **"Seismic performance of group pile foundation with ground improvement during liquefaction" (2021), Yasuo Sawamura , Keita Inagami , Tomohiko Nishihara, Takashi Kosaka ,Masahiro Hattori , Makoto Kimura.**

A pile foundation with ground improvement under the footing is a composite foundation with the objectives of enhancing the seismic performance and rationalizing the substructure by combining the pile foundation with ground improvement. Although the effectiveness of this method has been confirmed in previous studies for application to soft grounds, the applicability of this method to liquefiable grounds has yet to be fully investigated. In this study, therefore, centrifuge model tests and finite element analyses were conducted to clarify the effectiveness of this method and to ascertain the improvement in strength (stiffness) when the method is applied to a liquefiable ground. Firstly, in order to investigate the effect of an improved ground on the behavior of the pile foundation during liquefaction, dynamic centrifuge model tests were conducted for three cases with different strengths of the improved ground.

Then, three-dimensional soil–water coupled finite element analyses of the centrifuge model experiments were performed to validate the applicability of the analytical method. After that, parametric studies, in which the strength of the improved ground and the input ground motion were changed, were conducted using the same analytical model. The results confirmed that the horizontal displacement of the pile heads was reduced by the improved ground even in the liquefiable ground, and that the effect of this reduction was more remarkable in cases of high stiffness of the improved ground. Furthermore, it was possible to reduce the bending moments at the pile heads by applying the ground improvement. However, since the bending moment at the boundary between the improved ground and the natural ground became the local maximum, there was an optimum stiffness of the ground improvement at which the maximum bending moment of the piles was reduced.

This is because improving the ground around the pile heads has the same effect as extending the footing. It was thus concluded that the behavior of the pile foundation is similar to that of a composite foundation comprised of a caisson and group piles. It is possible to reduce the horizontal displacement of pile heads by improving the ground around the pile heads even in a liquefiable ground. By increasing the stiffness of the improved ground, a high reduction effect is exhibited. However, as the input seismic motion becomes larger, the reduction rate of the displacement decreases.

6) **"Effects of various factors on behaviors of piles and foundation soils due to seismic shaking" (2022), Muhammad Hamzah Fansuri , Muhsiung Chang , Pungky Dharma Saputra , Nina Purwanti ,Anasya Arsita Laksmi , Sabrina Harahap , Surya Dewi Puspitasari.**

A more comprehensive study of numerical simulation would include the effects of various factors on the responses of piles and foundations soils due to seismic loading. The findings reported that an increase in axial loading would generally increase the excess pore pressure in soils and would generally increase the deflection and bending moment in piles and acceleration responses in soils. An increase in pile spacing would generally increase the deflection and bending moment in piles, as a result of more soil volume among the piles. An increase in diameter of pile would increase in rigidity and maximum bending capacity of piles and thus would resist more energy released in liquefiable ground that amplifies the deflection (curvature) of pile. A comparison of two approaches confirms the pile would be safe from buckling failure against soil liquefaction during seismic loading. Finally, this study would provide for predicting pile buckling instability and the behaviors of piles and foundation soils due to seismic shaking and liquefied ground.

This study was designed to determine the effect of various factors on behaviors of piles and foundation soils in liquefiable ground, as well as to compare the two ways of computing liquefaction potential of foundation soil and buckling instability of pile.

3. Gap Analysis-

To identify the research gap in seismic studies focusing on lateral load-resisting systems (LLRS) at variable building heights under different soil conditions, we need to review the current scope and limitations in literature. Below is a synthesized research gap that may guide a new study or thesis: Lack of comprehensive studies that analyze how LLRS behave across multiple building heights (e.g.low-mid and high-rise) on various soil types (e.g.soft, medium, hard).Inadequate comparative evaluation of different LLRS under identical seismic and soil conditions across different heights. Limited incorporation of realistic soil models in assessing LLRS seismic response. Insufficient region specific studies that validate seismic performance of LLRS considering local codes and geotechnical settings. Scarcity of studies applying response spectrum analysis on LLRS across variable heights and soils, especially considering real earthquake records. While the square grid is the simplest and most common geometry for modeling in ETABS, primarily because it aligns well with typical rectangular building layouts, it does present a few structural and modeling drawbacks.

4. Model Design Data-

To study the seismic response of RCC structure as shown in plan in Fig. 3.1.The development of structural models that form the basis for further analysis in subsequent stages.STAAD Pro is used as the primary tool for modelling and analysis due to its advanced capabilities in handling seismic loads and soil-structure interaction parameters. Description of models developed four building models were created to represent different height and seismic zone combinations: Model 1: G+6 building in seismic zone III,Model 2:G+6 building in seismic zone V,Model 3 : G+15 building in seismic zone III, Model 4 : G+15 building in seismic zone V. All models were designed considering soft soil conditions as per IS 1893 (Part 1):2016 guidelines. Following are the various parameters considered for analysis of building:-

1. Type of Structure – RCC
2. Number of Stories – (G+6) and (G+15)
3. Floor to Floor Height – 3m
4. Earthquake Zone – III and V
5. External walls – 230 mm Thick Burnt Brick Masonry
6. Internal walls – 230 mm Thick Burnt Brick Masonry
7. Live Loads- 3KN/sq.m , 1.5 KN/sq.m
8. Concrete Grade – M25
9. Steel Grade – Fe500
10. Unit weight of concrete – 25 KN/sq.m
11. Unit weight of concrete – 25 KN/sq.m
12. Design Codes – IS:456-2000 , IS:1893(Part 1)-2016
13. Soil Bearing Capacity of soil -100 KN/sq.m

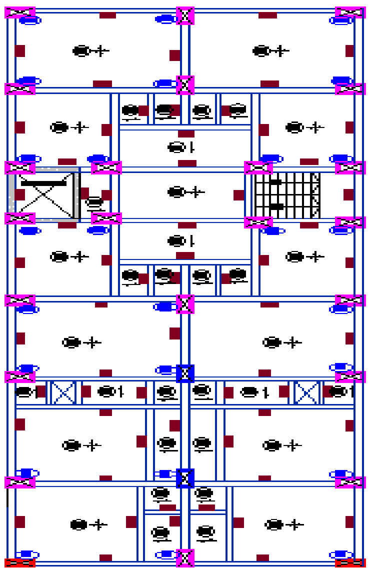

Fig.No.4.1 Framing Plan of Building

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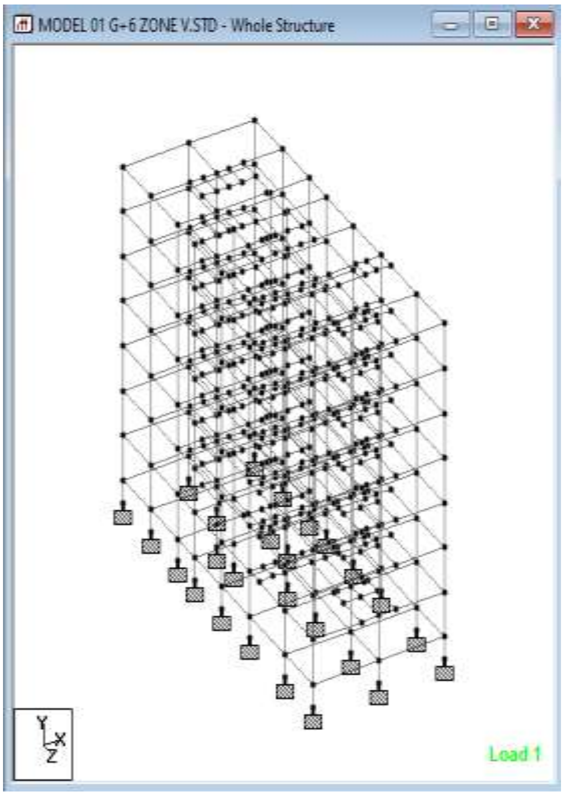

Fig.No.4.2 Model No.1- G+6 Building (Zone V)

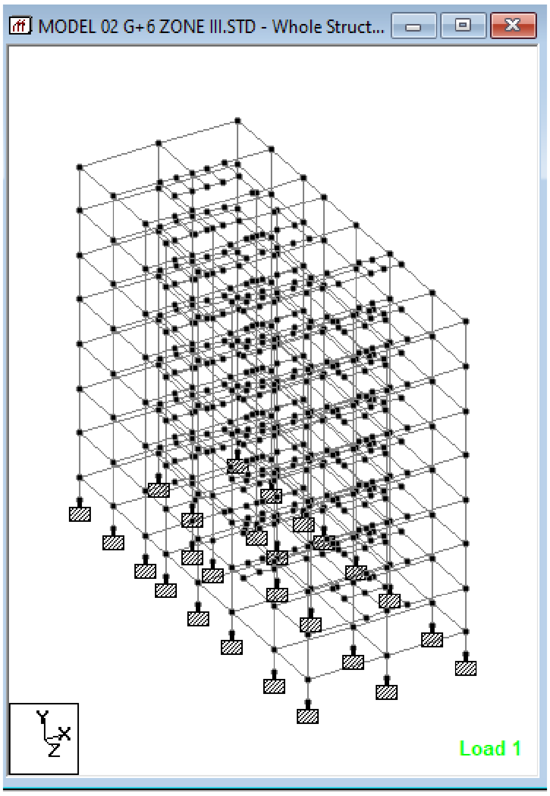

Fig.No.4.3 Model No.2- G+6 Building (Zone III)

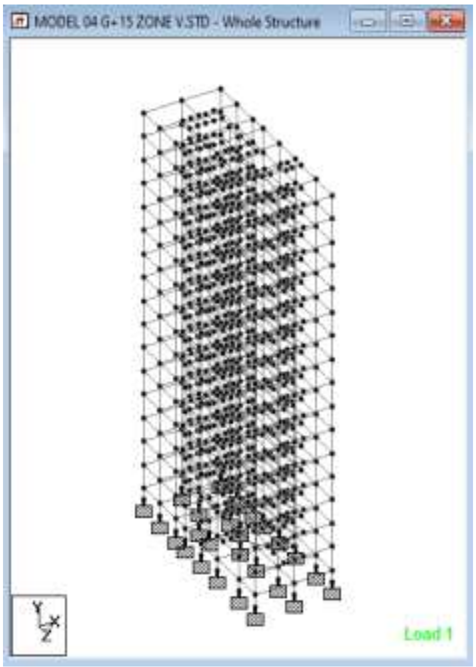

Fig.No.4.4 Model No.3- G+15 Building (Zone V)

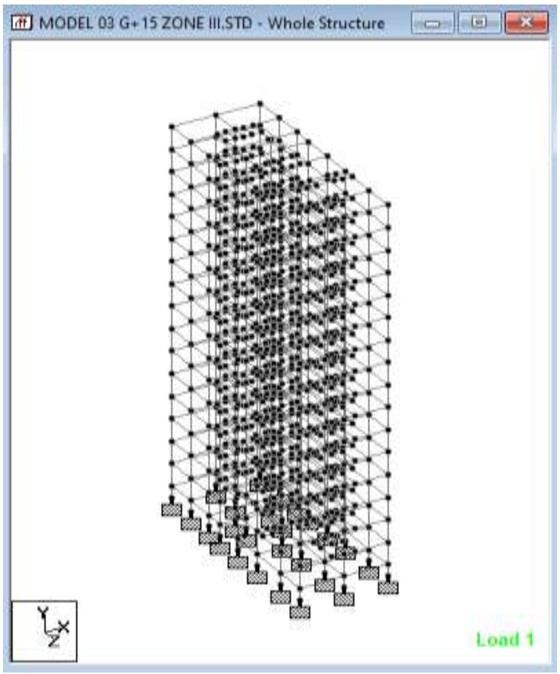

Fig.No.4.5 Model No.4- G+15 Building (Zone III)

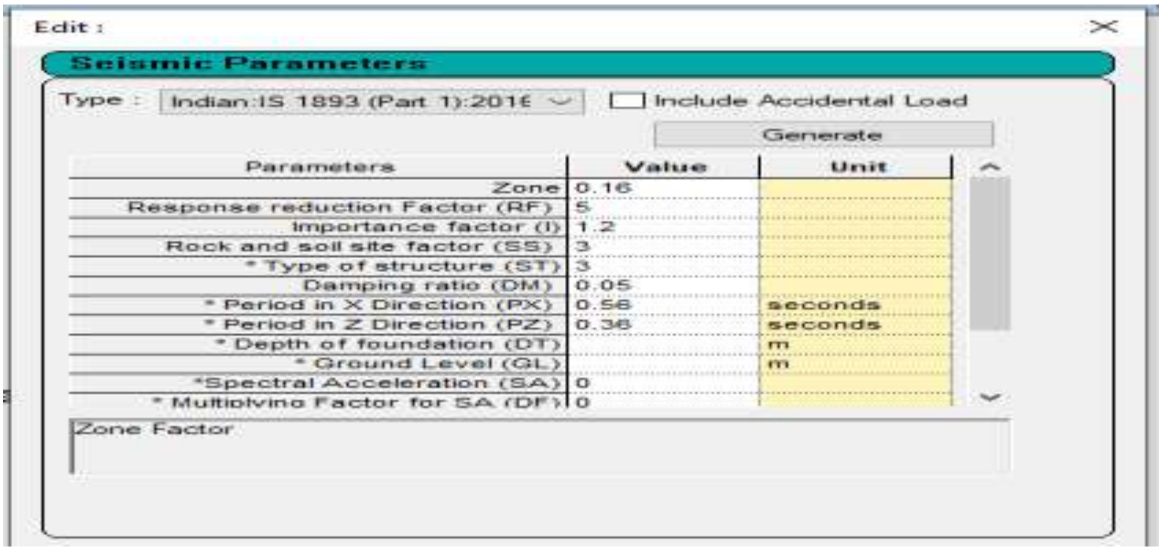

Fig.No.4.6 Seismic Parameters

- **Load Definitions**
  - **Dead Load (DL):** Self-weight of structural elements.
  - **Super Dead Load (SDL):** Filling load and extra dead load 2kN/m²
  - **Live Load (LL):** 3 kN/m² for all floors.
  - **Seismic Load:** As per IS 1893:2016 with Zone II and Zone V specifications.
  - **Importance factor:** 1.2
  - **Response reduction factor (R):** 5 (special RC moment-resisting frame)
  - **Soil Type:** Type III (Soft Soil) **Damping Ratio** :0.005

The load combination as per code 1.5 (D.L. +L.L.), 1.2 (D.L. +L.L. +EL), 1.5(D.L.±EL) and (0.9xd.l.5) ± (1.5 EL) are generated, the analysis is performed and results like base shear, storey drift, displacement are compared. The building location from zone III (Moderate damage risk) to zone V (Very high damage risk) necessitates a much stronger and stiffer structure to resist the significantly higher seismic forces, leading to a large increase in base shear, displacement and drift. The storey displacement for G+6 building is lower and for G+15 building is higher. The storey drift for G+6 building is generally lower and for G+15 building is higher.

5. Seismic Analysis Methods-

Once the structural model has been selected, it is possible to perform analysis to determine the seismically induced forces in the structures. There are different methods of analysis which provide different degree of accuracy. The analysis process can be categorized on the basis of three factors: the type of the externally applied loads, the behaviour of structure and the type of structural model. Linear static analysis applies simplified seismic forces to predict structural response, typically used for initial assessments. Linear dynamic analysis involves more detailed approaches, such as response spectrum and modal analysis, to understand how structures react to dynamic loads while assuming linear behaviour. Nonlinear static analysis, or pushover analysis, evaluates a structure's performance by incrementally applying lateral forces until failure, providing insights into its capacity and ductility. Nonlinear dynamic analysis, or time history analysis, offers a comprehensive view by simulating the structure's response over time to specific ground motion records, capturing both dynamic and nonlinear effects. Each method serves different needs based on the complexity of the structure and the level of detail required. Following figure shows the Methods of Seismic Analysis:-

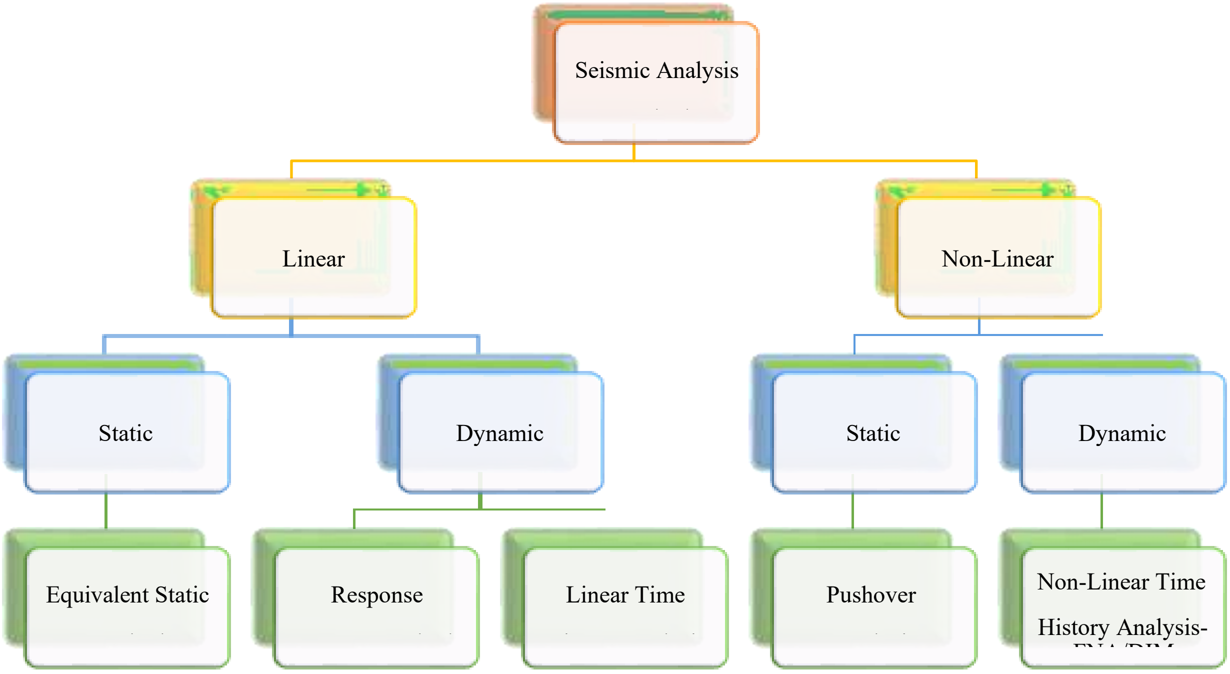

Fig.No.4.7 Types of Seismic Analysis Methods

5.1. Response Spectrum Method (RSM)–

Concept: The Response Spectrum Method (RSM) is a linear-dynamic statistical analysis method used to estimate the likely maximum seismic response of a structure. Instead of calculating the response at every single moment during an earthquake, it estimates the peak response based on the structure's natural frequency and damping. This is the primary application of the Response Spectrum Method. It is a statistical approach used in seismic analysis to estimate the maximum response of a structure to a

Specific earthquake ground motion.

Method: It uses a response spectrum to evaluate how different frequencies impact the structure, giving a detailed picture of its behavior under seismic forces.

When to Use: Best for complex structures where a thorough understanding of seismic response is crucial.

In essence, the Equivalent Static Method is quicker and more straightforward, while the Response Spectrum Method provides a comprehensive analysis of how a structure will handle seismic forces.

6. Results-

The Models were analyzed in order to obtain the seismic response of structure in terms of Storey Displacement and Base Shear. The RSM is the primarily focused method, but in order to compare the variation in seismic performance by RSM, the results for all the parameters have been discussed.

6.1. Displacement:

The term displacement indicates the relative position of the story displaced from the actual position i.e. fixed initial position. Excess displacement can cause generation of excess overturning moments, damage the building components, and cause failure. The Displacement Curve pattern shown by the models similar in X and direction.

Table No.6.1.1 Maximum Storey Displacement in X direction (G+6) Building -

	MODEL NO.1 (G+6) ZONE V	MODEL NO.2 (G+6) ZONE III
	DISPLACEMENT X-DIRECTION	DISPLACEMENT X-DIRECTION

STOREY NO.1	0.88	0.89
STOREY NO.2	1.483	1.518
STOREY NO.3	2.241	2.24
STOREY NO.4	2.98	2.985
STOREY NO.5	3.698	3.698
STOREY NO.6	4.365	4.365
STOREY NO.7	4.958	4.958

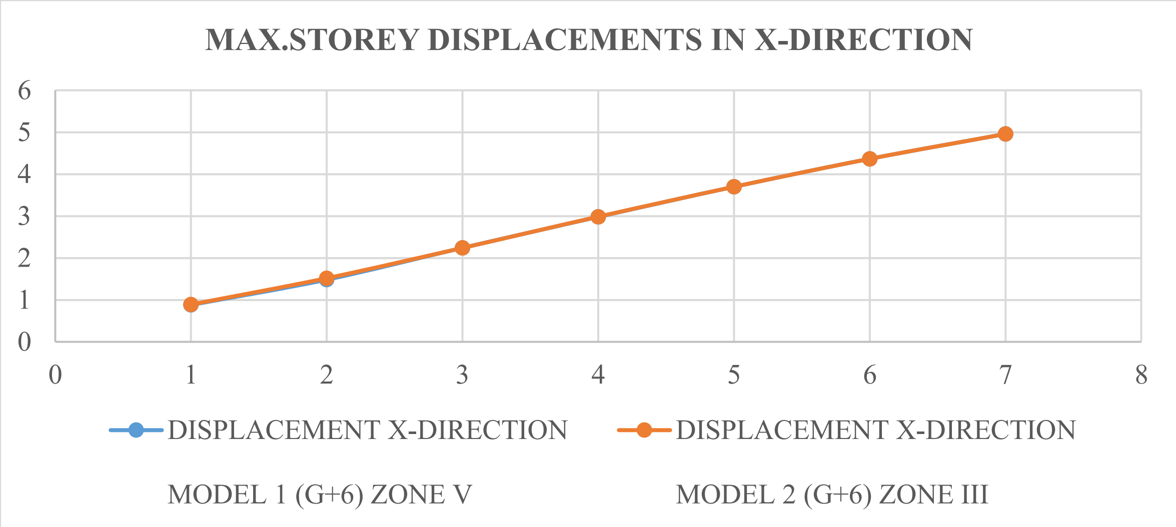

Fig. No.6.1.1 Maximum storey displacement in X direction

Table No.6.2.1 Maximum Storey Displacement in Z direction (G+6) Building -

	MODEL NO.1 (G+6) ZONE V	MODEL NO.2 (G+6) ZONE III
	DISPLACEMENT Z-DIRECTION	DISPLACEMENT Z-DIRECTION
STOREY NO.1	1.597	1.647
STOREY NO.2	3.5	3.348
STOREY NO.3	5.277	5.2
STOREY NO.4	5.883	7.217
STOREY NO.5	9.213	9.213
STOREY NO.6	11.112	11.112
STOREY NO.7	12.86	12.86

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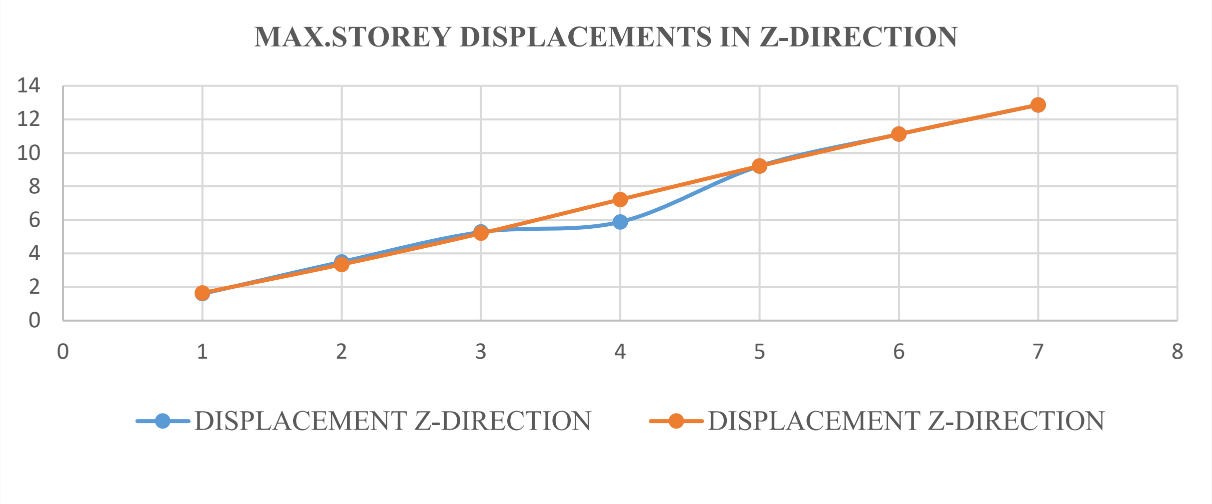

Fig. No.6.2.1 Maximum storey displacement in Z direction

Table No.6.3.1 Maximum Storey Displacement in X direction For (G+15) Building-

	MODEL NO.3 (G+15) ZONE V	MODEL NO.4 (G+15) ZONE III
	DISPLACEMENT X-DIRECTION	DISPLACEMENT X-DIRECTION
STOREY NO.1	1.596	1.565
STOREY NO.2	3.035	2.987
STOREY NO.3	4.875	4.752
STOREY NO.4	6.825	6.737
STOREY NO.5	8.992	8.992
STOREY NO.6	11.955	11.266
STOREY NO.7	13.623	15.676
STOREY NO.8	16.041	16.041
STOREY NO.9	18.495	18.795
STOREY NO.10	22.981	20.959
STOREY NO.11	25.850	23.406
STOREY NO.12	28.383	24.558
STOREY NO.13	31.075	28.135
STOREY NO.14	33.769	30.365
STOREY NO.15	36.065	32.478
STOREY NO.16	38.421	34.423

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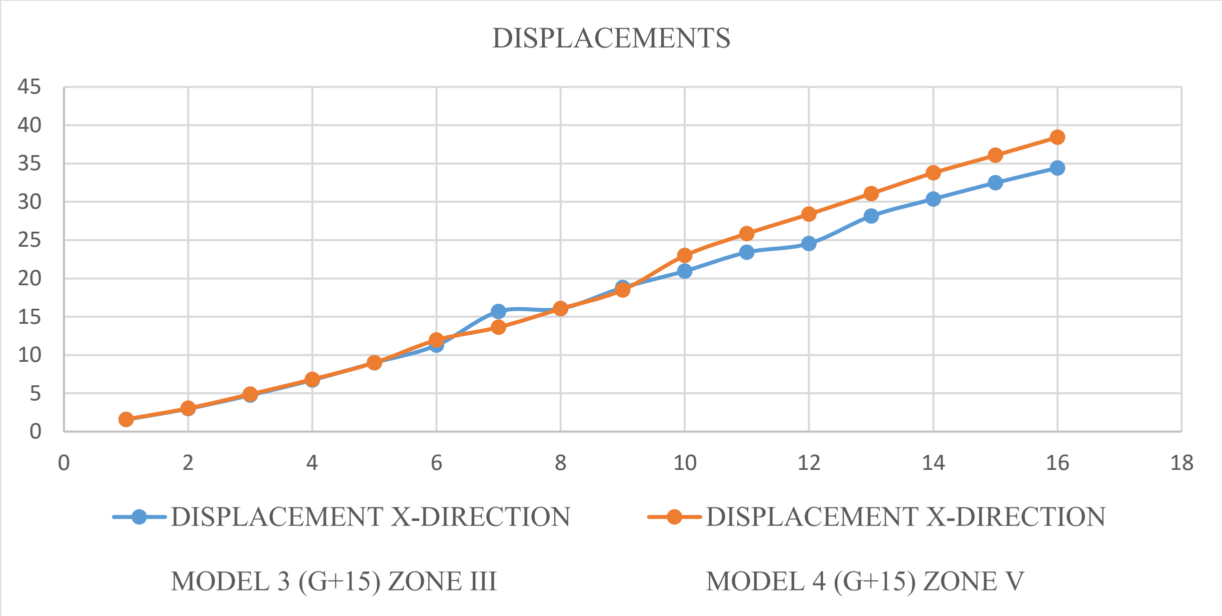

Fig. No.6.3.1 Maximum storey displacement in X direction

Table No.6.4.1 Maximum Storey Displacement in z direction For (G+15) Building -

	MODEL NO.3 (G+15) ZONE V	MODEL NO.4 (G+15) ZONE III
	DISPLACEMENT Z-DIRECTION	DISPLACEMENT Z-DIRECTION
STOREY NO.1	1.862	3.247
STOREY NO.2	3.998	6.976
STOREY NO.3	6.525	11.411
STOREY NO.4	9.316	16.317
STOREY NO.5	12.274	21.520
STOREY NO.6	15.322	26.877
STOREY NO.7	18.395	34.912
STOREY NO.8	18.488	41.066
STOREY NO.9	24.420	47.165
STOREY NO.10	27.290	52.122
STOREY NO.11	30.021	52.66
STOREY NO.12	32.589	57.153
STOREY NO.13	32.950	61.33
STOREY NO.14	33.152	65.198

STOREY NO.15	33.850	68.763
STOREY NO.16	34.425	80.979S

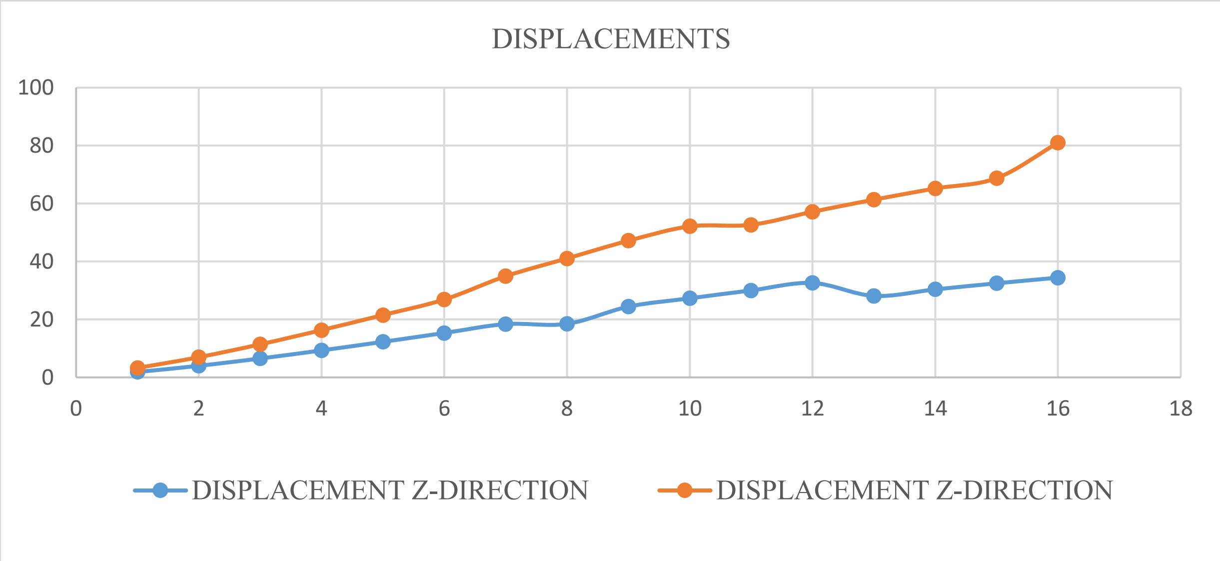

Fig. No.6.4.1 Maximum storey displacement in Z direction

6.2. Base Shear: -

The total lateral force on the structure base/foundation induced due to earthquake is known as Base Shear. Base Shear value helps in designing of the lateral load resisting systems. The intensity of this value depends upon the stiffness and rigidity of structure; hence, it reflects the stability and performance of the structure. When comparing two models, the structure with greater base shear is better in stability.

Table No.6.2.1 Base Shear-

	STATIC BASE SHEAR	DYNAMIC BASE SHEAR
MODEL 1 (G+6) ZONE V	2755.69 KN	3873.63 KN
MODEL 2 (G+6) ZONE III	1224.75 KN	3873.62 KN
MODEL 3 (G+15) ZONE III	8382.70 KN	11989.18 KN
MODEL 4 (G+15) ZONE V	11989.21 KN	11989.18 KN

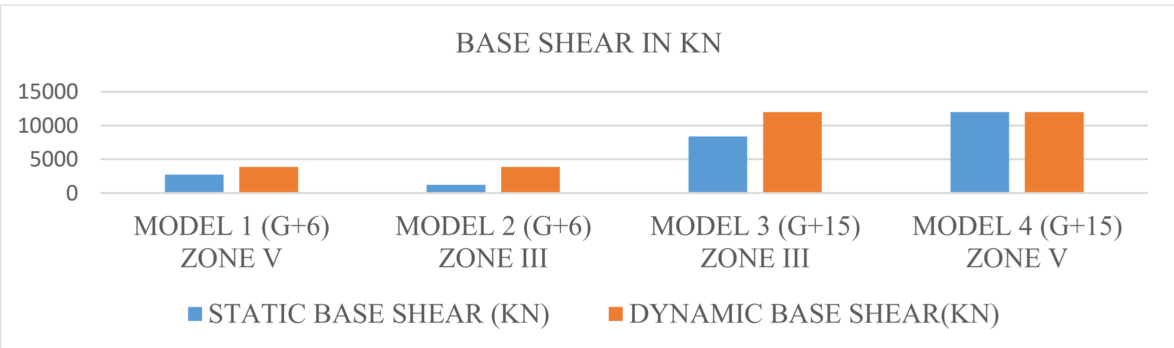

Fig. No.6.2.1 BASE SHEAR GRAPH

7. Conclusion

1) High-rise structures (G+15) on soft soil in Seismic Zone V experience critical displacements exceeding limits, requiring structural modifications or additional lateral load-resisting systems.
2) Structures in Seismic Zone III, irrespective of soil type, perform within safe limits for displacement and drift.
3) (G+6) structures perform satisfactorily in all soil and seismic conditions considered. Settlement criteria are generally satisfied across models, but displacement control is essential for taller buildings in severe seismic zones.

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