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EFFECT OF DIFFERENT SOIL CONDITION ON FOUNDATION DESIGN OF TALL BUILDINGS

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ABSTRACT

Above the past two decades, there has been a significant rise in the construction of tall structures over 150m in height, with an almost exponential development rate. Numerous similar structures have been built throughout the Middle East and Asia, and many more are proposed or now under development. Buildings over 300m in height are posing new engineering difficulties, especially in terms of structural and geotechnical design. Wind analysis is critical when it comes to big structures. Figure 1 illustrates the substantial increase in the number of such structures either built or acquired. Because many conventional design techniques involve extrapolation far beyond the boundaries of previous experience, structural and geotechnical designers are being pushed to use increasingly complex methods of analysis and design. Geotechnical engineers, in particular, are progressively abandoning empirical techniques in favour of state-of-the-art methods when designing foundations for super-tall structures. Numerous studies have investigated the structural behaviour of tall structures with SSI by taking into account a variety of factors such as foundation type, soil conditions, lateral stresses, and the ratio of the flexural stiffness of the beam and column. Very few studies on the soil-structure interaction of tall structures in clayey soil conditions, especially in Indian seismic zones, have been conducted. In zone III, a G+18-story rectangular structure with a 3 m floor-to-floor height was assessed using the Etabs software. The selected plan is rectangular in shape. The structure has been evaluated for static and dynamic wind and seismic forces. Structures have been developed for use in circumstances of hard, medium, and soft soil.

Keywords: ETABS, Tall Buildings, Foundation, Soil Condition.

I. INTRODUCTION

1.1 TALL BUILDINGS

The last two decades have seen a remarkable increase in construction of tall buildings in excess of 150m in height, and an almost exponential rate of growth. A significant number of these buildings have been constructed in the Middle East and Asia, and many more are either planned or already under construction. "Super-tall" buildings in excess of 300m in height are presenting new challenges to engineers, particularly in relation to structural and geotechnical design. Wind analysis is important in case of tall buildings. Figure 1 shows the significant growth in the number of such buildings either constructed.Many of the traditional design methods cannot be applied with any confidence since they require extrapolation well beyond the realms of prior experience, and accordingly, structural and geotechnical designers are being forced to utilize more sophisticated methods of analysis and design. In particular, geotechnical engineers involved in the design of foundations for super-tall buildings are increasingly leaving behind empirical methods and are employing state-of-the art methods.

The investigations have been carried out by many researchers on the structural behaviour of tall buildings with SSI by considering many parameters like foundation type, soil conditions, lateral forces, ratio of flexural stiffness of beam and column etc. Very few investigations have been carried out on soil-structure interaction of tall buildings under clayey soil conditions, particularly in Indian seismic zones.

There are a number of characteristics of tall buildings that can have a significant influence on foundation design, including the following:

1. The building weight increases non-linearly with increasing height, and thus the vertical load to be supported by the foundation, can be substantial.

2. High-rise buildings are often surrounded by low-rise podium structures which are subjected to much smaller loadings. Thus, differential settlements between the high and low-rise portions need to be controlled.
3. The lateral forces imposed by wind loading, and the consequent moments on the foundation system, can be very high. These moments can impose increased vertical loads on the foundation, especially on the outer piles within the foundation system.
4. The wind-induced lateral loads and moments are cyclic in nature. Thus, consideration needs to be given to the influence of cyclic vertical and lateral loading on the foundation system, as cyclic loading has the potential to degrade foundation capacity and cause increased settlements.

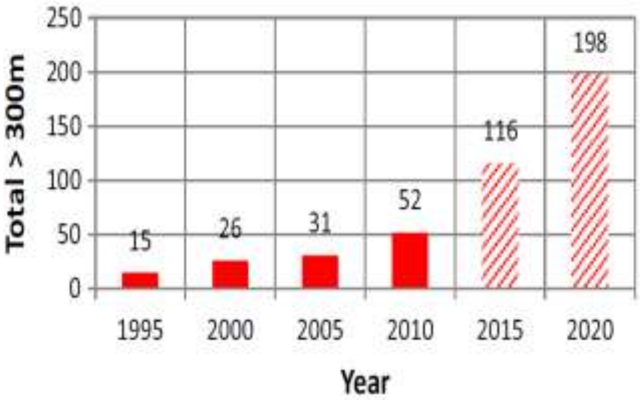

Fig 1: Total number of buildings in excess of 300 m tall

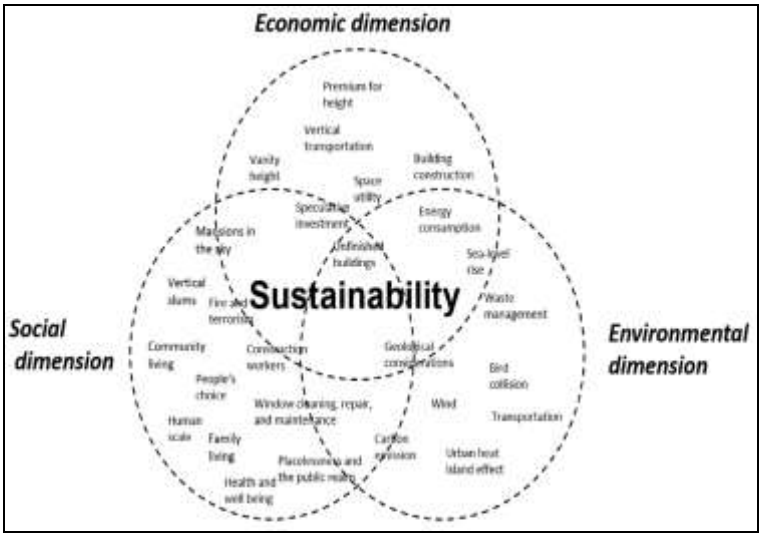

Fig 2: Development of Tall buildings

1.2 TYPICAL HIGH-RISE FOUNDATION SETTLEMENTS

Before discussing details of the foundation process, it may be useful to review the settlement performance of some high-rise buildings in order to gain some appreciation of the settlements that might be expected from two foundation types founded on various deposits. Table 1.1summarizes details of the foundation settlements of some tall structures founded on raft or piled raft foundations. The average foundation width in these cases ranges from about 40m to100m. The results are presented in terms of the settlement per unit applied pressure, and it can be seen that this value decreases as the stiffness of the founding material increases. Some of the buildings supported by piled rafts in stiff Frankfurt clay have settled more than100mm, and despite this apparently excessive settlement, the performance of the structures appears to be quite satisfactory. It may therefore be concluded that the tolerable settlement for tall structures can be well in excess of the conventional design values of 50-65mm. Amore critical issue for such structures may be overall tilt, and differential settlement between the high-rise and low-rise portions of a project.

Table 1: Examples of Settlement of Tall Structure Foundations

Sr no.	Foundation type	Founding condition	Location	No. of cases	Settlement per unit pressure mm/MPa
1	Raft	Stiff clay	Houston	2	227-308
		limestone	Amman; Riyadh	2	25-44
2	Piled Raft	Stiff clay	Frankfurt	5	218-258
		Dense sand	Berlin; Niigata	2	83-130
		Weak Rock	Dubai	5	32-66
		Limestone	Frankfurt	1	38

II. LITERATURE REVIEW

- **GENERAL: -**

The extensive literature review was carried out by referring standard journals, reference books, I.S. codes and conference proceeding. The major work carried out by different researchers is summarized below.

Yin Zhou and Ahsan Kareem [3] In this paper "Gust loading factors for design applications" Wind loads on structures under the buffeting action of wind gusts have been treated traditionally by the "gust loading factor" (GLF) method in most major codes and standards around the world. The equivalent static wind loading used for design is equal to the mean wind force multiplied by the GLF. Although the traditional GLF method can ensure an accurate estimation of the displacement response, it fails to provide a reliable estimate of some other response components. In order to overcome this shortcoming, a more realistic procedure for design loads is proposed in this paper.

Wakchaure M. R., Gawali Sayali [4] In this paper the gust effectiveness factor method takes into account the dynamic properties of the structure, the wind-structure interactions and then determines the wind loads as equivalent static loads. Wind loads are determined based on gust effectiveness factor method. The critical gust loads for design are determined. After the application of calculated wind loads to the building models prepared in finite element software package ETAB's 13.1.1v. Having different shapes are compared in various aspects such as storey displacements, storey drifts, storey shear, axial forces in column etc. Based on the results, conclusions are drawn showing the effectiveness of different shapes of the structure under the effect of wind loads.

III. METHODOLOGY

Following is flowchart of work for Project:

A study involving dynamic effect of wind load on RC buildings and study the behavior of the buildings. The gust factor method is used to determining along wind load effect. The methodology worked out to achieve the above-mentioned objectives is as follows:

1. Compilation of relevant research data from national and international journals, research papers web source, text books, reference books etc to get acquainted with past research.
2. Identification of scope of further research in the high rise buildings subjected to wind effects.
3. Define the scope of specimen for research like height, plan size of building, input parameters from IS code, Material specifications, member specifications etc.
4. The E-TABS software is used to develop 3D model and to carry out the analysis. The lateral loads to be applied on the buildings are based on the Indian standard IS-875-Part 3: 2015.
5. Comparison of results which have significant effects on foundation design of tall building varies as per soil conditions and preparation of discussion summary.
6. Result and discussions.

7. Conclusion will be drawn based on the result of analysis.

Fig 3: Flowchart

3.1 GUST FACTOR:-

A gust factor (GF) is defined as the ratio between the peak wind gust of a specific duration to the mean wind speed for a period of time. It is a simple statistic but is dependent on numerous inputs, including the roughness length (exposure), distance from an upstream terrain change, stability, height, and, potentially, the presence of convection. Wind speed fluctuations are associated with pressure and force fluctuations on a building, and result in fatigue loading on various structural components. Understanding differences in the structure of the wind, which may exist in various high-wind environments, is imperative for proper wind load design.

Gust factor method is only the method of calculating load along wind or drag load by using gust factor method is given in the code since methods for calculating load across-wind or other components are not fully matured for all types of structures. However, it is permissible for a designer to use gust factor method to calculate all components of load on a structure using any available theory. However, such a theory must take into account the random nature of atmospheric wind speed.

Gust Factor as per IS-875 (part 3) 2015:-

Gust Factor(G) = Peak Load/Mean Load

$$G = 1 + r\sqrt{\frac{gv^2Bs\,(1+\emptyset^2) + Hsg_R^2SE}{\beta}}$$

Where,

r =Roughness factor

gv =Peak factor for upwind velocity fluctuatio

Bs =Background factor

ϕ = Factor to account for second order turbulence intensity

Hs =Height factor for resonance response

g =Peak factor for resonant response

S =Size reduction factor

E =Spectrum of turbulence

B= Damping coefficient of the building or structure

IV. PROBLEM STATEMENT

In this project, a G+18-storey structure of a rectangular building with 3 m floor to floor height has been analysed Non-Linear Dynamic Analysis of Multi-storey R.C.C Buildings using Etabs software in zones III. The plan selected is Rectangular in shape. The structure has been analysed for both static and dynamic wind and earthquake forces. Hard, Medium and soft soil condition has been selected for the structure.

Gust factor method is method of calculating load along wind or drag load. Gust factor method is given in the code since IS 2015, these methods for calculating load across-wind or other components are not fully matured for all types of structures. However, it is permissible for a designer to use gust factor method to calculate all components of load on a structure using any available theory. Hence, following parameters are considered for the analysis.

4.1 MODEL DESCRIPTION FOR ANALYSIS:

Preliminary data required for Analysis

Table 2: Parameters to be consider for rectangular geometry analysis

Sr.	Parameter	Values
1.	Number of stories	G+18
2.	Base to plinth	1.5m
3.	Grade of concrete	M30
4.	Grade of steel	Fe 500
5.	Floor to Floor height	3 m
6.	Total height of Building	58m
7.	Dead Load	1.5 Kn/m2
8.	Imposed Load	4 Kn/m2
9.	Assumed City	Pune
10.	Basic Wind Speed	39 m/s
11.	Terrain Category	Type 2
12.	Frame size	18m X 18m building size
13.	Grid spacing	6 m grids in X-direction and Y-direction.
14.	Size of column	500mm x 500 mm
15.	Size of beam	300mm x 500 mm
16.	Depth of slab	125 mm

4.2 AIM: To investigate behavior of tall building of non-identical soil conditions on foundation design of tall buildings subjected to wind action.

4.3 OBJECTIVES:

1. To calculate wind loads by Gust Factor Method as per IS 875 Part III.
2. To investigate behavior of Tall building in terrain category 2 under wind loading having different soil conditions such as Hard, Medium and Soft soil.
3. To interpret effect of different soil conditions on design of foundations of Tall building.
4. Validation of results by software and literature.

Table 3: Models

MODEL 1	G+18 IN SOFT SOIL
MODEL 2	G+18 IN MEDIUM SOIL
MODEL 3	G+18 IN HARD SOIL

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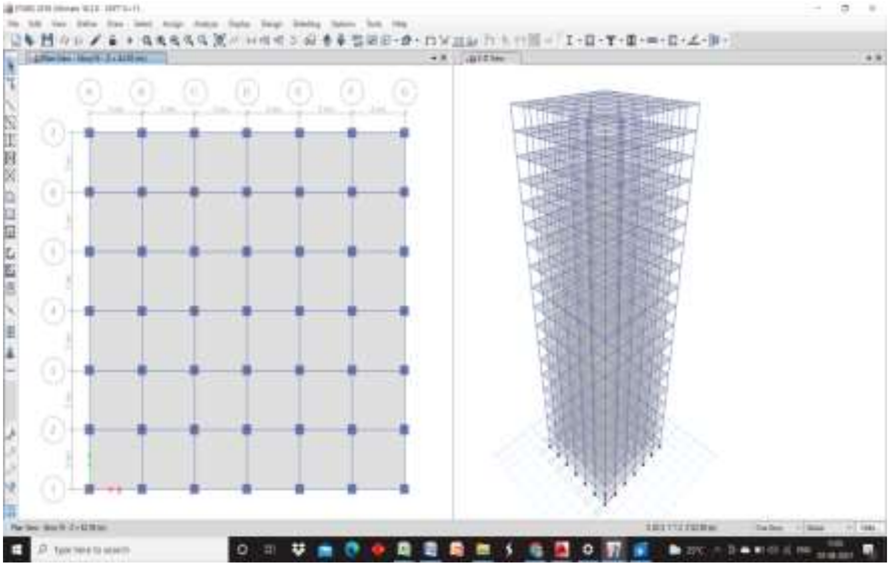

Fig 4: Prepare modeling in ETABS

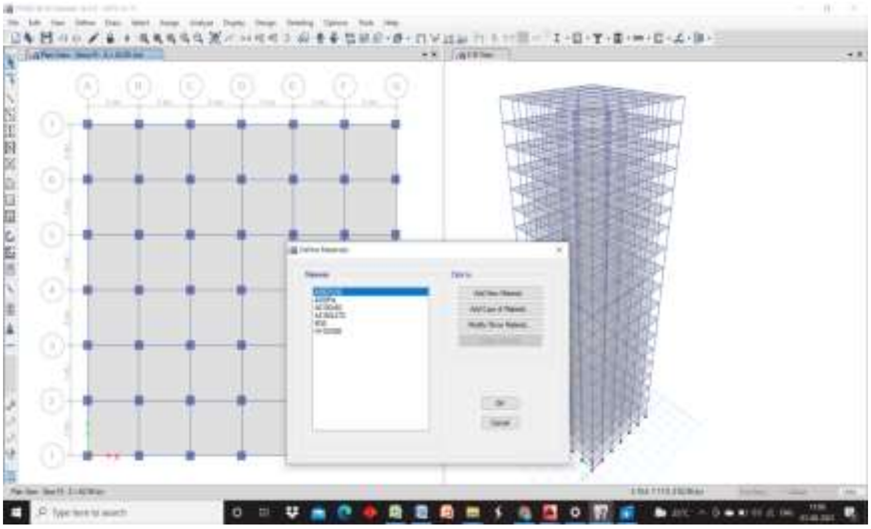

Fig 5: Define material property

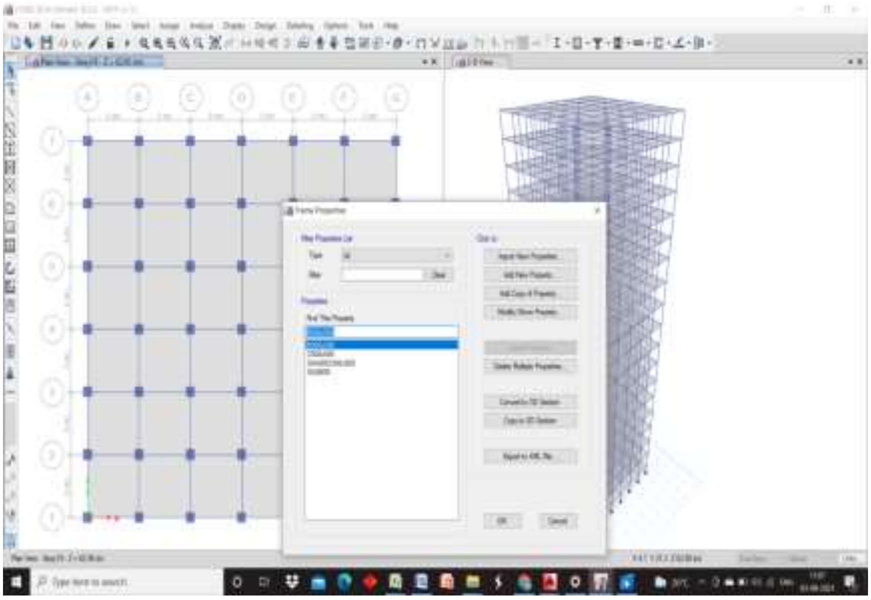

Fig 6: Define Member properties

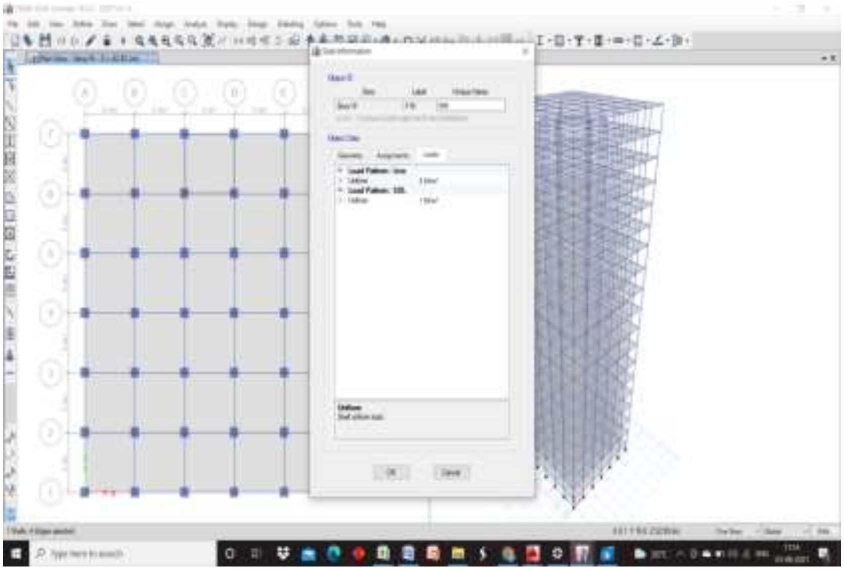

Fig 7: Assign Live and dead loads

4.4. G+18: DESIGN REACTION

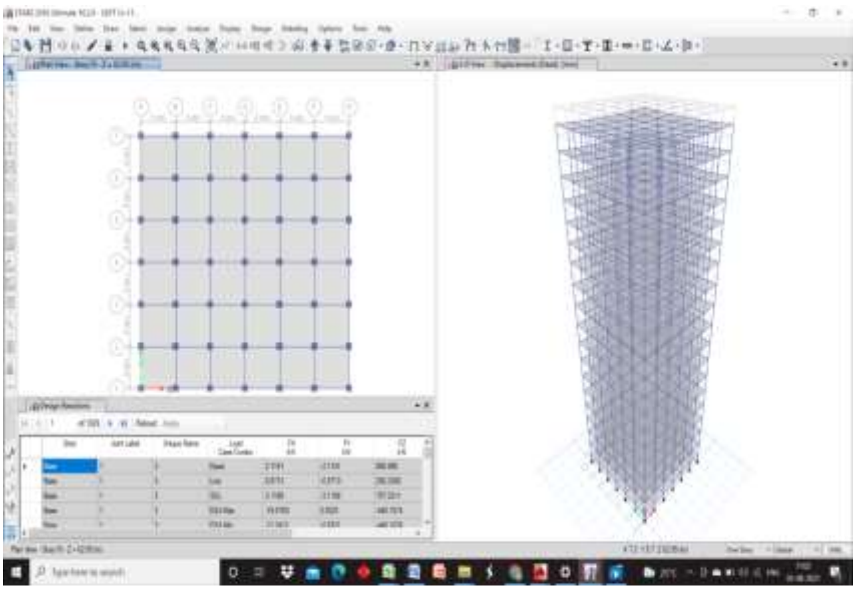

Fig 8: Design reaction for Soft Soil

V. RESULT AND DISCUSSION

In this project, a G+18-storey structure of a rectangular building with 3 m floor to floor height has been analysed Non-Linear Dynamic Analysis of Multi-storey R.C.C Buildings using Etabs software in zones III. The plan selected is Rectangular in shape. The structure has been analysed for both static and dynamic wind and earthquake forces. Hard, Medium and soft soil condition has been selected for the structure. The finite element method (FEM) is a widely used method for numerically solving differential equations arising in engineering and mathematical modelling.

Results are given below:

Table 4: Models

MODEL 1	G+18 IN SOFT SOIL
MODEL 2	G+18 IN MEDIUM SOIL
MODEL 3	G+18 IN HARD SOIL

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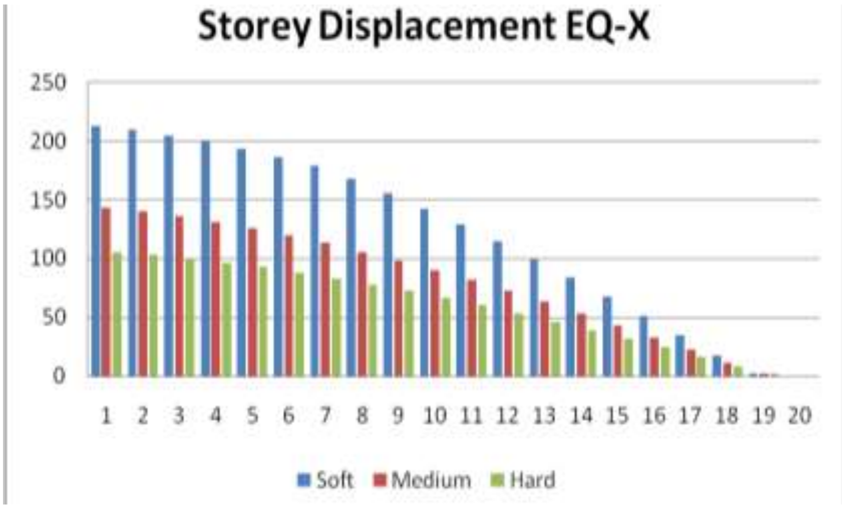
5.1. G+18: STOREY DISPLACEMENT X

Table 5: Results of G+18: Storey Displacement X

STORY	SOFT	MEDIUM	HARD
19	213.553	143.362	105.401
18	209.792	140.277	103.129
17	205.239	136.372	100.256
16	199.845	131.628	96.772
15	193.671	126.137	92.748
14	186.767	119.99	88.244
13	179.036	113.267	83.311
12	167.77	106.027	77.984
11	155.526	98.323	72.302
10	142.557	90.185	66.29
9	128.924	81.632	59.972
8	114.649	72.672	53.365
7	99.743	63.313	46.488
6	84.22	53.565	39.35
5	68.105	43.447	31.958
4	51.451	32.993	24.315
3	34.394	22.292	16.464
2	17.345	11.606	8.588
1	2.454	2.181	1.615
Base	0	0	0



Graph 1: G+18: Storey Displacement -X

Above graph.4.1. describes the results of storey displacement-X of G+18, as we see in the graph, maximum results of displacement value are for soft soil. Storey displacement value for Hard soil is in between 0-110,

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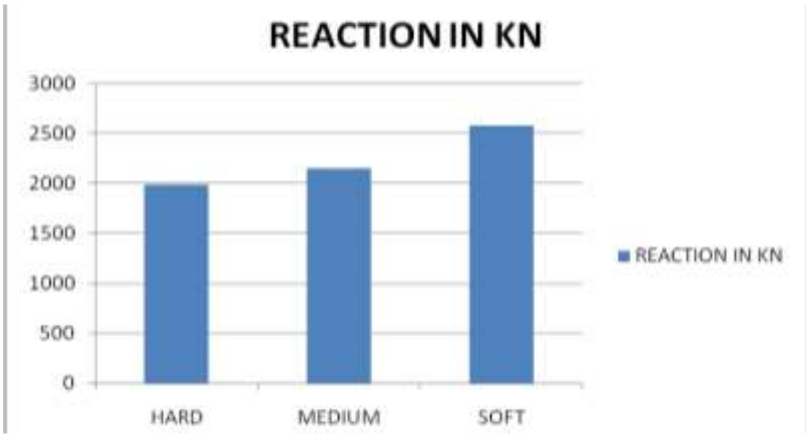
Storey displacement value for medium soil is in between 0-150, and Storey displacement value for soft soil is in between 0-220.

Table 6: Results of G+18: Design Reaction

SOIL TYPE	HARD	MEDIUM	SOFT
REACTION IN KN	1993	2152	2580



Graph 2: G+18: Design Reaction

Above graph.4.3. describes the results of Design Reaction of G+18, as we see in the graph, maximum results of Design Reaction value is for soft soil. Design Reaction value for Hard soil is 1993 KN, Design Reaction value for medium soil is 2152 KN, and Design Reaction value for soft soil is 2580 KN.

5.2. G+18: STOREY DRIFT

Table 7: Results of G+18: STOREY DRIFT X

STORY	SOFT	MEDIUM	HARD
19	1.561	1.287	0.966
18	2.069	1.716	1.301
17	2.557	2.119	1.602
16	2.961	2.441	1.829
15	3.282	2.691	1.998
14	3.538	2.889	2.134
13	3.741	3.051	2.252
12	3.904	3.186	2.354
11	4.033	3.297	2.44
10	4.143	3.392	2.513
9	4.243	3.477	2.58
8	4.337	3.553	2.638
7	4.428	3.62	2.682
6	4.513	3.681	2.716
5	4.595	3.743	2.755
4	4.658	3.799	2.799

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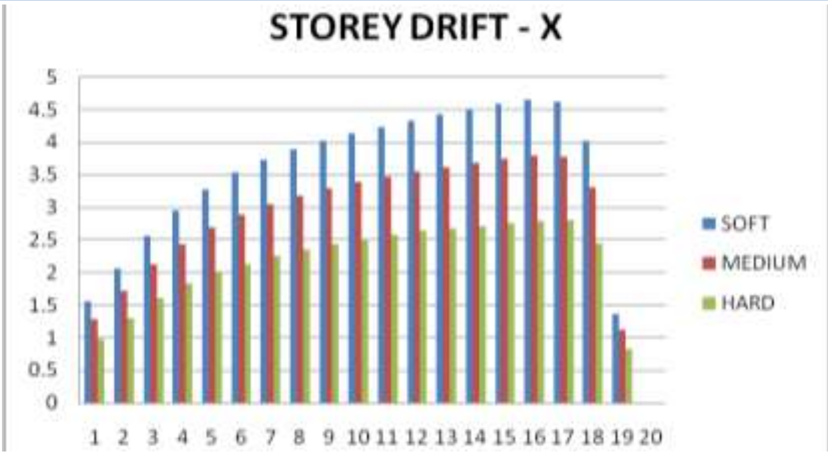
3	4.629	3.785	2.802
2	4.032	3.306	2.457
1	1.366	1.121	0.834
Base	0	0	0



Graph 3: G+18: STOREY DRIFT- X

Above graph.4.4. Describes the results of storey Drift-X of G+18, as we see in the graph, maximum results of storey drift value are for soft soil. Storey displacement value for Hard soil is in between 0-3, Storey displacement value for medium soil is in between 0-4, and Storey displacement value for soft soil is in between 0-5.

VI. CONCLUSION

Using the Etabs programme, a G+18-storey rectangular building with a 3 m floor-to-floor height was evaluated in zone III. Rectangular is the form of the chosen plan. Static and dynamic wind and seismic forces have been analyzed for the structure. Structures have been designed for hard, medium, and soft soil conditions.

- The findings of storey displacement-X of G+18, as seen in the graph, the highest displacement value is for soft soil. Hard soil has a storey displacement value of 0-110, medium soil has a storey displacement value of 0-150, and soft soil has a storey displacement value of 0-220.
- The findings of storey displacement-Y of G+18, as seen in the graph, the highest displacement value is for soft soil. Hard soil has a storey displacement value of 0-110, medium soil has a storey displacement value of 0-150, and soft soil has a storey displacement value of 0-220.
- The findings of Design Reaction of G+18, and as we can see from the graph, the highest Design Reaction value is for soft soil. Hard soil has a design reaction value of 1993 KN, medium soil has a design reaction value of 2152 KN, and soft soil has a design reaction value of 2580 KN.
- The results of storey Drift-X of G+18, as we see in the graph, maximum results of storey drift value are for soft soil. Storey displacement value for Hard soil is in between 0-3, Storey displacement value for medium soil is in between 0-4, and Storey displacement value for soft soil is in between 0-5.
- The results of storey displacement-Y of G+18, as we see in the graph, maximum results of displacement value are for soft soil. Storey displacement value for Hard soil is in between 0-3, Storey displacement value for medium soil is in between 0-4, and Storey displacement value for soft soil is in between 0-5.
- The results of storey displacement-Y of G+18, as we see in the graph, maximum results of displacement value are for soft soil. Storey displacement value for Hard soil is in between 0-6500, Storey displacement value for medium soil is in between 0-8500, and Storey displacement value for soft soil is in between 0-10500.
- The results of storey displacement-Y of G+18, as we see in the graph, maximum results of displacement value are for soft soil. Storey displacement value for Hard soil is in between 0-6500, Storey displacement

value for medium soil is in between 0-8500, and Storey displacement value for soft soil is in between 0-10500.

VII. REFERENCES

[1] K. Vishnu Haritha ,Dr.I. Yamini Srivalli (2013)“ Effect of Wind on Tall Building Frames Influence of Aspect Ratio”

[2] B. Dean Kumar and B.L.P. Swami (2010) “Wind effects on tall building frames-influence of dynamic parameters”

[3] Yin Zhou and Ahsan Kareem (1999) “Gust loading factors for design applications”

[4] Wakchaure M. R., GawaliSayali (2015)“Effects of Shape on Wind Forces of High Rise Buildings Using Gust Factor Approach”

[5] Mohammed Asim Ahmed, Moid Amir, SavitaKomur, VaijainathHalhalli (2015) “Effect of wind load on tall buildings in different terrain category”

[6] Pahwa Sumit P, Devkinandan Prajapati, Utkarsh Jain (2017) “A Study of 30-Storey Dual System Building with Different Soil Conditions”

[7] SangtianiSuraj, Simon J (2017) “Performance of tall buildings under Lateral loads with different type of Structural systems”

[8] Umamaheshwara. B, Nagarajan.P (2016) “Design Optimization and Analysis of Shear Wall in High Rise Buildings Using ETABS”

[9] Susheel S M, Sanjith J, Vidyashree B S , Ranjith A (2016) “Analysis of tall building in chikkamagaluru region”

[10] M.Mallikarjun, Dr P V Surya Prakash (2016) “Analysis and design of a multi storied residential building of by using most economical column method”

[11] Jadhav A. A., dr. Kulkarni, S. K. Galatage A. A. (2016) “Comparison of the effect of earthquake and wind loads on the performance of rc framed shear wall building with its different orientation”

[12] K. Rama Raju, M.I. Shereef, Nagesh R Iyer, S. Gopalakrishnan (2013) “Analysis and design of rc tall building subjected to Wind and earthquake loads”

[13] SinglaSarita, KaurTaranjeet, KalraMegha and Sharma Sanket (2012) “Behaviour of R.C.C. Tall Buildings Having Different Shapes Subjected to Wind Load”

[14] Mohammad Jafari, Alice Alipour, (2021) “Methodologies to mitigate wind-induced vibration of tall buildings: A state-of-the-art review”

[15] VahidMohseniana, Ali Nikkhooa, FarzadHejazi, (2019) “An investigation into the effect of soil-foundation interaction on the seismic performance of tunnel-form buildings”

[16] Mohammed Elwi, BassmanMuhammed and Nada Alhussiny, (2018) “Evaluation of soil-structure interaction for structures subjected to earthquake loading with different types of foundation”

[17] Ketan Bajaj, Jitesh T Chavda, Bhavik M Vyas (2013) “Seismic Behaviour Of Buildings On Different Types Of Soil”

[18] Amer Hassan, Shilpa Pal, (2018) “Effect of soil condition on seismic response of isolated base buildings”

[19] M Roopa, H. G. Naikar, Dr. D. S. Prakash, (2015) “Soil Structure Interaction Analysis on a RC Building with Raft foundation under Clayey Soil Condition”

[20] J. A. Knappett, P. Madden and K. Caucis, (2015) “Seismic structure soil structure interaction between pairs of adjacent building structures”