Effect of Different Soil Condition on Foundation Design of Tall Buildings: A Review

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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 favor of state-of-the-art methods when designing foundations for super-tall structures. Numerous studies have investigated the structural behavior 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- IS: 875(Part-3):2015, ETABS Software, Tall Buildings, Soil Conditions, Gust factor, Storey drift, Story Displacement, Design of Footing.

I. INTRODUCTION

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 behavior 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:

The building weight increases non-linearly with increasing height, and thus the vertical load to be supported by the foundation, can be substantial.[1] 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.[2] 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.[3]

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.[4] Seismic action will induce additional lateral forces in the structure and also induce lateral motions in the ground supporting the structure. Thus, additional lateral forces and moments can be induced in the foundation system via two mechanisms:

a. Inertial forces and moments developed by the lateral excitation of the structure;
b. Kinematic forces and moments induced in the foundation piles by the action of ground movements acting against the piles.[5]

The wind-induced and seismically-induced loads are dynamic in nature, and as such, their potential to give rise to resonance within the structure needs to be assessed. The fundamental period of vibration of a very tall structure can be very high, and since conventional dynamic loading sources such as wind and earthquakes have a much lower predominant period, they will generally not excite the structure via the fundamental mode of vibration. However, some of the higher modes of vibration will have significantly lower natural periods and may well be excited by wind or seismic action.[6]

The dynamic response of tall buildings poses some interesting structural and foundation design challenges. In particular, the fundamental period of vibration of a very tall structure can be very high (10 s or more), and conventional dynamic loading sources such as wind and earthquakes have a much lower predominant period and will generally not excite the structure via the fundamental mode of vibration. However, some of the higher modes of vibration will have significantly lower natural periods and may well be excited by wind or seismic action. These higher periods will depend primarily on the structural characteristics but may also be influenced by the foundation response characteristics. [7]

II. STATE OF DEVELOPMENT

- **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.

- **THE RESEARCH CARRIED OUT BY VARIOUS RESEARCHERS IS PROVIDED BELOW: -**

The summary of all the literature through standard publications and conference papers have summarized below in effective manner.

K. Vishnu Haritha, Dr.I. Yamini Srivalli [1] In this paper equivalent static method is used for analysis of wind loads on buildings with different aspect ratios. The aspect ratio can be varied by changing number of bays. Aspect ratio 1, 2, 3 were considered for present study. The analysis is carried out using ETAB.

B. Dean Kumar and B.L.P. Swami [2] In this paper the present work, the Gust Effectiveness Factor Method is used, which is more realistic particularly for computing the wind loads on flexible tall slender structures and tall building towers. In this paper frames of different heights are analyzed and studied.

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.

Mohammed Asim Ahmed, Moid Amir, Savita Komur, Vaijainath Halhalli [5] In this paper presents displacement occur in different storey due to wind in different terrain category. Three models are analyzing using ETABS 2015 package. Present works provides a good source of information about variation in deflection as height of model changes and percentage change in deflection of same model in different terrain category.

PahwaSumit P, Devkinandan Prajapati, Utkarsh Jain [6] In this paper project contains a brief description and analysis of Symmetrical frame having 30 storey building with shear wall and without shear wall with different types of soil condition for highly seismic area i.e. zone-5, thoroughly discussed structural analysis of a building to explain the application of shear wall. The design analysis of the multi storied building in their project was done through software STAAD.Pro.

SangtianiSuraj, Simon J [7] In this paper an attempt was made to compare the Performance of the three Structural Systems in all four earthquake zones Base shear, time period, top story displacement, story Drift, seismic weight of structure, and results were compared to arrive the foremost economical structure in a specific Earthquake Zone for a particular plan.

Umamaheshwara. B, Nagarajan.P [8] In this paper a study has been carried out to determine the optimum Structural configuration of a multi-storey building by changing the shear Wall locations. Three different cases of shear wall position for a 15 storey residential building with keeping zero eccentricity Between mass centre and hardness centre have been analyzed and designed as a space frame system by computer application Software, subjected to lateral and gravity loading.

Susheel S M, Sanjith J, Vidyashree B S, Ranjith A [9] In this paper this research paper discusses the analysis adopted for the evaluation of tall building under effect of Wind force and examines 30-storied building. This is analyzed under an effect of wind using ETABS. Tall building of height 99m has been analyzed for Chikkamagaluru region. Indian standard code of practice IS-875 (Part 3: 1987) is used for analysis. Here, the lateral story displacements, story shears and story drifts are analyzed for the same wind speeds in different direction for the same structure.

Jadhav A. A., dr. Kulkarni, S. K. Galatage A. A. [10] In this paper a studytherefore main objective is to determine the position of shear walls in multi-storey building. An earthquake load is applied to a building of twenty sixth storied located in zone iii. The analysis is performed using etabs software. Axial forces, shear force, bending moment, storey displacement and time period are computed and location of shear walls is established.

K. Rama Raju, M.I. Shereef, Nagesh R Iyer, S. Gopalakrishnan [11] In this paper the present study, the limit state method of analysis and design of a 40-storey reinforced concrete high rise building under wind and seismic loads as per IS codes of practice is described. Safety of the structure is checked against allowable limits prescribed for base shear, roof displacements, inter-storey drifts, and accelerations prescribed in codes of practice and other relevant references in literature on effects of earthquake and wind loads on buildings.

SinglaSarita, KaurTaranjeet, KalraMegha and Sharma Sanket [12] In this paper the present study, a 35 storied building of different shapes- Square, Hexagonal and Octagonal, having equal plan area and equal stiffness of the columns has been analysed. Based upon the study, it is concluded that shape of the structure plays an important role in resisting wind loads. Octagonal shaped building performed the best followed by hexagonal shaped and square shaped building.

Amer Hassan & Shilpa Pal [13] In this paper concluded that the hard soil and medium soil are suitable for base isolation building. In addition, analysis and design considerations for base isolated and conventional structures are suggested to enable the designer to get a better understanding at the preliminary design stage.

Md Ahesan, Md Hameed1, Salman Shaikh [14] In this paper study also focuses on Indian code i.e. IS 875 (Part-3):2015 and point out the advantages over IS 875 (Part-3):1987. The present study deals with the buildings of different shape such as regular plans and irregular plans. IS: 875 (Part-3):2015 is the standard code of practice for design load of buildings and structures which was used to calculate the along wind load effect i.e. gust factor. To determine along wind load effect on different shapes of building using Indian standard, spread sheets are prepared. Further, all these shapes were analysed using finite element software package ETAB-2016.

Prof. Syed Farroqh Anwar, Mr. MohdHashmath, Mohd Aslam Share Khan [15] In this paper thesis aims to determine the significance of using Base Isolation as a technique to withstand the seismic forces. This thesis also aims to show the importance to consider soil structure interaction rather than analyzing the structure as fixed base. The comparison is mainly done between structures with soil structure interaction effects and base isolated structures. The analysis is done using computer program SAP2000.

K. Nagarjuna1, Dr.S.R.KReddy [16] In this paper present investigation, a multi-storied building located in coastal region is chosen as an examplefor obtaining the response parameters like base shears and displacements when subjected to wind and earthquake loads.In the analysis, soil-structure interaction effects are also considered and the soil is represented by introducing twoadditional springs, one in horizontal direction and the other in rocking mode.

Harry G. Poulos1, Dist. MASCE [17] In this paper sets out the principles of a limit state design approach to design a pile or piled raft foundation system for tall buildings, and involves three sets of analyses:1. An overall stability analysis in which the resistances of the foundation components are reduced by the appropriate geotechnical reduction factor and the ultimate limit state (ULS) load combinations are applied. 2. A serviceability analysis, in which the best-estimate (unfactored) values foundation resistances and st iffnesses are employed and the serviceabilitylimit state (SLS) loads are applied. 3. An analysis to obtain foundation loads, moments and shears for structural design of the foundation system.

Mr. Rahul Sawant1, Dr. M. N. Bajad [18] In this paper, the interaction between the super-structure and sub-structure is investigated by modelling the soil as simple as possible to capture the overall response of the system. As new analytical hysteresis rules and more advanced tools of analysis have been developed in recent years, first the nonlinear response of a single-degree-of freedom system which can be representative of a broad range of newly designed structures, is investigated while allowing for flexibility of the soil-foundation system and SSI effects.

Harry G. Poulos [19] In this paper will review some of the challenges faced by designers of foundations for very tall buildings, primarily from a geotechnical viewpoint. Some characteristic features of such buildings will be reviewed and then the options for foundation systems will be discussed. A three-stage process of foundation design and verification will be described, and the importance of proper ground characterization and assessment of geotechnical parameters will be emphasized.

III. CONCLUSION

The study as a whole may prove useful in formulating design guidelines for foundation design of building frames incorporating the effect of soil flexibility. In this study, the effects of wind and SSI (Soil Structure Interaction) are analyzed for typical multi-story building using the ETABS programmed; a G+18 story square building with a 3 m floor-to-floor height was evaluated in zone III. Square is the form of the chosen plan. Static and dynamic wind and seismic forces have been analyzed for the structure for different soil conditions, the different soil conditions are directly affecting the design parameters of the foundation such as length, width, depth and reinforcement of the foundations, it also affects the displacement and storey drift of the structure. Structures have been designed for hard, medium, and soft soil conditions.

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