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Footing Dimensions of a Multistoried Building and Safe Bearing Capacity of Soil: A Collaborative Review

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Abstract: ***During these days, tall buildings have been widely used in semi-urban and urban areas of developed and developing countries, as they provide large space for commercial or residential use. The last two decades have seen a remarkable increase in construction of residential and commercial buildings. A significant number of these buildings have been constructed in the central region. There are a number of characteristics of buildings that can have a significant influence on foundation design, including such as the building weight increases non-linearly with increasing height, and thus the vertical load to be supported by the foundation, can be substantial by soil. Since the parameters are vary from place to place or different locality of earth crust. It is necessarily to evaluate and analysed this parameters***

The paper consist the study and prepared the summarised report based on different past research on analysis & design of foundation, assessment on soil bearing capacity and building design requirements. The research concluded that concern on foundation design is necessary due to soil strata are varying with zone and place to place. The type of foundation depends on the building capacity and soil strata. The stability of building can be achieved with respected the SBC and foundation strength of a particular construction place.

Keywords: Foundation, Soil Bearing Capacity, Tall Buildings, Building Design, Vertical Load

I. INTRODUCTION

Foundation is the most important part of any structure. It gets the load of the whole building and therefore it is important to properly design foundation of the building. Bearing capacity of the soil underneath and the settlement of footing are the two major concerns in the design. A lot of work from a long time is going on for finding the bearing capacity of soil and the settlement of the footing. Foundation is an integral part of a building whose stability determines the stability of the entire structure. It acts as a medium through which loads are transmitted to the soil or rock below. The stability of a foundation depends on its proper design based on the structural loads of the building it carries, the geology of the area and condition of the subsoil base.

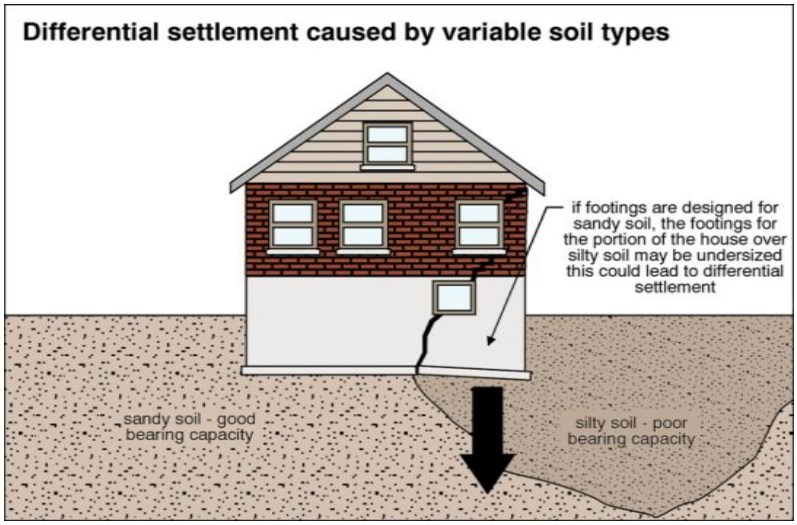


Fig. 1: Settlement Due To Soil Strata Variation

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Depending on the depth of load-transfer from the structure to the ground, foundations are classified as shallow and deep foundations. The definition of shallow foundations varies in different publications. The subject of bearing capacity is perhaps the most important of all the aspects of geotechnical engineering. Loads from buildings are transmitted to the foundation by columns, by load bearing walls or by such other load-bearing components of the structures. The two basic criteria to be satisfied in the analysis and design of a shallow foundation are stability and deformation requirements.



Fig. 2: Typical Foundation

Stability requirement ensures that the foundation does not undergo shear failure under loading, while deformation requirement ensures that settlement of a structure is within the tolerance limit of the superstructure. Where data for characteristics of a soil (cohesion, angle of internal friction, density, etc) are available, the allowable bearing capacity may be calculated from consideration of shear failure. A factor of safety of three shall be adopted.

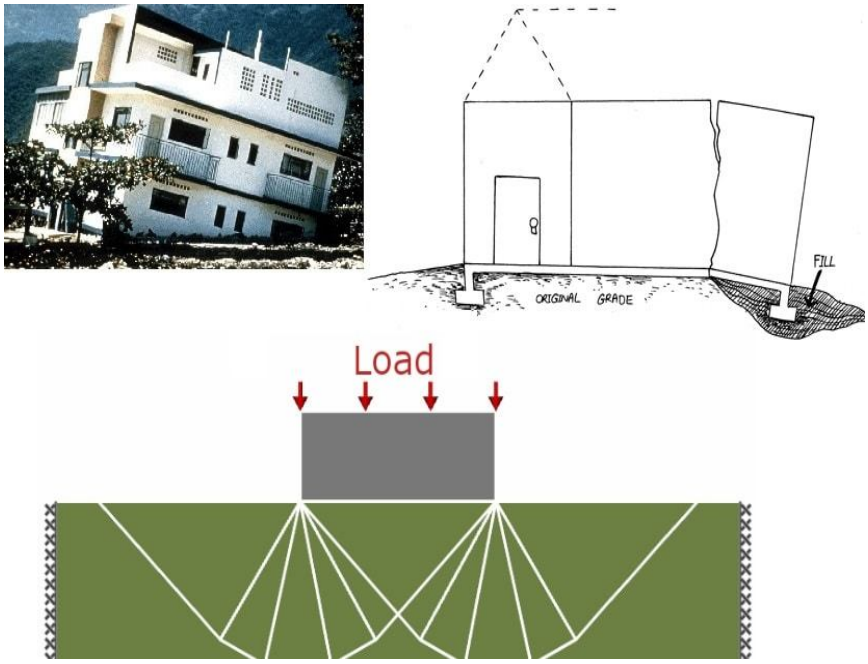


Fig. 3: Load Transfer through Building on Soil and Failure Phenomena

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The bearing capacity of the foundation is a primary concern in the field of foundation engineering. The load at which the shear failure of the soil occurs is called the ultimate bearing capacity of the foundation. The last two decades have seen a remarkable increase in construction of tall buildings. A significant number of these buildings have been constructed in the central region such Indore, Bhopal etc. and many more are either planned or already under construction. There are a number of characteristics of tall buildings that can have a significant influence on foundation design, including such as the building weight increases non-linearly with increasing height, and thus the vertical load to be supported by the foundation, can be substantial. Since the parameters are vary from place to place or different locality of earth crust. Soil Bearing Capacity and foundation depth is major concern from them. So it is required to analysis the buildings structure such that it is satisfy the ground data such, SBC of soil, Depth of foundation, Earthquake zones, wind parameters etc. through it. Since the different theories on the soil bearing capacity such Terzaghi, Skempton, mehroof etc. which is Cleary shows that the load transfer can in the form of trapezoidal and infected to surrounding soil strata. Based on theses theory the failure approach can be generated i.e. general, local and shear failure. The estimation of bearing can be evaluated and it directly impact on the foundation design.

II. LITERATURE REVIEW

The following literature articles are taken for the study foundation assessment, soil bearing capacity and building design based on soil conditions. The summarized reports on review on the different literatures are as follows:

Xia H., Zhang J. & et. al. (2020) In this research the work is based on the aeolian desert soil assessment. For analysis of theses soil the researcher's uses its physical and mechanical characteristics properties. The soil impart the loose soil structure, large pores, and a low bearing capacity with variation occur with other place. The mechanical parameters have been collected through in SLT and CCT to evaluate the effect of foundation treatments. There are six typical test sites were selected in the Mu Us Desert and reinforced by each method. After study on soil it concluded that for foundations, improvement in bearing capacity can be achieved by adding a geogrid or replacing a weak soil layer with stone and Aeolian. The strength is increases by geogrid or replacing it with stone, the mud content and water content can significantly reduce the bearing capacity.

Magar J., Kudtarkar A. & et. al. (2020) The research study presented the analysis on different types of foundation. The main focus of the researchers to make the foundation base eco-friendly cost efficient and more durable and strong to withstand the natural climate. All the different types of foundation and footing types have a specific use in a specific area for a particular weather condition. It is very important to know the foundation work to carry out construction activities. The main objective of this article is to provide detailed and collective information about the types of foundation, there advantages and disadvantages, suitable conditions, design construction. The final conclusion made such that all the major types of foundation are covered in this article to give an overview about various types of foundation.

Nashaat W. and Samee A.E. (2019) The article based on the FEA to develop numerical models to study the failure mechanism of sandy soil and the wedge angle. The sandy soil is simulated by a semi-infinite element isotropic homogeneous elastic material. The analysis program consists of five footings with different L/B b/w 1-8. Each footing was analyzed with different foundation depth. In addition, also different angle of internal friction of sandy soil was taken. It was concluded that, the obtained failure mechanism in the study is identical with the conventional failure mechanism. it was also concluded that the wedge angle values obtained in the study decrease with increasing depth of footing and increasing angle of internal friction of the soil as well as increasing L/B ratio while the wedge angle value of sandy soil obtained from previous theoretical approaches is constant.

Gupta S. and Mital A. (2019) This study investigates the effects of the soil bearing pressure values of the rectangular shape footing located on the horizontal ground surface analysis. The software analysis is taken using PLAXIS software. It is FEM based software, used to analysis deformation and stability in engineering projects. It has a wider application in constitutive soil model (stress-strain-time relationship). PLAXIS software is a good tool which can be used for explaining the soil behavior and settlement under different loading conditions. The two dimensional (2D) and three dimensions (3D) model of rectangular footing were analyzed and compared. The results concluded that the 3D analysis provides more accurate results as compared to the 2D analysis and also observed the failure mechanism of the soil model.

Vishwakarma A. & S. Maru S. (2019) The articles analyzed the is different no of floor consideration to find human comfort range for different asset the human comfort behavior based on peak acceleration calculation. The project includes Four different Framed Tubes tall building circular structure having a G+20, G+30, G+40, and G+50 with different condition i.e. Normal Slab, Secondary Beam, Waffle Slab & Ribbed Slab are taken.

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Then using ETABS-2013 software maximum displacement is evaluated using dynamic wind analysis of building by applying the gust factor method. The article concluded that up to G+40 building is satisfying the human perception range and 50 storey building undergo unsafe range.

Mohammed Y., Aranganathan S.M. (2018) The research is carried out the evaluation of bearing capacity. The aim of this study is determining the allowable bearing capacity of soils. The computations of carrying capacity of soil were done by collecting the results obtained from laboratory and some of the index and Engineering properties were investigated. The shear strength parameters were determined using unconsolidated undrained direct shear test. The applied analytical methods for determination of this pressure are Terzhagi, Meyerhof and Vesic bearing capacity equations. The allowable bearing capacity values obtained for typical isolated rectangular footing calculated, The results for test pit (TP1) are 2537.6, 3527.4 and 3185.8kPa; and for TP2 are 743.9, 946.6 and 1020.6kPa respectively. Final conclusion made such that the obtained required for supporting high rise buildings construction.

Fahmi K.S., Fattah M.Y. & et. al. (2018) The assessments were made in the current practice based on the design foundation of high-rise buildings in Moscow to find a method for improving the soil foundation. Many references showed that the current design was controlled by structural engineers. They commonly used the old methods of analysis, the first part was carried out for the design of the structure and architecture of high-rise building, the second part of the study was to explore the benefit of adopting the application of stone columns raft foundation design concept. A comparative study was made between the results of the 3-dimensional finite element (3D FEM) analysis in SCAD software. The results concluded that the plate foundation of the building does not satisfy to carry the total load without some meaning of improvement. The total settlement decreased by about 75% from the total settlement, when using stone columns as reinforcement material.

Ajdukiewicz A., Brola J. & et. al. (2017) In this paper, some aspects of structural design of the massive, reinforced concrete slab foundations are presented. The plane dimensions equal from approx. 50×80 m to approx. 100×100 m. The interaction between the slab foundation and soil in largely diversified geotechnical conditions and for different variants of the foundations. This type of foundation shall ensure as uniform distribution of ground pressures as possible. This concept of continuous slab foundation is typical and often used in the civil structures of this type. At the finalized stage, when the detailed design is made and geometry of foundation and its neighbouring is already fixed, any corrections are limited practically only to change in amount of reinforcement and partially, only if possible, in change in depth of the slab. Additional problems in design of the power plant foundation arise from simultaneous design of the main boiler house steel structure and update of load values and their location. These changes also affect amount of reinforcement in final, detailed design stage.

Zhu F., Zhang W., & et. al. (2017) The research is carried by analytical approach of foundation along with soil assessment. The effects of consolidation, intermediate principal stress, earth pressure at rest, and presence of a crusty layer were all considered. The new theoretical formulas for critical edge load and critical load were deduced. The solution of the Mohr–Coulomb strength theory is a special case of the unified strength theory. The proposed formulas were analyzed and validated on a practical railway sub grade filling project in an area with soft soils. The calculated results concluded that good agreement with experimental results. The new formulas provide not only a theoretical basis for the calculation of the bearing capacity of a soft soil foundation but also a reference for calculating the safe height of sub grade filling in a soft soil area. Using the new formulas to calculate the bearing capacity of the soft soil foundation and the filling height of embankment under different degrees of consolidation, it is possible to understand the variation pattern of the bearing capacity of the foundation during construction of the embankment filling, which provides significant guidance for the safe filling of the embankment on a soft soil foundation.

Du P., Liu X. & et. al. (2017) This paper has carried out Contrastive analysis of the theoretical formula method and finite element method about the ultimate bearing capacity of foundation, To verify rationality and superiority of the incremental load method in finite element ABAQUS in solving the bearing capacity of foundation soil. The study can provide certain reference for practical engineering calculation and analysis of foundation bearing capacity. In this research, the traditional bearing capacity calculation formula is used to calculate the ultimate bearing capacity of the foundation, and then the finite element software ABAQUS is used to model and calculate. Finally, the plastic strain, displacement cloud and load-displacement diagram are obtained. It is concluded that the incremental loading method is used to solve the rationality of the foundation bearing in finite element ABAQUS

Arya A., Ameta N.K. (2017) The research showed the importance of Foundation part of any structure. It gets the load of the whole building and therefore it is important to properly design foundation of the building. Bearing capacity of the soil underneath and the settlement of footing are the two major concerns in the design. A lot of work from a long time is going on for finding the bearing capacity of soil and the settlement of the footing.

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This paper reviews the work done so far on these. Calculations of bearing capacity of soil and settlement of footing is most important work in footing design so it is very important to properly determine their exact values. The results must be established parallel to their theoretical solutions. More and more research work is required in this field for various types of soils available.

Przewlockia J., Zielinskab M. (2016) The article is based on the analysis and behavior of the foundations of historic buildings. The key aspect taken under foundation engineering, with an emphasis placed on its development, applied techniques, and materials. Several different approaches and methods for the analysis of foundations of historical buildings are presented. A particular analysis has been focused on an example of a typical stone foundation from the sixteenth century. First, the calculations have been performed using the finite element method, then the bearing capacity and the settlement analysis has been determined according to EC-7. Next, the bearing capacity has been evaluated using simplified analysis. A settlement of the foundation has been also estimated using Kerisel's proposal. The information should allow for a better understanding of the behavior of foundations discussed in this research, and especially of methods of their analysis. A comparison analysis has been performed and possible directions for further research in this field have been indicated.

Lanko A. and Aleksey Ulybin A. (2016) The article described the methods for determined the depth of laying Foundation base. This is a key element for investors when they determining future costs for reconstruction. Through experimental examination of the basement, the comparison of different methods was made. The methods were compared from the standpoint of the survey (difficulty, labor, damage), and from the quality of the data obtained. The article describes procedure of the survey. Also you can find an algorithm for determining the depth of the Foundation. In conclusion, recommendations on the choice of a method for determining the depth of the Foundation base were made.

Poulos H.G. (2016) This paper will review some of the challenges faced by designers of foundations for very tall buildings. The 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. The application of the foundation design principles will be illustrated via four projects, each of which has presented a different challenge to the designers: 1. The La Azteca building in Mexico City, Mexico. 2. The Burj Khalifa in Dubai. 3. The Incheon 151 Tower in Incheon, South Korea.4. A high-rise tower in Jeddah, Saudi Arabia. three-stage process A preliminary design stage,A detailed design stage, A final design phase, The La Azteca building in Mexico City, Mexico— here, the challenge was to construct a tall building on avery deep deposit of soft clay and limit the settlements. The Burj Khalifa in Dubai—the world's tallest building, founded on a layered deposit of relatively weakrock. The Incheon 151 Tower in Incheon, South Korea—a settlement sensitive building on reclaimed land, with variable geotechnical conditions across the site.

Acharyya, R.,.Dey, A (2015) These researchers investigate geotechnical attempted for a site at Teli, Arunachal Pradesh, where a monastery school building is to be built on the slope face of a hill. Soil samples have been collected from the site and several laboratory investigations have been carried out. Based on the soil properties, both theoretical analysis and numerical simulations have been carried out to estimate the bearing capacity and explore the deformation mechanisms of a single isolated footing. It has been concluded that the ultimate bearing capacity of the foundation obtained from the numerical technique is consistently higher than that obtained from analytical estimates, which is attributed to the inherent assumptions behind the theoretical calculations which does not take into account the 3-D confinement effect at the site.

Vilas and Moniuddin M.K. (2015) In this project a numerical model is developed using PLAXIS. Finite element analysis is carried out using Mohr coulomb failure criteria to represent two dimensional soil model. Foundation is modelled as square footing and load increment is applied till the soil model fails. Ultimate bearing capacity is identified as that minimum pressure on footing at which the foundation soil experiences shear failure. The stress distribution in soil and displacement experienced at different locations are obtained. In plaxis effective stress is considered as a ultimate bearing capacity. The preliminary investigation of black cotton soil was collected from crossroad which is six km away from Bhalki taluk, shows that it belongs to inorganic clays of high plasticity (CH) according to USCS. The ultimate bearing capacity for varying D/B ratio was computed by Terzaghi's equation by knowing the preliminary values of black cotton soil and loading frame which was successfully compared with Plaxis software. The results will show small variation. Hence the plaxis software is useful.

Namdar A. , Xiong Feng X. (2014) In this paper, several types of soil foundations have been made from mixed soil. The bearing capacity of soil foundations by using mixed soil parameters and change footing dimensions have been calculated. 180 footings, placed on 15 soil foundation types have been designed. It is assumed the underground water has not effect to bearing capacity of soil foundation. The results of numerical analysis and mixed soils technique have been combined. The numerical analysis has supported mixed soil design, and introduced an appropriate result for soil foundation design. The effects of mixed soil on depth and width of footing have been compared.

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The mixed soil design influenced numerical analysis result, and economically, soil foundation design helps to select the appropriate dimensions of footings. The result of numerical analysis supports geotechnical and structural engineering codes, predicts structural stability with different age, natural hazard and prevention. It is useful in understanding safe bearing capacity of soil foundation behavior. It has been concluded that the mixed soil technique has the ability to predict soil foundation behavior. The results show soil parameters control footing dimensions.

Taie E.A., Ansari N.A. & et. al. (2014) This research is to study the effect of bearing capacity on shallow foundations in different regions of Iraq. Seventy nine samples were collected from 23 boreholes at three different locations (Mosul at the North, Baghdad at the middle and Basrah at the south of Iraq). The samples were collected at varying depth between 1 to 24m. They were subjected to the following testes: Atterberg limits, sieve and hydrometers, consolidation, direct shear, unconfined compression and the filed (SPT test). The values of the bearing capacity parameters (ϕ and c) were obtained from the above tests. The results obtained were used in the application of the general equation of the bearing capacity. Then, the model of a building was designed (two floors, with mat foundation type) using STAAD Pro software. The results obtained from the average and worst bearing capacity indicated that for Mosul, we could use shallow foundation (spread and mat used if there was basement) for different areas and for buildings with many stories. For Baghdad region, shallow foundation was more suitable for building not higher than five stories. Finally, concluded that for Basrah region, shallow foundations were an appropriate selection, but for most areas deep foundation was the right choice.

Baker W.F., James B.C. & et. al. (2013) The paper examines the two built towers: Burj Khalifa, Trump International Hotel and Tower, and the partially built Plaza Rakyat, a 77 story tower in Malaysia. The research represent the foundation conditions were considered in the design of the buildings, and how the foundations were anticipated to influence the behavior of the towers. For Burj Khalifa, Trump International Hotel and Tower and Plaza Rakyat, their foundation systems provide the interface between the man-made structure above and the natural geotechnical soil strata below grade. Understanding the relationship between the two is critical for the successful design of supertall building structures. In the case of the Burj Khalifa, the pile supported mat provided the required strength and settlement control which enabled the construction of the world's tallest building. For Trump Tower, the strength and constructability of the caissons were the controlling elements; bedrock strata provided outstanding settlement results and allowed for a very heavy reinforced concrete tower. For Plaza Rakyat Office Tower, the normally highly variable strata of the Kenny Hill Formation was determined to be consistent enough, over this project site, to enable the more economical drilled friction-type piles to be utilized, in lieu of bored piles to bedrock.

Amornfa K., Phienwej N. & et.al. (2012) The research article assessment was made on the current practice on foundation design of high-rise buildings in Bangkok, Thailand to explore rooms for improvement. An interview survey revealed that the current design practice was dominated by structural engineers. They commonly used the conventional method of analysis, namely the combined stress equation, as well as the plate on springs analysis. The finding from the survey study indicates the current design practice does not encourage an optimal design outcome in term of cost effectiveness. The second part of the study is to explore the benefit in adopting the piled raft foundation design concept. A comparative study on the results of the 3- dimensional finite element (3D FEM) analysis and various analysis methods currently used. The results concluded that the plate on pile springs method which neglects pile-pile and raft-pile interaction give results significantly different from that of the 3D FEM. The 3D FEM shows that only about 70-80% of total building loads are carried by piles when raft is placed in the stiff clay layer. The number of piles in the piled raft foundation can be significantly reduced particularly if the true piled raft foundation concept is adopted, while the foundation settlement only increases slightly.

Dev H., Ramana G.V. & et.al. (2012) Dev H., Ramana G.V evaluate the bearing capacity of soil or gravel-boulder strata using the field test. The load displacement characteristics of gravel boulder deposits depends upon various factors, viz. type of soil, compaction/interlocking of soil molecules and more importantly size of boulders beneath the footing. Load-settlement curve can also be utilized to determine the yield pressure and recommended allowable pressure for foundation design. The laboratory tests conducted on the tiny samples do not represent the exact behavior of such a complex matrix. The results and interpretation of the in-situ footing load tests conducted at proposed colony at Sangaldan station yard of USBRL Project. The test results of two footing load tests, the ultimate bearing capacity (at design load) of the geological formation at proposed residential colony Sangaldan station yard may be taken as 13.33t/m2. The conclusions is made such that failure had not occurred at the specified design load, the ultimate bearing capacity and safe bearing capacity of the formation may be higher which may be ascertained by applying higher load.

C.M. Martin (2003) This paper has introduced a new computer program ABC, for calculating the vertical bearing capacity of strip and circular foundations. The research used the weighty Mohr Coulomb soil method to find the characteristics of soil.

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The governing equations and boundary conditions have been described in detail, as have the procedures used to construct 'incomplete' lower bound stress fields for both smooth and rough footings. Previous research suggests that for the classical case of associated flow ($\psi = \varphi$) a collapse load calculated in this manner is in fact exact, i.e. the incomplete stress field can be extended throughout the soil mass in a statically admissible manner, and a coincident upper bound collapse load can be obtained. The conclusion made such that ABC allows fast, semi-automated refinement of a mesh of characteristics, and it can therefore be used to produce highly accurate benchmark solutions as well as 'coarse' bearing capacities for routine analysis and design.

Dixit. M.S. and Patil K.A. (2009) The paper deals with the study of effect of shape and depth of footing for a particular bearing capacity of soil. The other factors remaining constant, bearing capacity of soil goes on increasing as depth or width of foundation increases. The comparison of bearing capacity of soil with methods of analysis given by Terzaghi and IS code method is carried out for different shapes i.e. strip, square, circular and rectangle. The conclusions made such that in case of local shear failure, amongst different shapes of footing the bearing capacity of strip footing is found to be lowest in comparison with square, circular and rectangular shaped footings. The effect of increase in width of footing on ultimate bearing capacity is marginal. For cohesive and frictional soil leading to local shear failure, the effect of water table correction on safe bearing capacity is less in comparison with non-cohesive soil.

III. CONCLUSIONS

Based on the above different research papers of the different research following conclusions are made which are as follows:

A. It is found that study of foundation design with respected to soil condition is must required to get the stable and safe design of high rise and multi-storey buildings.
B. To evaluated earthquake resisting building under the foundation depth can be evaluated through both manually and software mode and for the analysis of building or any structure using linear and non linear approach is compulsory.
C. Some researcher work on the historical building study and some are design for new buildings shape and orientation building. The study of burj khalifa etc.
D. The assessment of bearing capacity wither manual and test procedure such SPT, Core test is required the before the construction of building design.
E. The study is also based on use of different types of software used for analysis such Plaxis, FEM, ABACUS, ETABS with 3D FEM analysis in it. etc.
F. The studies of some researchers are based on the testing approach used in the analysis the soil and foundation Foundations and its Failure Mechanism.
G. The some research are introduced the new computer program, ABC, for calculating the vertical bearing capacity of strip and circular foundations on weighty Mohr Coulomb (c-φ-γ) soil using the method of characteristics.

IV. FUTURE SCOPE

The Following work is carried out under the future scope work which is listed below:

A. Analysis of different types of foundation through software mechanism.
B. Comparative analysis the structure both software and manual analysis.
C. To model and analysis the residential building for the different depth cases of foundation required.
D. To take the case study on SBC under different test conditions.
E. The comparative study of different codes on foundation and soil bearing capacity.
F. Software programming on different theory of SBC and to find the foundation dimensions.
G. Dynamic wind analysis by wind tunnel, CFD or gust forces method for coastal area building and foundation design and analysis.

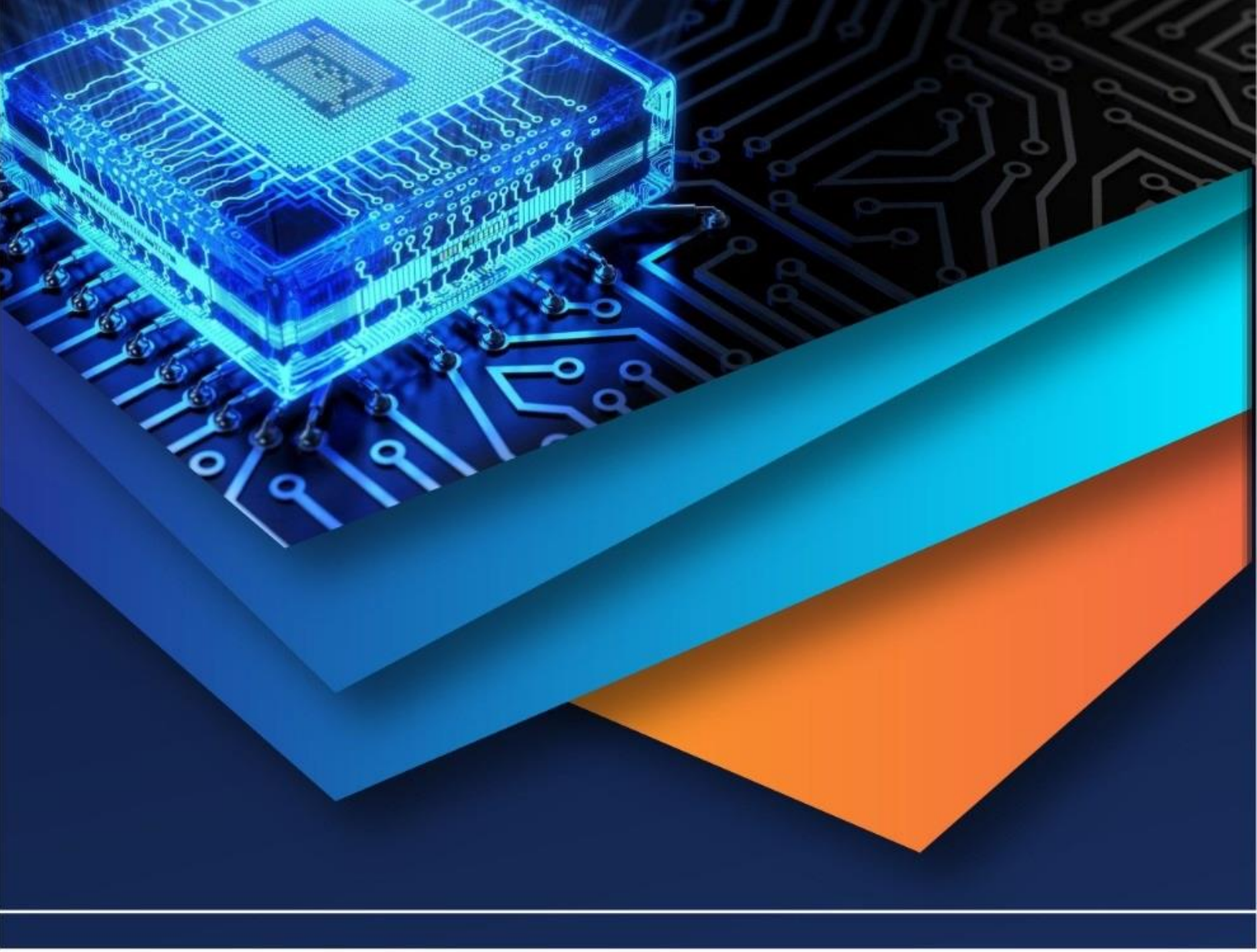
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