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A Review on Determination of Efficiency of Soil Parameters Below Multi-Storied Building

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Abstract: ***The construction of high-rise structures is widely utilized in urban and semi-urban areas of developed and developing countries. These tall structures, including residential apartments, commercial, and semi-commercial spaces, are characterized by their efficient use of construction area relative to their footprint. During the structural analysis stage, significant characteristics such as vertical load, horizontal load, superstructure design, and foundation design are considered. However, prior to this stage, the larger construction area is planned by architecture. It is essential that this preliminary selection not only considers structural design configurations but also incorporates soil parameters, which should be assessed beforehand. This paper presents a review of past research on the aforementioned topics and draws conclusions based on the reviews. It is concluded that the location parameter, determined based on soil investigation reports, should be prioritized for the selection of the construction area's optimal Soil Bearing Capacity (SBC), ensuring the suitability of the soil for structural performance.***
Keywords: Vertical Load, Soil Bearing Capacity (SBC), Tall Buildings, Foundation, Building Design.

I. INTRODUCTION

The foundation is considered the most crucial component of the substructure. Footings, which are types of foundations, bear the entire building load and transfer it to the subsoil. Since soil directly influences settlement, designing the footing according to building types and soil parameters is paramount. Significant effort has been dedicated over time to determining footing settlement and soil bearing capacity.

Foundations serve as the medium through which loads are transmitted to the firm soil and are integral to a building's stability, thereby affecting the entire structure's stability. The key factors influencing foundation stability include:

1) Structural loads.
2) Subsoil conditions.
3) Geological characteristics of the area.

The allowable bearing capacity is typically calculated considering shear failure, with a safety factor of three. This calculation involves:

- Soil cohesion.
- Soil density.
- Soil's angle of internal friction.

To ensure foundation stability under loading conditions, the design ensures no shear failure occurs. Comparing with deformation requirements confirms that settlement within the superstructure remains within acceptable limits.

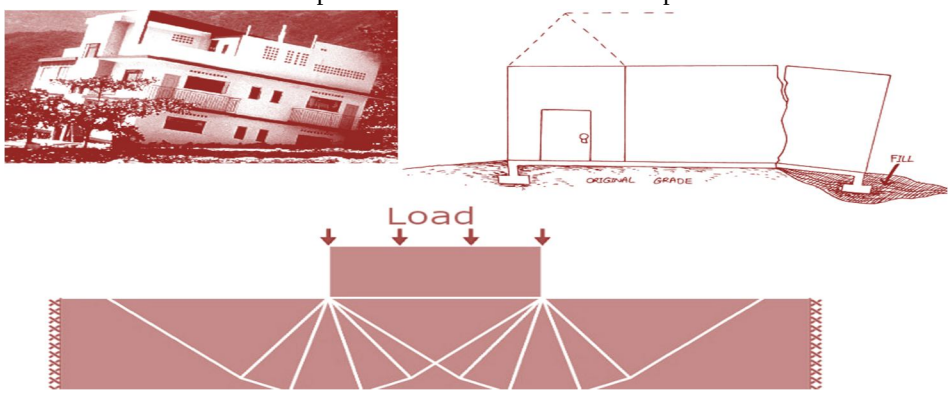


Fig. 1: Soil failure phenomena

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The explanation of shallow foundations varies according to different perspectives, with foundations being classified as shallow or deep based on the depth at which loads are transferred from the structure to the ground. In geotechnical engineering, bearing capacity is considered the most crucial parameter.

In the analysis and design of footings, two fundamental criteria must be addressed: deformation requirements and stability. Loads from buildings are safely transmitted to the foundation, usually through columns or load-bearing components like walls.

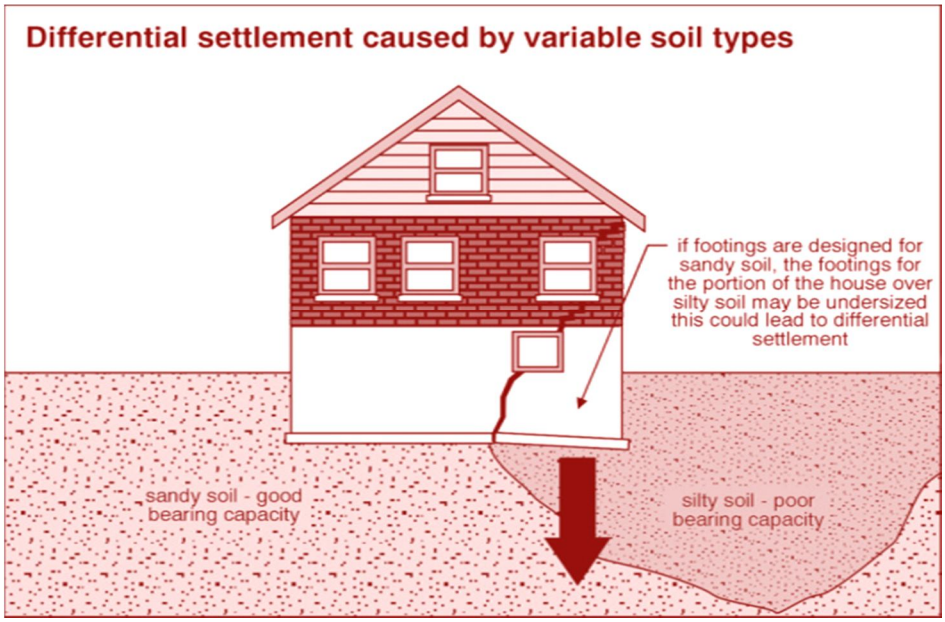


Fig. 2: Variation in soil strata causing settlement

II. REVIEW OF LITERATURE

The following literature articles have been selected for the current research study based on soil conditions and construction over it. The individual summaries are as follows:

Namdar, A., & Feng, X. (2014). In this paper, the pivotal role of soil mechanic laboratory results in facilitating precise soil foundation design and mitigating failure is underscored. The utilization of mixed soil design in various geotechnical engineering applications for soil improvement is acknowledged. The present study focuses on the creation of diverse soil foundations employing mixed soil, wherein the bearing capacity is determined by manipulating mixed soil parameters and altering footing dimensions. A total of 180 footings distributed across 15 soil foundation types were meticulously designed, assuming negligible influence of underground water on the bearing capacity. The integration of numerical analysis and mixed soils technique is emphasized, revealing the supportive nature of numerical analysis in endorsing mixed soil design and yielding pertinent results for soil foundation design. Comparative assessments were conducted on the effects of mixed soil on both the depth and width of the footings. The findings indicate that mixed soil design significantly impacts numerical analysis outcomes, contributing to the economic selection of optimal footing dimensions in soil foundation design. The results of the numerical analysis not only align with geotechnical and structural engineering codes but also offer predictive insights into structural stability under diverse conditions, including different ages, natural hazards, and preventive measures. The comprehensive understanding derived from this study enhances the assessment of the safe bearing capacity and behavior of soil foundations.

Przewlocki, J., & Zielinska, M. (2016). In this paper, the examination of the behavior of foundations in historical buildings. It delves into fundamental aspects of foundation engineering, highlighting its evolution, applied techniques, and materials. The study introduces various approaches and methods for analyzing the foundations of historical structures, placing particular emphasis on a case study involving a typical stone foundation from the sixteenth century. The investigative process involves initial calculations using the finite element method, followed by the determination of bearing capacity and settlement analysis in accordance with EC-7 standards. Additionally, an assessment of bearing capacity is conducted through simplified analysis, and foundation settlement is estimated using Kerisel's proposed methodology. The insights gained from these analyses contribute to a deeper comprehension of the foundations discussed in this research, with a specific focus on analytical methods. The article concludes with a comparative analysis and identifies potential avenues for further research in this domain.

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Lanko, A., & Ulybin, A. (2016). In this paper, the imperative task faced by property investors is the thorough examination required before property acquisition, particularly in the context of potential reconstruction. Emphasis is placed on the intricate inspection of concealed portions of basements. The paper explores various methods utilized to determine the depth of the foundation base, a crucial factor influencing investors' projections of future reconstruction costs. Through experimental basement examinations, the paper conducts a comparative analysis of different methods, considering survey-related factors such as difficulty, labor intensity, potential damage, and the quality of the obtained data. The procedural aspects of the survey are detailed, accompanied by the presentation of an algorithm for determining foundation depth. In conclusion, the paper provides recommendations for selecting an appropriate method to ascertain foundation base depth, aiming to assist property investors in navigating the complexities of property examination and reconstruction planning.

Ajdukiewicz, A., Brol, J., Kotala, B., & Węglorz, M. (2017). In this paper, the intricate design challenges of foundations for large industrial buildings, particularly power plants, emphasizing the complexity arising from diverse load combinations and equipment influences. The reliability of power plant structures is crucial for the national economy, leading to a uniform classification in the third geotechnical category, irrespective of soil conditions. The boiler house, the largest and heaviest structure in a coal power plant, necessitates foundations meeting safety requirements and ensuring collaboration with neighboring structures. Key criteria involve strict adherence to values of total vertical displacements and differential settlements. This study focuses on the structural design of massive reinforced concrete slab foundations recently constructed in Poland. Noteworthy for their extraordinary dimensions (approx. 50×80 m to 100×100 m without expansion joints), these foundations are examined in the context of widely varied geotechnical conditions and diverse foundation variants. The paper delves into the critical interaction between these substantial slab foundations and the underlying soil, providing insights into the complexities of their design and construction.

Vilas, & Moniuddin, M. K. (2015). In this paper, a numerical model developed using PLAXIS for finite element analysis. The Mohr-Coulomb failure criteria are utilized to represent a two-dimensional soil model, with the foundation conceptualized as a square footing. Load increments are applied until shear failure of the soil model is observed, and the ultimate bearing capacity is identified as the minimum pressure on the footing leading to this failure. The stress distribution in the soil and displacement at various locations are analyzed, with effective stress in PLAXIS serving as the ultimate bearing capacity. A preliminary investigation of black cotton soil, obtained from a crossroad six kilometers away from Bhalkitaluk, reveals its classification as inorganic clays of high plasticity (CH) according to the Unified Soil Classification System (USCS). The ultimate bearing capacity for varying D/B (Depth to Width) ratios is computed using Terzaghi's equation based on the initial characteristics of black cotton soil and the loading frame. The calculated values are successfully compared with results obtained using Plaxis software, validating the accuracy and reliability of the numerical model in predicting the ultimate bearing capacity in varying soil conditions.

Gupta, S., & Mital, A. (2019). In this paper, the impact of soil bearing pressure values on a rectangular footing situated on a horizontal ground surface, utilizing PLAXIS software. As a Finite Element Method-based tool, PLAXIS is instrumental in analyzing deformation and stability in engineering projects, with a versatile application in constitutive soil models, including stress-strain-time relationships. The software serves as a valuable instrument for comprehending soil behavior and settlement under diverse loading conditions. The study involves the analysis and comparison of two-dimensional (2D) and three-dimensional (3D) models of rectangular footings. The findings reveal that 3D analysis yields more accurate results in comparison to 2D analysis, providing enhanced insights into the failure mechanisms of the soil model. This underscores the significance of considering three-dimensional aspects in assessing the soil-structure interaction and underscores the efficacy of PLAXIS in capturing the nuanced behavior of soil under varying loading conditions.

Fahmi, K. S., Fattah, M. Y., & Pustovgar, A. (2018). In this paper, the current practices focused on the design foundations of high-rise buildings in Moscow, aiming to identify methods for enhancing soil foundation performance. Numerous references indicated that prevailing design practices were predominantly influenced by structural engineers utilizing conventional analysis methods. The initial phase involved the design of the high-rise building's structure and architecture, while the subsequent part of the study explored the potential advantages of incorporating the stone columns raft foundation design concept. A comparative analysis was conducted between the outcomes obtained from a 3-dimensional finite element analysis (3D FEM) in SCAD software. The findings indicated that the existing plate foundation of the building was inadequate to support the total load without enhancements. The 3D FEM analysis using PLAXIS 3D demonstrated that the utilization of stone columns substantially reduced settlement, with approximately 70-80% of the total building loads being efficiently carried by these columns when the raft was positioned in a stiff clay layer. The study suggested that the number of columns in the raft foundation could be notably reduced, especially in soil with robust characteristics, leading to a significant reduction in settlement for the raft foundation, particularly in soils with strong characteristics.

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Poulos, H. G. (2016). In this paper, challenges encountered by foundation designers for exceptionally tall buildings will be examined, primarily focusing on geotechnical considerations. The distinctive features of such towering structures will be scrutinized, followed by a discussion on various foundation system options. A comprehensive three-stage process for foundation design and verification will be outlined, underscoring the critical significance of accurate ground characterization and assessment of geotechnical parameters. The practical application of foundation design principles will be elucidated through the analysis of four illustrative projects, providing insights into the complexities and considerations inherent in designing foundations for very tall buildings.

Dixit, M. S., & Patil, K. A. (2010). In this paper, the analysis of bearing capacity traditionally assumes a uniform contact pressure between the foundation and the underlying soil. However, various factors such as the type of soil failure, foundation depth, and the influence of the water table play crucial roles in determining the soil's bearing capacity. This paper specifically explores the impact of the footing's shape on soil bearing capacity and investigates how the depth of the footing affects this capacity. Generally, keeping other factors constant, the bearing capacity tends to increase with an increase in the depth or width of the foundation. The study involves a comparative analysis of the bearing capacity of soil using methods proposed by Terzaghi and the IS code for different footing shapes, including strip, square, circular, and rectangular shapes. In instances of local shear failure, it is observed that among various footing shapes, strip footings exhibit the lowest bearing capacity compared to square, circular, and rectangular footings. This research contributes insights into the nuanced influence of footing characteristics on soil bearing capacity, providing valuable information for foundation design considerations.

Baker, W. F., Brown, C., Pawlikowski, J. J., & Rankin, D. S. (2013). In this paper, the study investigates the reflective impact that foundations exert on the design and behavior of tall buildings, as exemplified by the analysis of two constructed towers: BurjKhalifa and Trump International Hotel and Tower, alongside the partially built Plaza Rakyat—a 77-story tower in Malaysia. The paper critically reviews the incorporation of foundation conditions in the design phase of these structures and investigates how these foundations were anticipated to shape the overall behavior of the towers. The examination of BurjKhalifa and Trump International Hotel and Tower provides insights into the strategic considerations and engineering solutions applied to address foundation challenges in the context of their towering structures. Additionally, the study scrutinizes the foundation-related aspects of Plaza Rakyat, offering an understanding of the impact of foundation conditions on the ongoing construction process. By exploring these cases, the paper contributes valuable knowledge to the broader understanding of the intricate relationship between foundations and the design, as well as the subsequent behavior, of tall buildings.

Du, P., Liu, X., & Zhang, Y. (2017). In this paper, a contrastive analysis of the theoretical formula method and finite element method for determining the ultimate bearing capacity of foundations by combining relevant literature examples. The primary focus is on validating the rationality and superiority of the incremental load method within the finite element software ABAQUS in addressing the bearing capacity of foundation soil. Through this comparative study, the paper aims to provide valuable insights and references for the practical calculation and analysis of foundation bearing capacity in engineering applications. The findings contribute to a comprehensive understanding of the effectiveness of different methodologies, enhancing the reliability of foundation design and analysis practices.

Magar, J., Kudtarkar, A., Pachpohe, J., & Nagargoje, P. (2020). This paper aims to delve into various aspects of foundations in the construction industry, encompassing their types, design considerations, and the exploration of alternative materials to enhance firmness, durability, and eco-friendliness. Constructing a robust base is essential to ensure the stability of the superstructure under diverse climatic conditions, preventing collapse or decay. The study underscores the importance of selecting the appropriate foundation type, materials, and design for a specific superstructure. The utilization of inappropriate materials poses a significant risk of structural failure. Different foundation bases are employed in diverse structures, each characterized by a unique design and specific configuration tailored to enhance durability and stability. Whether applied in bungalows or high-rise buildings, each foundation type is chosen with careful consideration. In summary, this study comprehensively presents various foundation types, their suitability for different superstructures, and the importance of eco-friendly, cost-efficient, and durable foundation bases capable of withstanding natural calamities. By addressing these crucial aspects, the paper aims to contribute to informed decision-making in the construction industry, promoting resilient and sustainable foundation practices.

Fahmi, K. S., Fattah, M. Y., & Pustovgar, A. (2018). In this paper, the study focusing on the design foundation of high-rise buildings in Moscow, with the aim of identifying methods to enhance the soil foundation. Notably, it was observed that structural engineers predominantly influenced the current design, utilizing conventional analysis methods. The initial phase of the study involved the design of the high-rise building's structure and architecture, while the subsequent part explored the advantages of adopting the stone columns raft foundation design concept.

A comparative study was executed, contrasting the results of a 3-dimensional finite element (3D FEM) analysis using SCAD software. Findings indicated that the existing plate foundation of the building failed to adequately support the total load without improvement. Utilizing 3D FEM in PLAXIS 3D, it was revealed that the incorporation of stone columns significantly reduced settlement, with around 70-80% of the total building loads efficiently borne by the columns when the raft was placed in a stiff clay layer. The study suggests that the number of columns in the raft foundation can be substantially reduced, particularly in soils with robust characteristics, leading to a significant reduction in settlement. This underscores the potential of the stone columns raft foundation design concept to enhance the overall performance and stability of high-rise buildings in Moscow.

Gupta, S., & Mital, A. (2019). In this paper, the impact of soil bearing pressure values on a rectangular footing situated on a horizontal ground surface, employing PLAXIS software, a Finite Element Method (FEM) based tool widely used for analyzing deformation and stability in engineering projects. With a versatile application in constitutive soil models, PLAXIS facilitates the exploration of stress-strain-time relationships, providing insights into soil behavior and settlement under varying loading conditions. The study involves a comprehensive analysis and comparison of two-dimensional (2D) and three-dimensional (3D) models of rectangular footings. Results demonstrate that the 3D analysis yields more accurate outcomes compared to its 2D counterpart, offering enhanced precision in understanding the failure mechanisms of the soil model. By employing PLAXIS software, this study contributes valuable insights into the nuanced behavior of soil under different loading conditions, emphasizing the importance of adopting three-dimensional analyses for a more comprehensive understanding of soil-structure interaction.

Arya, A., & Ameta, D. N. (2017). In this paper, foundation constitutes the cornerstone of any structure, shouldering the entire load of the building. Consequently, meticulous design of the foundation is imperative. The two primary considerations in foundation design are the bearing capacity of the underlying soil and the settlement of the footing. Extensive research over an extended period has been dedicated to understanding and determining these crucial aspects. This paper undertakes a comprehensive review of the existing body of work on the bearing capacity of soil and the settlement of footings, consolidating and presenting the collective knowledge accumulated over time in these fundamental areas of foundation engineering.

Xia, H., Zhang, J., Cai, J., Pan, H., & She, X. (2020). In this paper, the confirmation of the safety and suitability of engineering projects, it becomes crucial to thoroughly investigate the engineering characteristics of aeolian sand. This paper specifically concentrates on the bearing capacity parameters of aeolian sand within the Mu Us Desert. Six weak foundation areas were selected as test sites, where extensive data on fundamental soil mechanical parameters were gathered through in situ static load tests (SLT) and laboratory confined compaction tests (CCT). The aim was to assess the impact of various foundation treatments. The findings reveal that the aeolian sand in the Mu Us Desert is characterized by low moisture, poor cohesion, and a propensity for easy compaction. Mud and water content emerged as critical factors influencing the bearing capacity of aeolian sand. The study further establishes that, for weak foundations, implementing strategies such as adding a geogrid or replacing a weak soil layer with stone and aeolian sand can significantly enhance the overall bearing capacity of the foundation.

Current practice on foundation design of high-rise buildings in bangkok, thailand. (2012). In this paper, an assessment was conducted on the existing foundation design practices for high-rise buildings in Bangkok, Thailand, with the objective of identifying areas for improvement. An interview survey unveiled that the predominant influence in the current design practices was held by structural engineers, who commonly employed conventional analysis methods such as the combined stress equation and the plate on springs analysis. The survey findings indicated that the prevailing design approach did not necessarily yield optimal outcomes in terms of cost-effectiveness. The subsequent phase of the study explored the potential benefits of embracing the piled raft foundation design concept. A comparative analysis was performed on the results obtained from 3-dimensional finite element (3D FEM) analysis and various conventional analysis methods currently in use. The outcomes revealed significant differences, particularly when utilizing the plate on pile springs method that neglects pile-pile and raft-pile interactions. The 3D FEM demonstrated that only around 70-80% of the total building loads are borne by piles when the raft is situated in a stiff clay layer. Moreover, the study suggested that adopting the true piled raft foundation concept could substantially reduce the number of piles required, with only a marginal increase in foundation settlement. This highlights the potential for optimizing foundation design practices by incorporating innovative concepts such as piled raft foundations in the context of high-rise buildings in Bangkok.

Zhu, F., Zhang, W., Dong, W., & Sun, M. (2017). In this paper, the consideration of the impacts of consolidation, intermediate principal stress, earth pressure at rest, and the presence of a crusty layer. Employing the unified strength theory, novel theoretical formulas for critical edge load and critical load were derived, with the Mohr–Coulomb strength theory solution identified as a specific case within the unified strength theory framework. The proposed formulas underwent analysis and validation through application to a practical railway subgrade filling project situated in an area with soft soils. Calculated results exhibited notable alignment with experimental findings.

These newly formulated theoretical expressions not only establish a basis for calculating the bearing capacity of a soft soil foundation but also serve as a reference for determining the safe height of subgrade filling in soft soil areas. The application of these formulas enables an understanding of the variation pattern of foundation bearing capacity during the construction of embankment filling under different degrees of consolidation.

LOAD TEST. (2012). In this paper, the assessment of the bearing capacity of soil or gravel-boulder strata poses a considerable challenge due to the intricate field arrangements required for testing. The load-displacement characteristics of gravel-boulder deposits are influenced by factors such as the type of soil, compaction/interlocking of soil molecules, and, notably, the size of boulders beneath the footing. This paper focuses on footing load tests conducted to investigate subsurface conditions for the design of foundations in boulder-gravel deposits, applicable to single and multi-storeyed buildings, overhead water tanks, and various infrastructure elements. The load-settlement curve derived from these tests offers insights into yield pressure and recommended allowable pressure for foundation design. Notably, field tests stand as the primary tool for acquiring in-situ characteristics of gravel-boulder deposits, given that laboratory tests on small samples may not accurately represent the complex behavior of such matrices. The paper discusses the results and interpretation of in-situ footing load tests conducted at the proposed colony at Sangaldan station yard of the Udhampur-Srinagar-Baramulla Rail Link (USBRL) Project. These findings contribute to a better understanding of the foundation behavior in gravel-boulder deposits, aiding in informed design decisions for infrastructure projects in similar geological contexts.

III. CONCLUSION AND OUTLINE OF PROPOSED WORK

It appears that a research gap exists in the literature concerning the various analyses and design work previously conducted on the current topic. Further research is needed to explore the effect of this factor and to formulate appropriate design guidelines for mitigating its impact on the response of multistoried buildings. Based on the literature review, we have reached a conclusion that highlights the key findings of the research and lists the necessary outcomes:

1) Software analysis for determining the best location is not used by any of the research papers.
2) Complete information on the soil investigation report is not provided by any of the papers.
3) The case study approach is not demonstrated by any of the papers.
4) The strata profile beneath the ground at a particular place of the applied research is not shown by any of the papers.
5) The best location for proposed construction, determined using soil investigation reports, is not evaluated by any of the papers.

The primary objective of this study is to assess the feasibility of determining the efficiency of soil parameters beneath a multi-storied building, which will be a focal point for the upcoming proposed work.

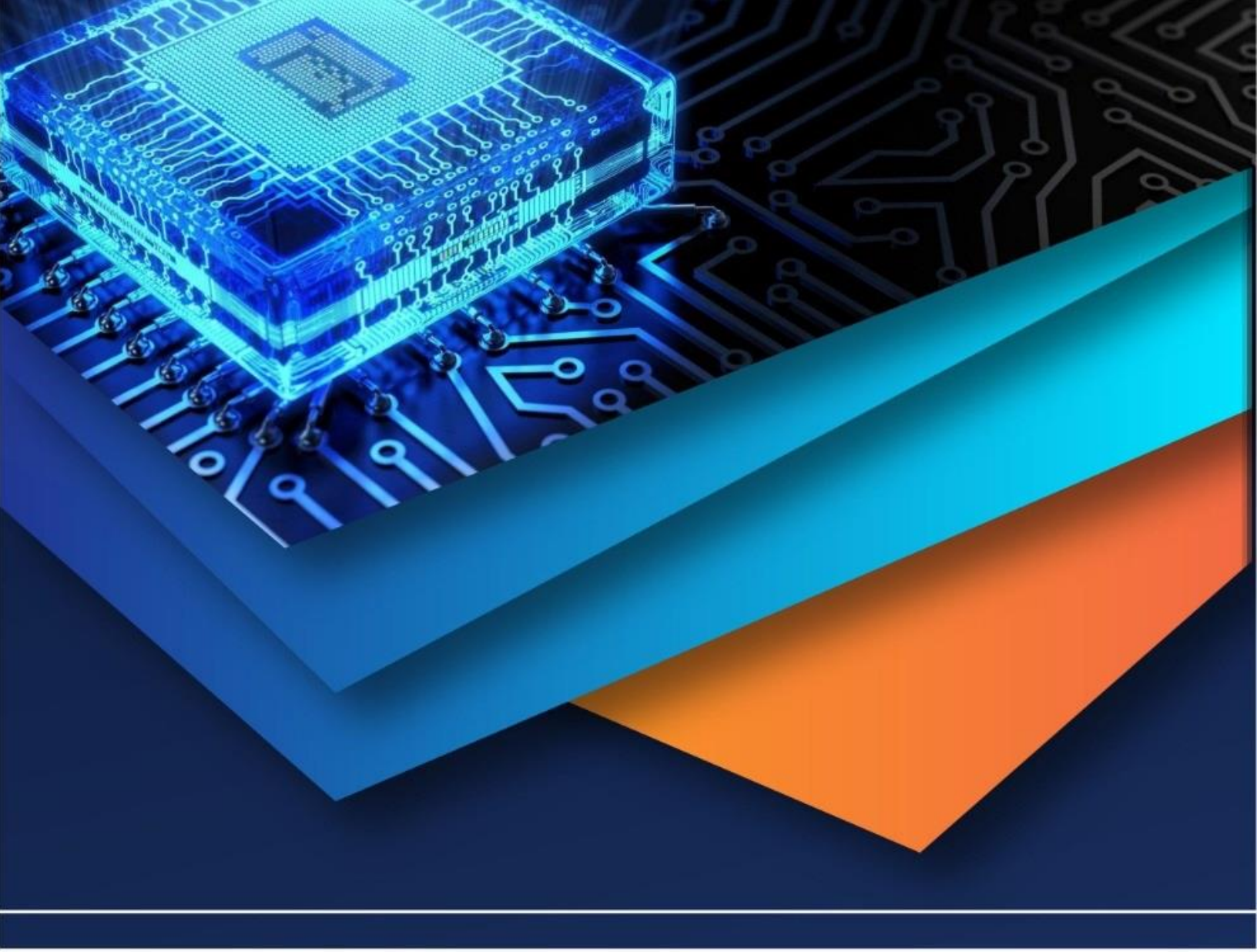
IV. ACKNOWLEDGEMENTS

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