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Soil Bearing Capacity and Techniques to Improve the Bearing Capacity of Soil

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Abstract: Soil at a construction site may not always be totally suitable for supporting structures in its natural state. In such a case, the soil needs to be improved to increase its bearing capacity and decrease the expected settlement. This paper gives an overview of techniques that are commonly used to improve the performance of saturated clayey soil in situ, its functions, methods of installation. Then, this study concluded that there is an urgent need to study the technique of removal and replacement for improving soil behaviour taking into consideration geotechnical requirements (i.e.bearing capacity and settlement) and cost to achieve the optimum thickness of replacement layers and the most suitable material corresponding to minimum total cost of foundation works.
Keywords: Bearing capacity failure, Preloading, drains, stone column, Dynamic compaction, Grouting methods of soil improvement

I. INTRODUCTION

Bearing capacity is the ability of soil to safely carry the pressure on the soil from any engineering structure without undergoing a shear failure with accompanying large settlement. Bearing capacity is the strength of soil to support the loads applied to the ground. The bearing capacity of soil structure system is the maximum average contact pressure between the foundation and the soil. Which should not produce shear failure or excessive settlement in the soil. Since the population is increasing rapidly land availability for the structures are reducing now, we have sites having poor soil for development of any civil engineering structure. These sites soil have very less amount of bearing capacity so for the structure to sustain on the ground we required to increase the foundation area.

A. Types of bearing capacity of soil Ultimate Bearing Capacity

The generally accepted method of bearing capacity analysis is to assume that the soil below the foundation along a critical plane of failure is on the verge of failure and to calculate the bearing pressure applied by the foundation required to cause this failure condition.

1) *Safe Bearing Capacity:* The maximum pressure which the soil can resist without any failure is called as the safe bearing capacity of the soil. It is the value of bearing capacity used in the design of foundations. This value is obtained by dividing with ultimate bearing capacity with suitable factor of safety. Generally, the factor of safety is kept between 3 to 5.
2) *Allowable Bearing Capacity:* It is net load intensity, including the surcharge on the foundation at which neither the soil fails due to shear rupture nor there is excessive settlement of the foundation. But this bearing pressure is not considered while designing. Generally, for uncertainty and unknown factors always a sufficient factor of safety is used.

B. Factors influencing the bearing capacity of soil

Soil strength Foundation width & Depth Soil weight and surcharge Spacing between foundation.

C. Types of bearing capacity failures

A bearing capacity failure is defined as a foundation failure that occurs when the shear stresses in the soil exceed the shear strength of the soil. Bearing capacity failures of foundations can be grouped into three categories, as follows:

1) *General Shear Failure:* As shown in Fig-1, a general shear failure ruptures and pushes up the soil on both sides of the footing. Foractual failures in the field, the soil is often pushed up on only one side of the footing with subsequent tilting of the structure. A general shear failure occurs for soils that are in a dense or hard state.

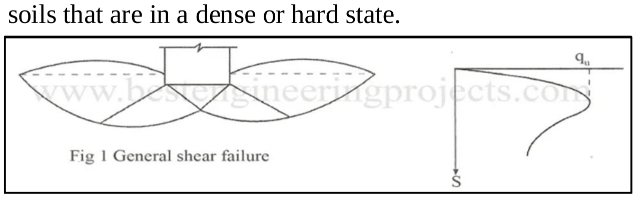

Fig-1 (General Shear Failure)

2) *Local Shear Failure:* As shown in Fig-2, local shear failure involves rupture of the soil only immediately below the footing. There is soil bulging on both sides of the footing, but the bulging is not as significant as in general shear.

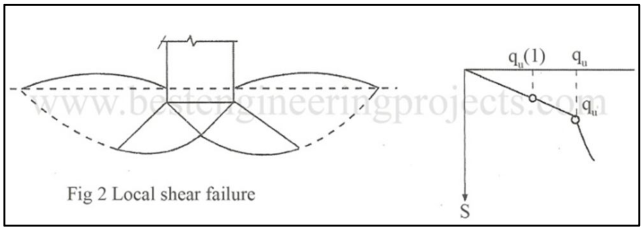

Fig-2 (Local Shear Failure)

Local shear failure can be considered as a transitional phase between general shear and punching shear. Because of the transitional nature of local shear failure, the bearing capacity could be defined as the first major nonlinearity in the load-settlement curve or at the point where the settlement rapidly increases. A local shear failure occurs for soils that are in a medium dense or firm state.

3) *Punching Shear Failure:* As shown in Fig-3, a punching shear failure does not develop the distinct shear surfaces associated with a general shear failure. For punching shear, the soil outside the loaded area remains relatively uninvolved and there is minimal movement of soil on both sides of the footing. The process of deformation of the footing involves compression of soil directly below the footing as well as the vertical shearing of soil around the footing perimeter. As shown in Fig- 3, the load settlement curve does not have a dramatic break and for punching shear, the bearing capacity is often defined as the first major non linearity in the load-settlement curve. A punching shear failure occurs for soils that are in a loose or soft state.

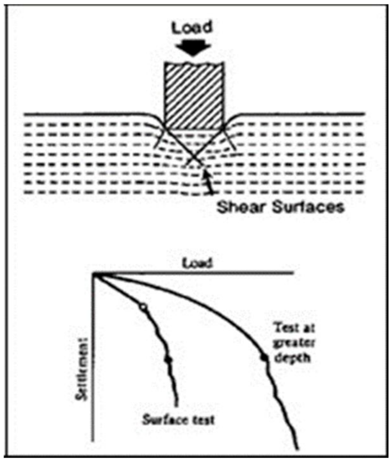

Fig-3 (Punching Shear Failure)

II. TECHNIQUES TO IMPROVE THE BEARING CAPACITY OF SOIL

A. *Grouting*

Grouting is an earth construction material used to embed rebars in masonry walls and fill voids, and seal joints. Grouts are applied as a thick liquid and hardens over time, much like mortar. Grouting is the process to inject grout into the ground. Materials used for grouting areCement and water etc.

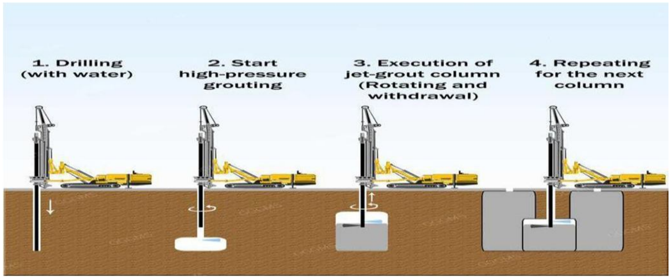

Fig 4 (Grounds stabilization by Grouting)

There are many technics of grout mainly known as Compensation grouting, Jet Grouting, Compaction Grouting, Chemical grouting, Cement grouting. Compensation grouting is the process of injecting grout that can compensate for stress relief and associated ground settlement. Jet grouting is the process of grout injection that cuts and mixes the soil to be treated with cement or cementitious grout. Compaction grouting is also known as Low Mobility Grouting. Compaction Grouting is a grouting technique that densifies reinforces fine grained soils and loose granular soils and stabilizes subsurface voids, by the staged injection of low-slump, low mobility aggregate grout.

Chemical grouting is a ground treatment method for soils with low viscosity grout. Cement grouting is also known as high mobility grouting. It is a grouting technique that fills pores in voids in rock or granular soil with flowable particulate grouts.

B. Soil Nailing

Soil nailing Soil nailing is one of the earth retention techniques using grouted tension-resisting steel elements that can be used for permanent or temporary support. In soil nailing 3 to 6 feet of earth is excavated from the top of the planned excavation. Near-horizontal holes are drilled into the exposed face at typically 3 to 6 feet centers.

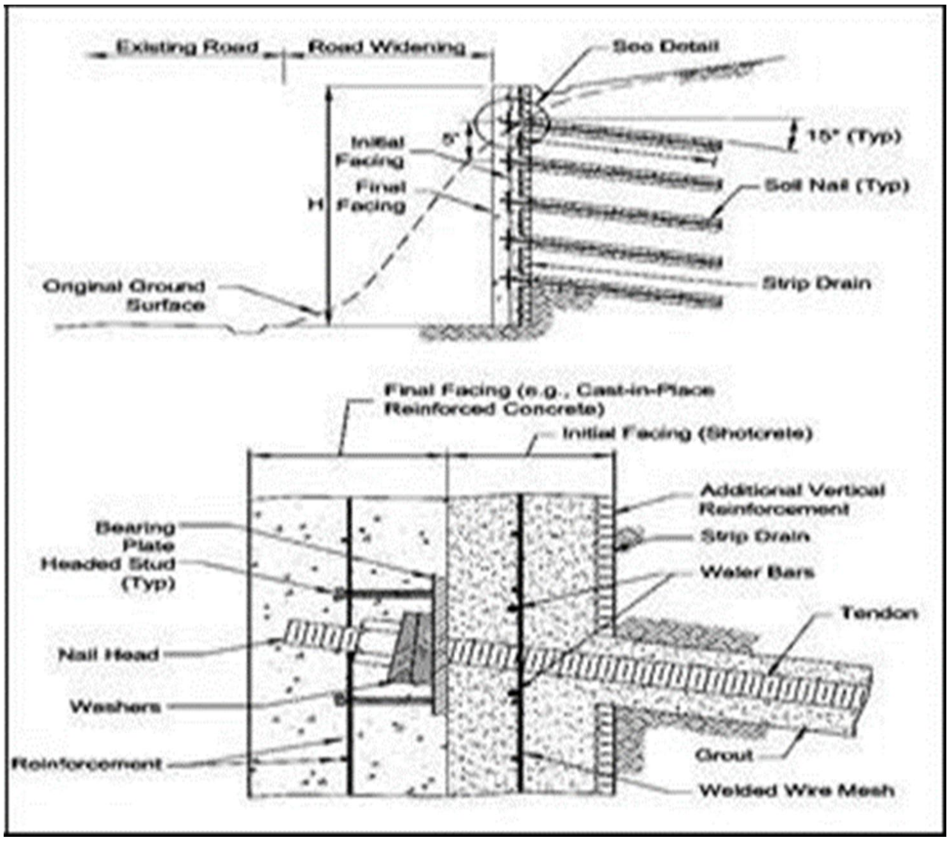

Fig: 5(Installation of soil nail)

1) *Components of Soil Nail:* The various components of a soil nail Steel Bar- Steel bar is the main component of soil nail system. Steel bar acts as a tension member. It may be solid with necessary required strength. Centralizers- Centralizer is fixed with steel bar so that nail can be placed centrally in drill hole. Grout- Grout is used to fill the space between ground and installed nails. Nail Head- Nail Head works as a reaction pad for generation of tensile force in the nails and it also prevent local failure between the nails. Hex Nut, Washer and Bearing Plate- It provides support to the exposed surface of soil nail. After thisthe permanent facing should be installed over temporary facing. Temporary and Permanent Facing- Permanent Facing provide support to the exposed surface of the soil nail and acts as bearing surface for bearing plate. And then permanent facing is installed over temporary facing. A prefabricated synthetic drainage is placed vertically to the excavation face to prevent any seepage against the excavation face. Type of Soil Nailing- Driven nails, Grouted nails, Jet grouted nails, Launched nails. Materials used for Soil Nailing- Steel reinforcements, Shot Crete/gunite, Grout mix.

C. Stone Columns

A stone column is a ground improvement technique that improves the load bearing capacity of the soil. The stone column is made up of crushed coarse aggregates of various sizes. The ratio in which the stones of different sizes will be mixed is decided by design criteria. Stone columns are ideally suited for improving soft silt sand clays and loose silty sands. Stone columns under suitable conditions will:

1) Increase a soil's bearing capacity and shear resistance
2) Reduce settlements
3) Increase the time-rate of consolidation
4) Reduce liquefaction potential

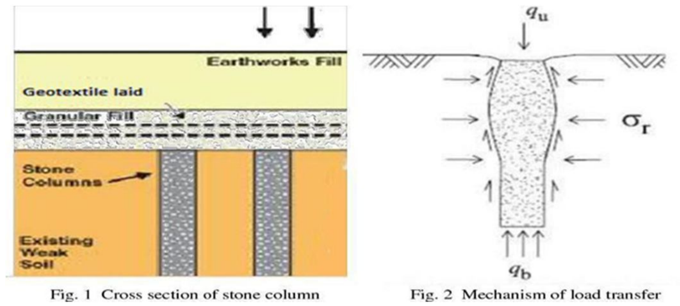

Fig. 6: Stone Columns

D. Dynamic Compaction

Dynamic compaction is the ground improvement technique by using weights dropped from a height that results in the application of high energy to the in-situ soil resulting in improvement of the soil. Typically, the weight from height dropped ranges from 11 to 39. 6 kips and is dropped from heights of 30 to 100 feet.

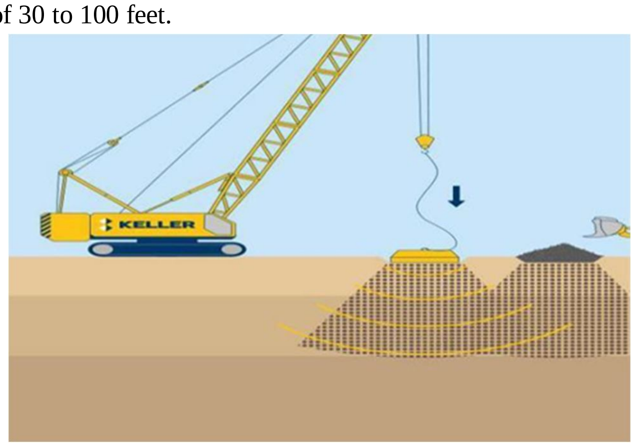

Fig 7. Dynamic Compaction

1) Advantages

a) Increases soil density and collapses voids
b) Increases the bearing capacity of granular soils
c) Reduces the volume of landfills
d) Reduces the potential of soil liquefaction and seismic settlement
e) Reduces post-construction settlements

2) Application

Treatment for industrial warehouses,
Port and airport platforms,
Road and railways embankments,
Heavy storage tanks.

E. Preloading

Preloading technique is simply to place a surcharge fill on the top of the soil that requires large consolidation settlement to take place before construction of the structure. Once sufficient consolidation has occurred, the fill can be removed and construction process takes place. In general, this technique is adequate and most effective in clayey soil. Since clayey soils have low permeability, the desired consolidation takes very long time to occur, even with very high surcharge load. Therefore, with tight construction schedules, preloading may not be a feasible solution. Hence, sand or vertical drains may be used to accelerate consolidation process by reducing the drainage paths length.

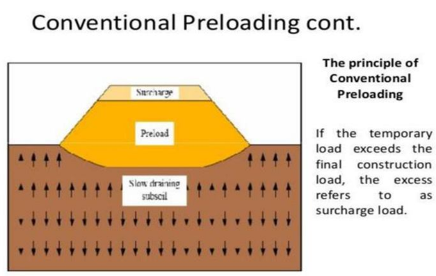

Fig. 8: Preloading

1) Advantages

a) Requires only conventional earthmoving equipment
b) Any grading contractor can perform the work
c) Long track record of success

2) Disadvantages

a) Surcharge fill must extend horizontally at least 10 m beyond the perimeter of the planned construction, which is generally not possible at confined sites
b) Transport of large quantities of soil required
c) Surcharge must remain in place for months or a year that delays the construction.

F. Prefabricated vertical Drains:

Prefabricated vertical drain is defined as any prefabricated product consisting of a synthetic filter jacket that surrounds a plastic core because of their shape. These are also known as band or wick drains. After being they are manufactured in rolls of 200-300 m they are inserted into ground to required depths using special drain stitcher rigs. Generally, installation takes place up to full depth of compressible soils. The prefabricated band drains are used for accelerating the consolidation of marine deposits or soft soils.

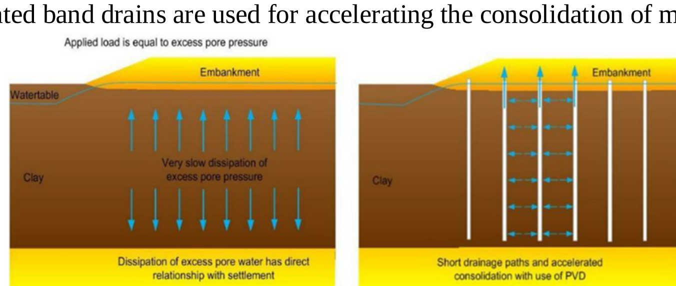

Fig 9 Prefabricated Vertical Drains

1) Components of PVD

There are two components of pre-fabricated vertical drains.

a) Core: It is also called drain body which is a unique, corrugated, and flexible and made of polypropylene that is specifically designed for providing high discharge capacity, high tensile and compressive strength.
b) Filter Jacket: It is strong non-woven, thermically bonded polypropylene fabric wrapped around the core. The fabric has random texture with high tensile strength, high permeability and effective filtering properties.

2) Applications of PVD

a) Airport Runways
b) Golf Courses
c) Dredge Consolidation
d) Mine Tailings Consolidation
e) Tailing Ponds
f) Wetland Development
g) Building Foundations
h) Retaining Walls
i) Parking Lots
j) Landfills

3) Advantages

a) Minimum disturbance to the soil layers during installation.
b) High water discharge capacity.
c) High compressive strength core prevents the collapse of the flow path.
d) Fast and easy installation.
e) Deep installation exceeding 40 m in depth.
f) High installation speed 1500 m/hr.
g) Close spacing is possible.

G. Removal of Water from Soil

Some sites have high water table level and since we know that when soil goes into the submersed condition the bearing capacity is reduced by half amount. So if we are able to reduce the water table i.e. decrease the water content in the soil we can get an enhanced bearing capacity for that soil structure system. The technique associated with this concept is very old method as by pumping the water out from the soil. Some techniques involve putting load on the soil which creates a head that allows water to come out. Some sites have very low permeability which does not allow the water to flow out easily we can introduce the sand drains which allow it to remove water rapidly.

H. Cement Stabilization

Cement is the oldest binding agent since the invention of soil stabilization technology in 1960's. It is commonly used to stabilize wide range of soils, provided sufficient quantity is added. As clay content increase, soils become more difficult to pulverize and work, and larger quantities of cement must be added to harden them. Cement reaction is not dependent on soil minerals, and the key role is its reaction with water that may be available in any soil. This can be the reason why cement is used to stabilize a wide range of soils. In this technique, cement is mixed with water and soils by special equipment in site. Physical and chemical reactions within cement and soil are happened. Setting of cement will enclose soil as glue, but it will not change the structure of soil. The soil is hardened as cemented soil. Hardening process can be affected by physical and chemical properties of soil, water-cement ratio, curing temperature and the degree of compaction. On the other hand, the nature of soil treated, the type of cement utilized, the placement and cure conditions adopted affect determining the correct proportion of soil – cement.

III. CONCLUSION

There are many available improvement techniques that can be used for the purposes of increasing bearing capacity, enhancing shear strength and decreasing consolidation settlement of saturated medium clay such as soil replacement, preloading with vertical drains, stone columns, stabilization with additives and thermal methods. Unfortunately, there is a lack of researches which consider all the governing factors such as soil bearing capacity and settlement, cost of foundation works and simple execution. This paper concluded that there is an essential need to study the technique of removal and replacement for improving soil behavior taking into consideration geotechnical requirements and cost to achieve the optimum replacement layer thickness and the most suitable material corresponding to minimum total cost of foundation works.

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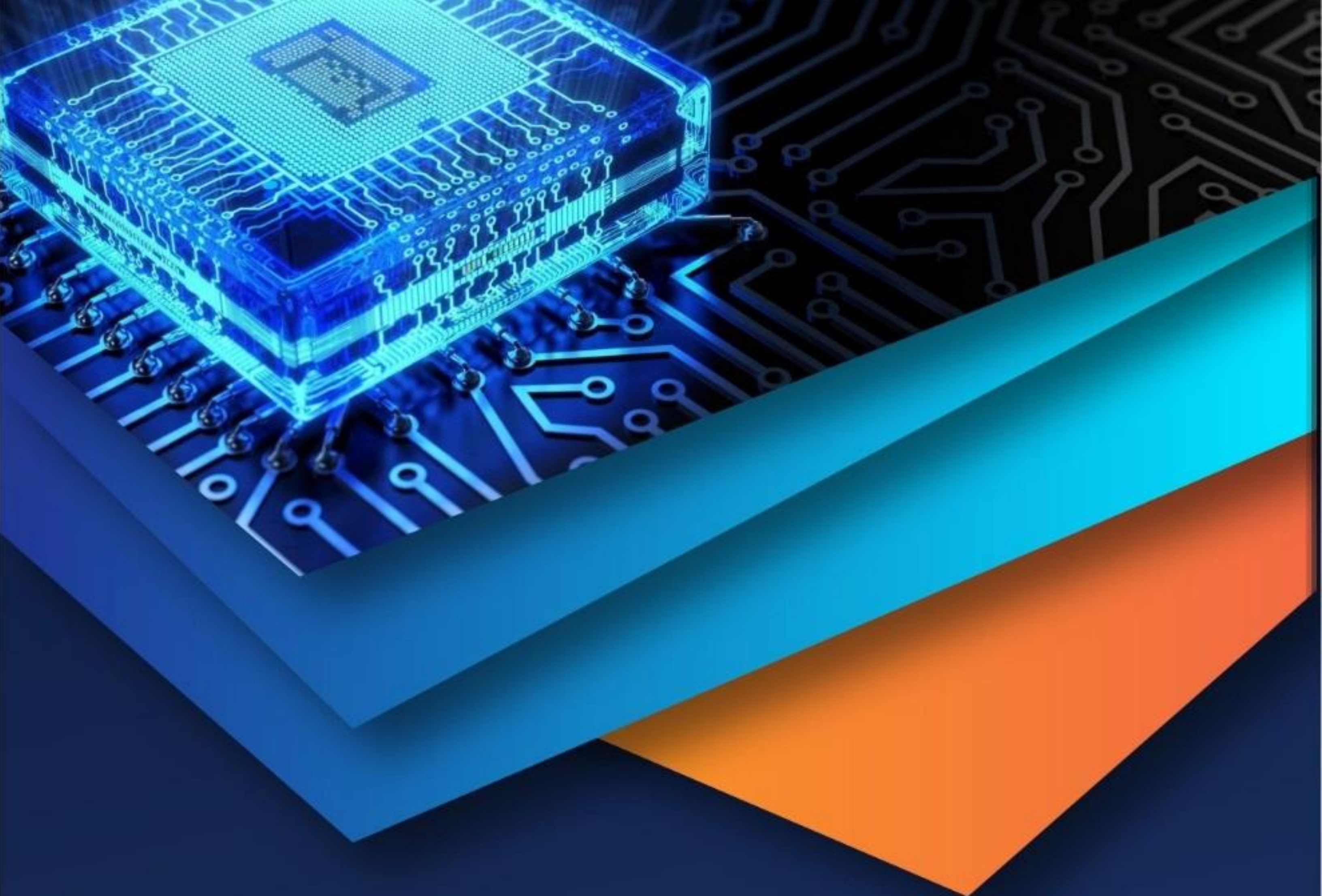

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