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# Behaviour of Piles in Non-Liquefiable and Liquefiable Strata

Supriya Chinivar[1], Vivek Aabhyanar[2]
[1]*Civil Engineering Department*

***Abstract: Impact of soil liquefaction on various parameters like vertical load, time period, seismic load varies with spacing which depends on the state of soil being liquefiable or not. Additionally fixity depth, lateral capacity, diameter of piles, cumulative skin friction also plays important role. In present paper, same where compared and results are depicted. For comparing the impact of liquefiable and non-liquefiable soil on different parameter, the geotechnical report of Delhi which comes in the region of zone IV, there becomes the necessity to find whether the soil is liquefiable or not. Borehole log data i.e. SPT data and peak ground acceleration plays important role in determining the nature of soil.***
***Keywords: liquefiable, non-liquefiable, fixity depth, cumulative skin friction, end bearing capacity.***

## I. INTRODUCTION

A state of 'soil liquefaction' occurs when the effective stress of soil is reduced to essentially zero, which corresponds to a complete loss of shear strength. Nature of soil varies with location and basic property of soil also varies which is why whether the soil will get liquefiable or not also varies with location. Sandy soil and non- plastic silty soil are more susceptible to liquefaction but rare in case of gravels and clayey soil. Deposits most susceptible to liquefaction are young sands and silts of similar grain size, in beds at least meters thick, and saturated with water which are often found along stream beds, beaches, dunes, and areas where wind -blown silt (loess) and sand have accumulated. Earthquake is a natural activity which may convert non-liquefiable to liquefiable soil and this change impacts deep foundation as compared to shallow foundation. Hence it is important to make sure that whether soil is liquefiable or not and necessary care need to be taken while designing the piles in such conditions.

## II. PROBLEM DEFINITION

In present paper, analysis of various diameter piles was considered in which the behaviour of pile from non-liquefaction to liquefaction state were determined and consecutive results are presented. Basic data required for evaluating liquefaction potential, modulus of subgrade reaction, spring constants, etc. were calculated on the basis of soil properties as stated in geotechnical report.

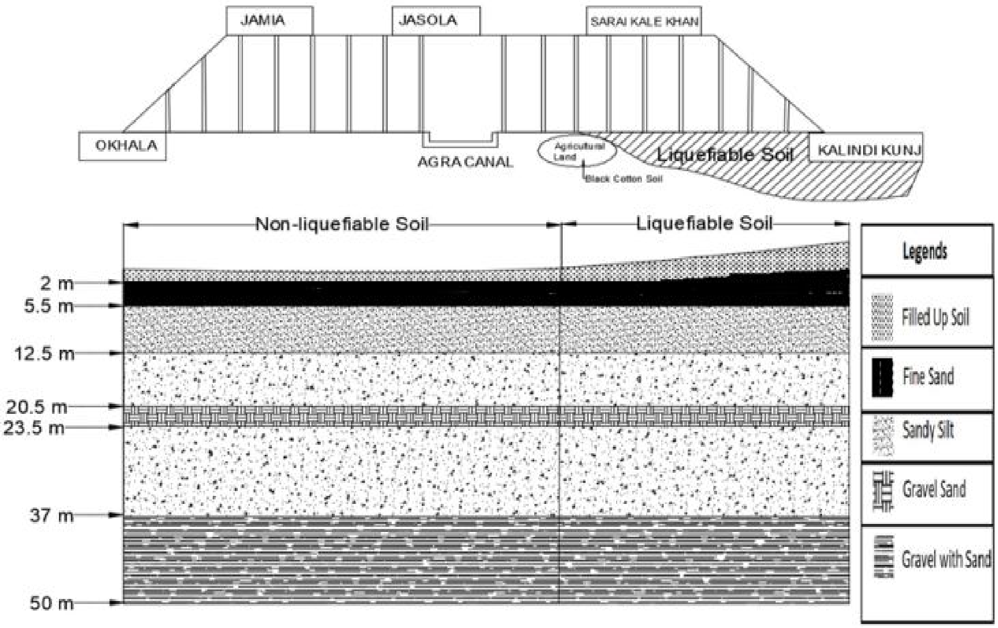


Fig. 1 A Soil Profile

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TABLE I
PROPERTIES OF SOIL

| Depth | Type | N | w (%) | G | Ƴd (T/m³) |
|---|---|---|---|---|---|
| 1.5 | SM | 23 | 10.8 | 2.67 | 1.55 |
| 3 | SM | 26 | 10.8 | 2.67 | 1.55 |
| 4.5 | SM | 11 | 10.8 | 2.68 | 1.55 |
| 6 | SP-SM | 20 | 10.8 | 2.68 | 1.55 |
| 7.5 | SP-SM | 23 | 10.8 | 2.68 | 1.55 |
| 9 | SP-SM | 30 | 10.8 | 2.68 | 1.67 |
| 10.5 | SP-SM | 24 | 10.8 | 2.7 | 1.67 |
| 12 | SP-SM | 44 | 10.8 | 2.7 | 1.67 |
| 15 | SM | 70 | 10.8 | 2.66 | 1.67 |
| 18 | SM | 90 | 10.8 | 2.67 | 1.77 |
| 19.5 | SP-SM | 70 | 10.8 | 2.67 | 1.77 |
| 22.5 | SG | 68 | 10.8 | 2.72 | 1.8 |
| 25.5 | SM | 65 | 10.8 | 2.69 | 1.79 |
| 27 | SM | 74 | 10.8 | 2.7 | 1.79 |

## III. ANALYSIS

The condition of liquefaction is evaluated by finding out liquefaction potential depth. Initially non-liquefiable soil may convert to liquefiable soil due to impact of earthquake. Hence this condition will govern majorly in earthquake prone areas. SPT value plays major role because the depth of fixity changes as soil property changes thereby slowly converting the soil from non-liquefiable state to liquefiable state.

### *A. Liquefiable Soil*

From geotechnical soil data, borehole log data was analysed and liquefaction potential depth was evaluated. SPT value plays the most important role for evaluation of liquefaction potential depth. Other parameters on which liquefaction potential depth is dependent are CSR and CRR. Analysis is tedious and due to earthquake impact, the topmost layer of soil loses its shear strength because of which free head of pile is increased which consequently leads to increase in fixity depth. Hence actual evaluated length of pile as in non-liquefiable case is less than that required in liquefiable case.

### *B. Non-Liquefiable Soil*

Analysis is simple in which only the soil bearing capacity will help to evaluate diameter and length of pile which does not get impacted due to earthquake.

### *C. Parametric Comparison*

The analysis of change in spacing versus vertical load carrying capacity is shown in following table which indicates that increase in spacing decreases vertical load carrying capacity. Even though increase in diameter of pile will not help to increase vertical capacity.

TABLE II
LOAD CARRYING CAPACITY OF SOIL

| Diameter (m) | 1 | 1.2 | 1.5 | 2 |
|---|---|---|---|---|
| Spacing (m) | 2.5D | 3D | 3.75D | 5D |
| Vertical Load (T) | 569 | 516 | 483 | 467 |

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## IV. RESULTS & DISCUSSIONS

The results so obtained are graphically represented and interpreted as follows:

### *A. Comparative Parameters*

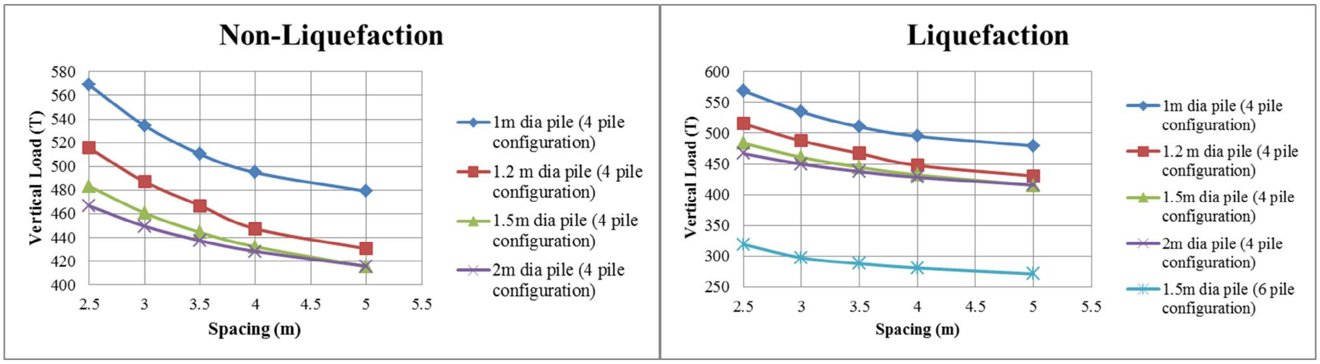


Fig. 2 Graph showing relation between Spacing (m) v/s Vertical Load (T)

*1)* As spacing between the piles increases, lever arm increases, hence vertical load acting on the pile apparently decreases.
*2)* This is happening because with the increase in spacing between the piles, the lever arm distance increases hence the normal vertical load acting per pile decreases.

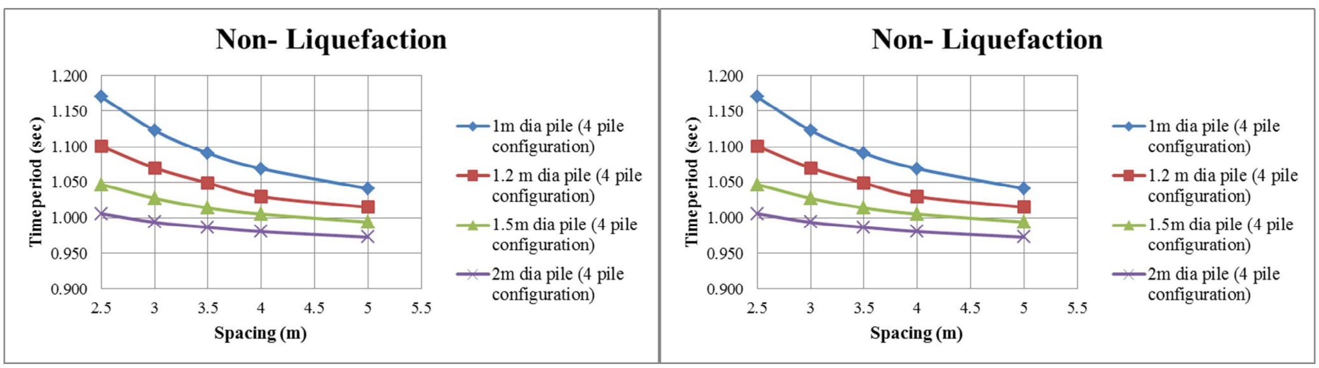


Fig. 3 Graph showing relation between Spacing (m) v/s Time period (s)

*3)* As spacing between the piles increases, time period decreases.
*4)* This is happening because the relative stiffness of the beam is more than column, making the time period decrease. This happens within a certain range of pile cap thickness beyond which merely increasing pile spacing does not work without thickening the pile cap thickness as the pile cap and pile will act as cantilever section which will not affect the time period.

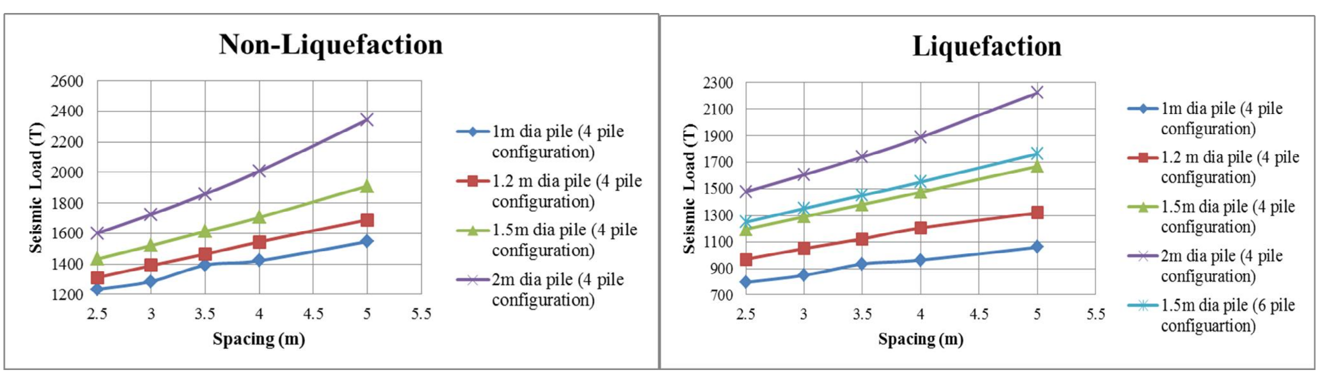


Fig. 4 Graph showing relation between Spacing (m) v/s Seismic Load (T)

*5)* As spacing between the piles increases, the time period reduces and hence, seismic load acting on the pile increases.
*6)* It is because that stiff structure attracts more seismic force acting on the structure.

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*B. Affected Parameters*

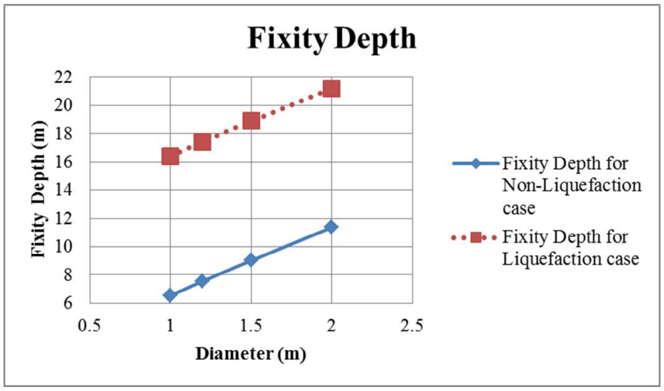


Fig. 5 Graph showing relation between Diameter (m) v/s Fixity Depth (m)

1) As diameter the piles increases, fixity depth of the pile increases linearly.
2) Due to liquefaction, the SPT value of soil decreases thereby decreasing the modulus of subgrade reaction of soil, ultimately increasing the stiffness factor of the pile, which leads in increase in the fixity depth.

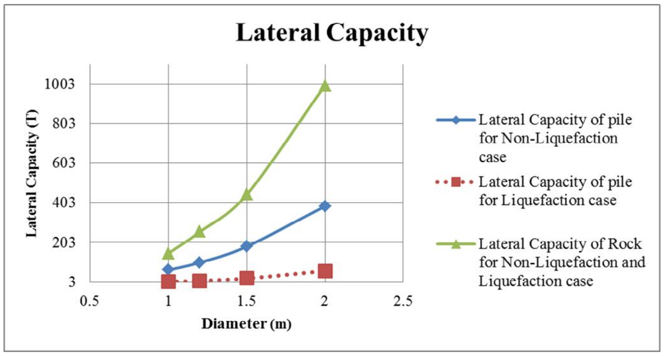


Fig. 6 Graph showing relation between Diameter (m) v/s Lateral Load Capacity (T)

3) As diameter increases, lateral load carrying capacity of the pile increases.
4) Due to liquefaction in soil, the time period of the structure increases thereby decreasing the lateral load acting on the pile decreases.
5) Whereas in case of liquefaction in rock, the time period does get affected but the lateral load.

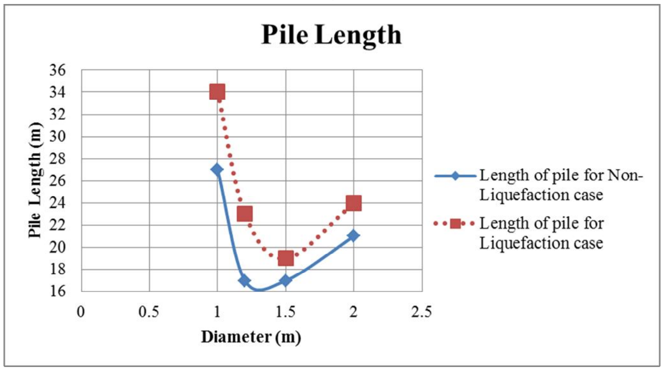


Fig. 7 Graph showing relation between Diameter (m) v/s Pile Length (T)

6) As diameter of the piles increases, length of the pile decreases initially and then increases.
7) This happens because as the diameter increases, fixity depth increases and at a certain point, the fixity depth required becomes to minimum length of the pile even though the geotechnical capacity is acheieved at a depth above than the fixity depth.
8) With increase in the diameter of the pile, the pile length decreases but this trend follows for 1m, 1.2m, 1.5m diameter piles and not for 2m diameter piles.

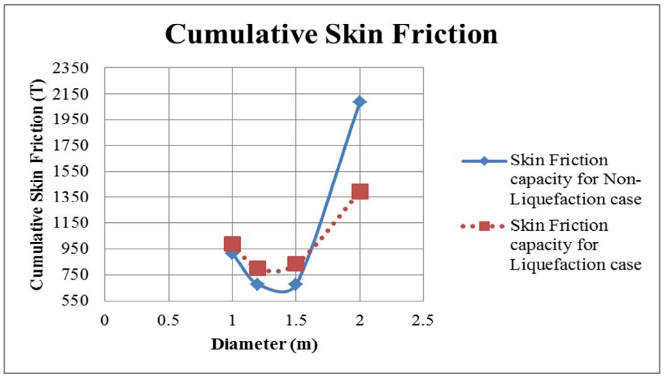


Fig. 8 Graph showing relation between Diameter (m) v/s Cumulative Skin Friction (T)

*9)* As diameter of the piles increases, cumulative skin friction of the pile decreases and increases for 2m diameter pile.

*10)* The increase in skin friction capacity in case of liquefaction and non-liquefaction is steady and steep respectively in case of 2m diameter pile because of the requirement of minimum fixity depth.

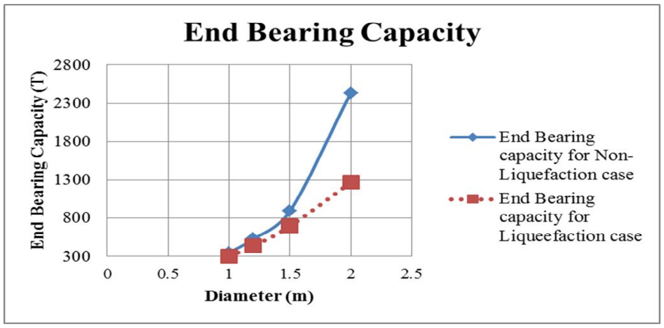


Fig. 9 Graph showing relation between Diameter (m) v/s End Bearing Capacity (T)

*11)* As diameter of the piles increases, end bearing capacity of the pile increases.

*12)* The increase in end bearing capacity in case of liquefaction and non-liquefaction is steady and steep respectively.

## V. OTHER RECOMMENDATIONS

A study can be done on effect of ground improvement of soil on liquefaction of soil, performance of piles in the liquefaction zone, constructability & its overall cost. Feasibility check for use of Isolated Footing, Well Foundation or Caissons instead of piles in ground improved zone can also be done.

## VI. ACKNOWLEDGMENT

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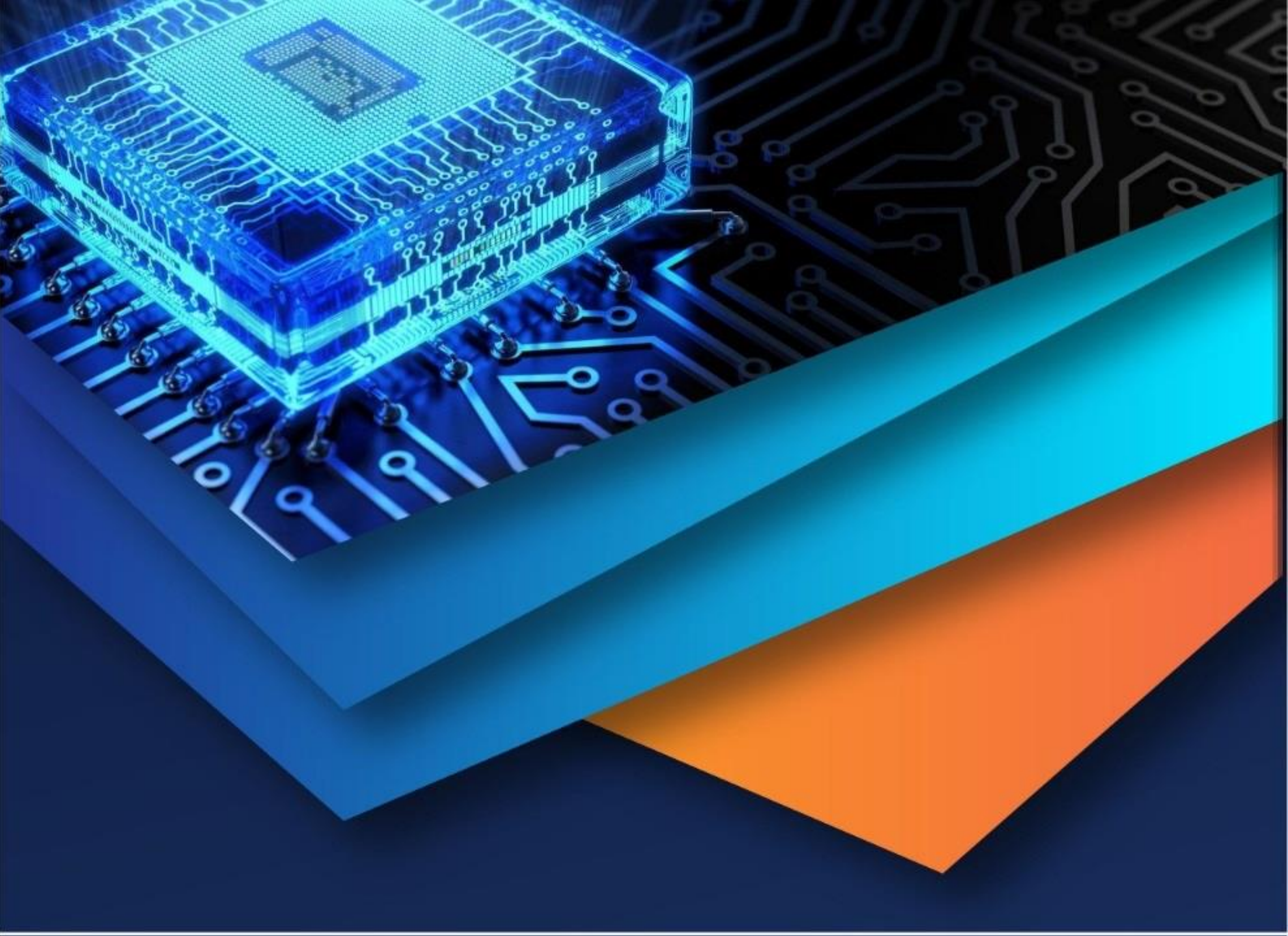


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