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Improvement of Subgrade Clayey Soil using Eggshell

Diana Johns[1], Naveena Joseph[2], S Naveen Prasath[3]
[1,3]PG Research Scholar, Department of Civil Engineering, Coimabatore Institute of Technology, Coimbatore
[2]PG Research Scholar , Department of Civil Engineering,Amaljyothi College of Engineering ,kanjirappilly

Abstract: ***Eggshell powder has not been used as a stabilizing material however, it could be a replacement for other types of stabilization. This study is aimed at determining the geotechnical properties of eggshell stabilized kuttanad clay with a view to determining its suitability as stabilizing agent for kuttanad clay. Laboratory tests were carried out on eggshell stabilized kuttanad clay and lime stabilized kuttanad clay. Lime stabilized kuttanad clay served as control experiment. The results of Atterberg limits, Hydrometer test, Free swell test, Unconfined compression test, Standard proctor test and California Bearing Ratio indicate that eggshell-stabilized kuttanad clay at 12% have similar engineering properties with Lime-stabilized kuttanad clay at 4%. Though from this study, eggshell powder mixed with kuttanad clay has been found to possess low binding properties, it can be used to significantly improve the strength of soil to be used as a sub grade where very high performance is not necessary. It could serve as a fair replacement for use as stabilizers for sub grade but not for base and sub base. The capacity as a stabilizer does not meet the minimum requirement for use as base and sub base materials for road construction.***

Keywords: ***Eggshell powder, Atterberg limits, Hydrometer test, Free swell test, Unconfined compression test, Standard proctor test.***

I. INTRODUCTION

This document Every engineering structure, such as buildings, bridges, highways, canals and dams requires a suitable foundation for optimum performance without failure. Shrink-swell soils depending on the amount of moisture in the ground will experience changes in volume of up to thirty percent (30%) and the associated damages can be very extensive. That makes expansive clay soils a natural hazard that ranks with hurricanes, earthquakes and floods in regards to overall cost[8]. Soil Stabilization is the process by which the engineering properties of soil layers can be improved or treated by addition of other soil types, mineral materials or by mixing the appropriate chemical additive into the pulverized soil and then carry out compaction. Eggshell powder has not been widely and commonly used. The capacity as a stabilizer does not meet the minimum requirement for use as base and subbase materials for road construction. Lime is widely used in civil engineering applications such as road construction, embankments, foundation slabs and piles. When lime is added to clay soils in the presence of water, a number of reactions occur leading to the improvement of soil properties[7]. These reactions include cation exchange, flocculation, carbonation and pozzolanic reaction. Eggshell waste falls within the category of waste food. The use of stabilization agents like cement, lime and bitumen proves expensive and requires an economic replacement. It has been shown that eggshell primarily contains lime, calcium and protein. The quality of lime in eggshell waste is influenced greatly by the extent of exposure to sunlight, raw water and harsh weather conditions. Eg. This study is aimed at determining the geotechnical properties of eggshell stabilized kuttanad clay with a view to determining its suitability as stabilizing agent for kuttanad clay[6].

A. Materials

The materials used for the study are kuttanad clay from Thiruvalla in Allepey district, lime and eggshell.

B. Soil

The black cotton soil used for the study was collected from Thiruvalla in allepey district. Black cotton soils are inorganic clays of medium to high compressibility and form a major soil group in India. They are characterized by high shrinkage and swelling properties. The index properties of kuttanad clayey soil are summarized in Table 3.1.

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Table 1. B.1.Index properties of Kuttanad clay

Property	Value
Liquid limit,%	54
Plastic limit, %	16.66
Plasticity index	37.34
Free swell index (%)	150
Optimum moisture content, %	18
Unconfined compressive strength, KN/m^2	11.8

C. Lime

Lime is used for the stabilization of clayey soils. Lime stabilization is done by adding lime to a soil.

Lime used in this study was hydrated lime. In the present study soil was mixed with 3, 4, 5 and 6% of lime by dry weight of soil. Properties of lime are given in Table 3.2.

TableI. C.2. Properties of lime used

Property	Value
Calcium hydroxide $Ca(OH)_2$,%	90
Silica,%	1.5
Ferric oxide,%	0.5
Magnesium oxide (MgO),%	1
Alumina,%	0.2
Carbon dioxide,%	3

D. Eggshell

Eggshell, preferably the chicken eggshell perceived a waste material could be annexed for use as a replacement for soil stabilizer like lime since they share the same chemical composition. Eggshell waste falls within the category of waste food; they are materials from the preparation of foods and drinks, if subjected to adequate scrutiny could be suitable for soil stabilization.

II. METHODOLOGY

A. Atterberg's Limit Test

Atterberg limits such as liquid limit and plastic limit were determined as per IS2720 part V & VI. Liquid limit and Plastic limit of soil treated with different percentages of lime (3, 4, 5 & 6% by weight of soil) & eggshell (8, 9, 10, 11 & 12% by weight of soil) were determined. PI = LL - PLWhere PI is the Plasticity Index, LL is liquid limit and PL, plastic limit.

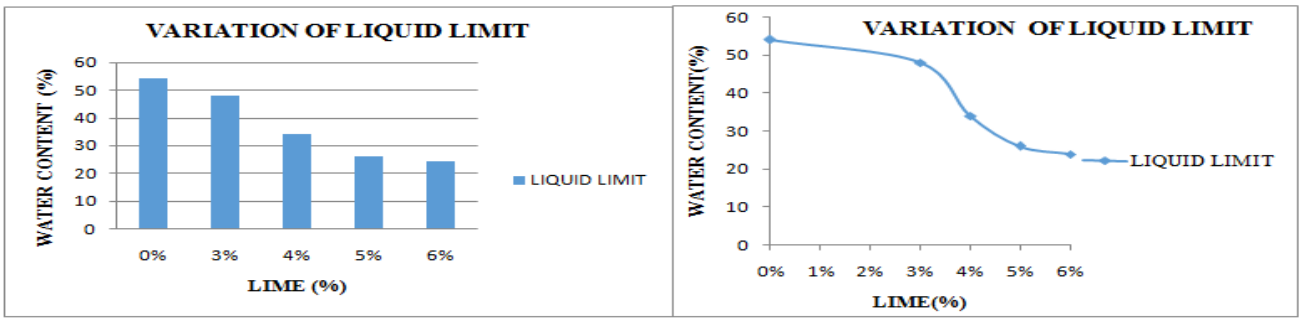

Fig 2.A.1.Variation of LL on different percentage of lime

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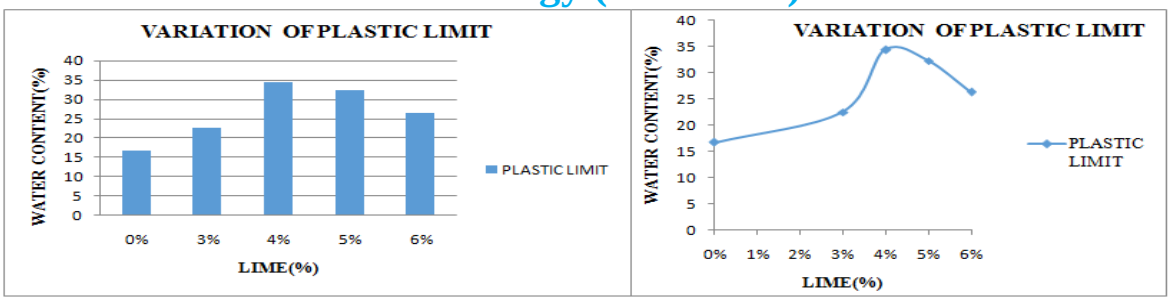

Figure 2.A.2.Variation of PL on different percentage of lime

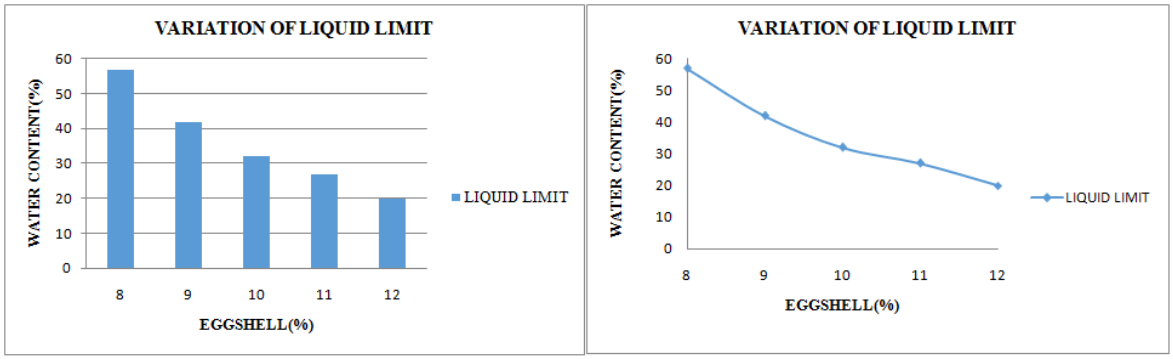

Fig. 2.A.3.Variation of LL on different percentage of eggshell

B. Hydrometer Analysis

The hydrometer analysis is based on Stokes' Law, which gives the relationship among the velocity of fall of spheres in a fluid, the diameter of the sphere, the specific weights of the sphere and of the fluid, and the fluid viscosity.

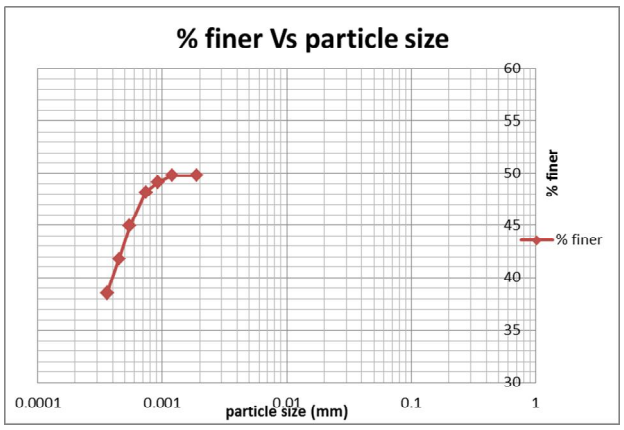

Fig.2.B.1.Variation of percentage finer vs particle size

From the graph it was noted that the curve comes under particle size less than 0.002 mm, hence the sample can be classified as clay.

C. Free Swell Test

The soil samples were passed through a 425µm IS Sieve and oven-dried. One specimen of soil, lime-soil and eggshell-soil mixtures of 10g each were prepared. Each soil specimen was poured into a graduated glass cylinder of 100ml capacity. Distilled water was poured in the cylinder up to 100ml mark. Entrapped air was removed by gently shaking or stirring with a glass rod. The suspension was allowed to attain the state of equilibrium (for not less than 24hours). The final reading in the cylinder was read out and the free swell index calculated as follows.

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Table2.C.1.Degree of expansion of fine graded soil (IS 1498-1970)

Free Swell Index(%)	Degree of Expansion	Degree of Severity
<50	Low	Non-critical
50-100	Medium	Marginal
100-200	High	Critical
>200	Very high	Severe

FSI = (final reading- initial reading)\ (initial reading) X 100%
Where, FSI is the Free Swell Index.

1) Observations:

Table 2. C.2. Free swell index for different materials

MATERIAL	FREE SWELL INDEX (%)
Clay	150
Lime	10
Eggshell	50

According to IS 1478-1970 clay used for testing comes under high degree of expansion so stabilization is needed

D. Unconfined Compression Test

Unconfined confined compression tests were carried out on cylindrical specimens of 38mm diameter and 76mm height. If the lime was used alone, the soil with the required water content was prepared first, and then the different percentage of lime(3, 4, 5, 6 and 7%) were added to the soil before the test samples were to be compacted. If Eggshell was used alone, the prescribed content of eggshell (8, 9, 10 and 11% by weight of soil) was first mixed into the air-dried soil in small increments, making sure all the eggshell were mixed thoroughly to achieve a fairly uniform mixture, and then the required water was added. A graph was plotted against compressive stress Vs strain.

1) Observations: UCC on Lime-Clay Mixture:

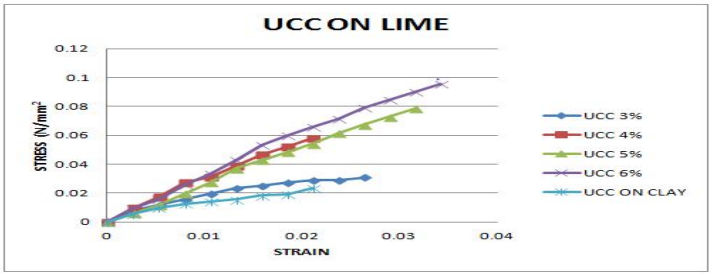

Fig2.D.1.Variation of UCC on different percentage of lime mixed with clay

2) UCC on Eggshell-Clay Mixture

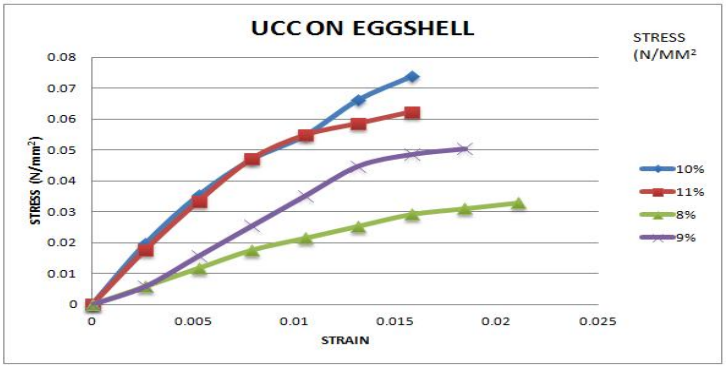

Fig 2.D.2. Variation of UCC on different percentage of eggshell mixed with clay

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From the above results the compressive strength of clay increases with increase in lime content up to 6%, and then the value decreases with further addition of lime and the compressive strength of clay mixed with eggshell were comparatively lower than the compressive strength of clay mixed with lime

E. Standard Proctor Test

1) Observations: Standard Proctor on Lime-Clay Mixture

Table 2. E.1. Maximum dry density and optimum moisture content for different percentages of lime mixed with clay

% LIME	OMC%	DRY DENSITY(g/cc)
0	18	1.47
3	16	1.64
4	14	1.70
5	12	1.68
6	13	1.67

2) Standard Proctor On Eggshell-Clay Mixture:

Table 2.E.2. Maximum dry density and optimum moisture content for different percentages of eggshell mixed with clay

%EGGSHELL	%OMC	DRY DENSITY(g/cc)
8	18	1.62
10	16	1.68
12	13	1.72

From the above tables it was noted that maximum dry density was obtained at 4% of lime mixed with clay that is 1.70g/cc and when 12% of eggshell was added maximum dry density obtained was 1.72g/cc.

F. California Bearing Ratio Test

The CBR value is an estimate of the quality of the material as compared to that of an excellent base material, for which the CBR is assumed to equal 100 percent. Thus, CBR states the quality of the material in terms of that of an excellent base course, which has a CBR of 100

CBR= (TEST LOAD/STANDARD LOAD) X 100

Table 2. F.1. Standard Load for different penetration values

Penetration of plunger (mm)	Standard load (N)
2.5	13700
5.0	20550
7.5	26300
10.0	31800
12.5	36000

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1) Observations: CBR on Lime-Clay Mixtue:

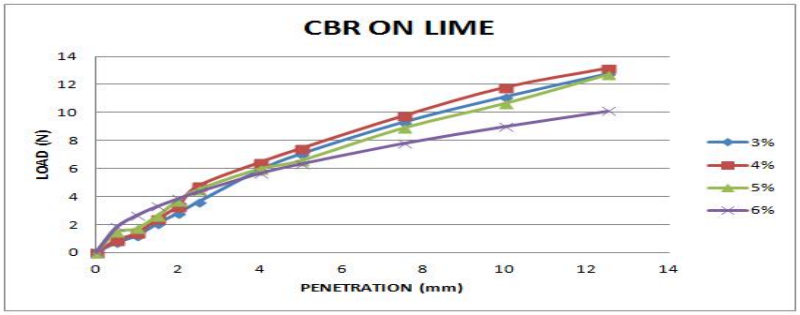

Fig.2.F.1 Variation of CBR on different percentage of lime mixed with clay

2) CBR on Eggshell-Clay Mixture:

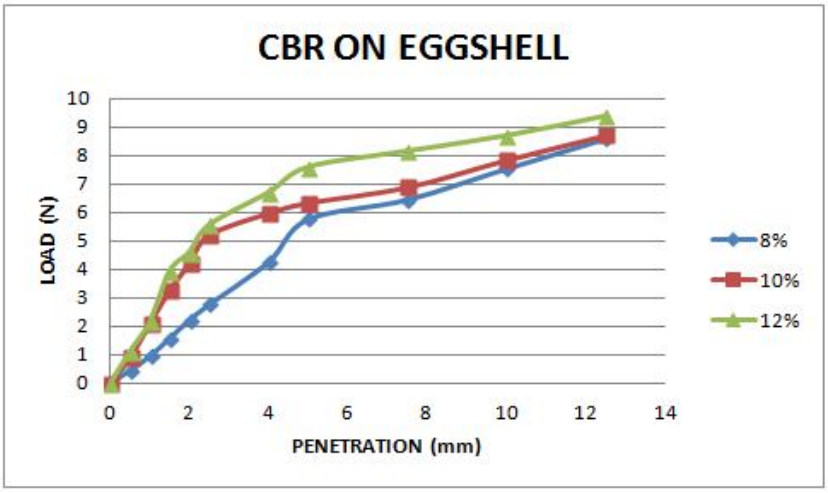

Fig.2.F.2Variation of CBR on different percentage of eggshell mixed with clay

From the above observations it was noted that 12% of eggshell can be effectively replaced 4% of lime as it gives approximately same CBR value.

III. RESULTS AND DISCUSSIONS

Table3.1 Observations when lime is added

% LIME	OMC %	DRY DENSITY(g/cc)	CBR %	SHEAR STRENGTH(kpa)
0%	18	1.47	11.4	11.79
3%	16	1.64	34.3	15.38
4%	14	1.70	36.7	29
5%	12	1.68	33	41
6%	13	1.67	31.78	41

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Table 3.2 Observations when eggshell is added

% LIME	OMC %	DRY DENSITY(g/cc)	CBR %	SHEAR STRENGTH(kpa)
8%	18	1.629	28	16.4
10%	16	1.68	33	36.9
12%	14	1.72	37	31.10

Tables shows our final project observations. Optimum shear strength, CBR value and dry density were obtained when clay was mixed with 4% of lime and with 12% of eggshell.

IV. CONCLUSION

A. Eggshell can be effectively replaced in place of 4% of lime by adding 12% of eggshell.
B. Compressive strength of clay increases with increase in lime content up to 6%, and then the value decreases with further addition of lime.
C. Compressive strength of clay mixed with eggshell was comparatively lower than the compressive strength of clay mixed with lime.
D. Plastic limit was obtained as zero for eggshell mixed clay because of its low binding property.
E. Plasticity index decreases with addition of lime as well as with addition of eggshell.The swelling nature of clay was significantly altered with addition of eggshell.

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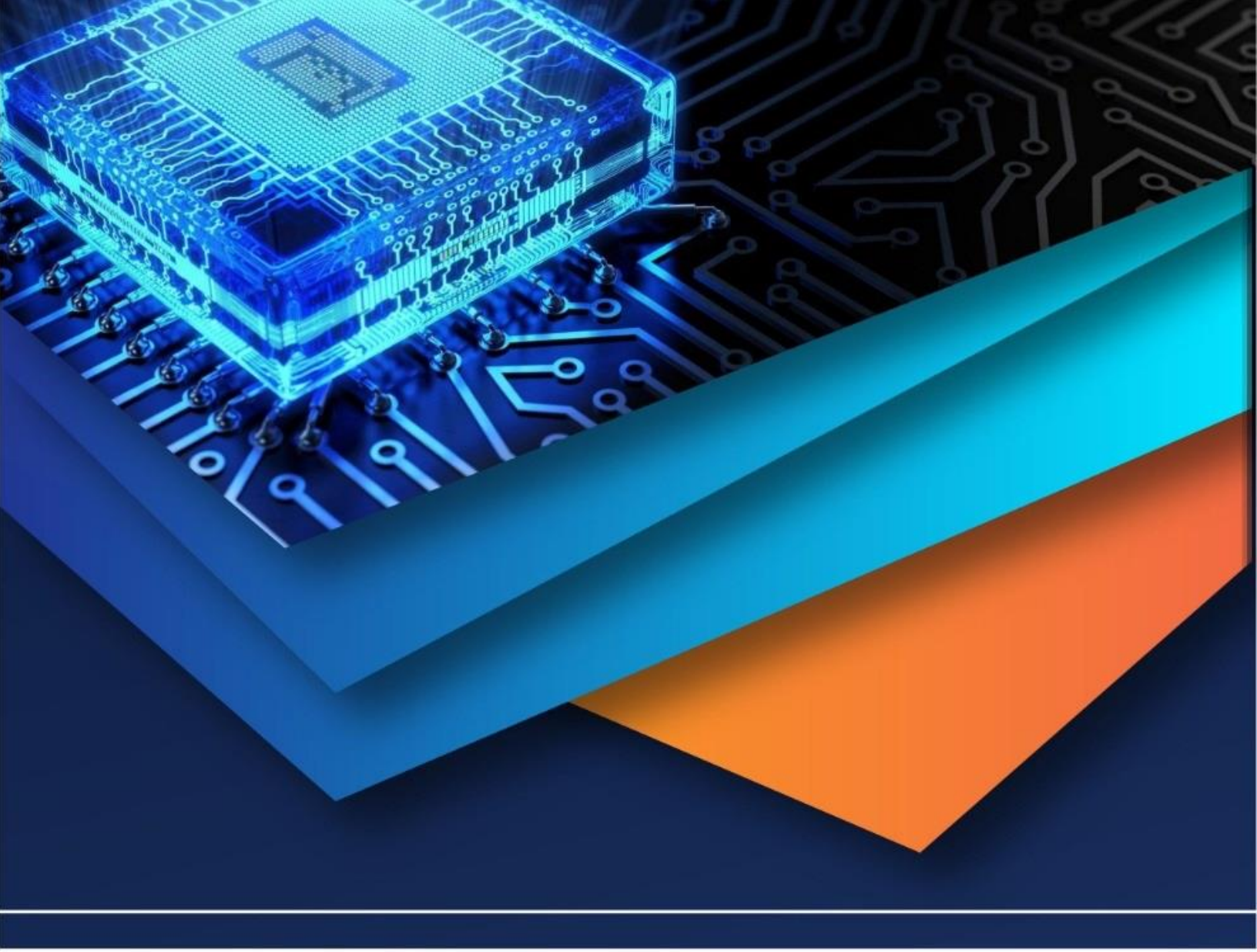

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