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Stabilization of Expansive Kuttanad clay using Lime treated Rice straw fibres

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Abstract: ***Reinforced earth technique is considered as an effective ground improvement method because of its cost effectiveness, easy adaptability and reproducibility. In All eppey district in Kerala, Rice Straw reinforced bunds are built between paddy fields. These bunds are used for transport of both men and vehicles. In this context, a detailed study is undertaken to study the effect of Rice Straw as a reinforcement material in Kuttanad clay used as a pavement material. The study is intended to investigate the strength behaviour of the soil reinforced with randomly included Rice Straw fibres. The samples were reinforced with untreated Rice Straw. The untreated Rice Straw was added to soil in addition with Lime also. The reinforced soil samples were then subjected to Unconfined Compressive Strength, Light Compaction and California Bearing Ratio tests to study the effect of fibre reinforcement on Kuttanad clay.***

Keywords: Kuttanad clay, CBR, Rice Straw, Unconfined Compressive strength, Lime.

I. INTRODUCTION

This Kuttanad clayey soil is one of the expansive soils where any type of construction is very difficult as the soil is poor in drainage and weak in shear strength. Therefore it requires an efficient stabilization method to improve its load bearing capacity. Kuttanad clays are dark brown coloured, medium sensitive, alluvial deposit, spread over the Kuttanad region in the state of Kerala in India. The soil in this region is black or grey marine clay which has got high organic content. The dominant mineral constituents in this clay are kaolinite and illite, which have low shrink-swell capacity. These clays are characterised by high compressibility, low shear strength and high percentage of organic matter, which are unfavourable from the geotechnical point of view. The increase in population and the development of the area has demanded construction activities to be undertaken in Kuttanad region. But, a large number of pavement failures, embankment failures and foundation failures have been reported in this soil due to its poor shear characteristics.

In this project, a detailed study is undertaken to study the effect of Rice Straw as a reinforcement material in Lime treated Kuttanad clay used as a pavement material. The Kuttanad clayey soil to be reinforced is first stabilized by the addition of Calcium oxide or Calcium hydroxide. The properties of soil – lime mixture depends on the character of the clayey soil, type and period of curing, method and quality of construction etc. The proper amount of lime should be investigated before the application of lime stabilization. It provides structural improvement to many soil and aggregates. It provides finely divided clay to mass together with coarser particles, which improves the load bearing properties and subsequently the Lime treated soil hardens by chemical reaction. Lime treatment of soil is a proven method to save money and time on construction projects. Lime modification chemically transforms clay soils into friable, workable, compactable material. Lime stabilization creates long - term chemical changes in unstable clay soils to create strong, but flexible, permanent structural layers in pavement systems and other foundations.

The samples were then reinforced with untreated Rice Straw fibres. The untreated Rice Straw is added to the soil in addition with lime. The brittleness imparted by the lime in the stabilization of clayey soils can be countered by the fibre reinforcement, suggesting the usefulness of the technique for rural road development in low lying areas with clayey subgrades. Rice Straw fibres used in the project is collected from Kuttanad region, in Alleppey district. The Rice Straw is air dried to remove the moisture from it. The Rice Straw fibres are of 2.5 mm diameter and are taken in random length. Even for a small replacement of Rice Straw fibre we get a high percentage increase in the properties. Rice Straw fibre alone cannot achieve this. This result is due to the combined effect of lime and Rice Straw fibre. Lime improves the strength characteristics and change the chemical composition of clay. It improves workability and reduces swelling potential of highly plastic clay. The reinforced soil samples were then subjected to various soil tests like Compaction test, California Bearing Ratio test and Unconfined Compressive Strength test to study the effect of fibre reinforcement on Kuttanad clay.

The paper is organized as follows. Section II contains the literature surveys conducted about the project and some related research works. Section III is experimental study. It includes introduction, materials used, preparation of samples, procedures for the soil

tests. Section IV contains results of the soil properties and related graphs and tables of the materials such as Kuttanad Clay, Lime and Rice Straw Fibres. The effect of various percentages of Lime (2%, 4%, 6% and 8%) and Rice Straw Fibres (0.25%, 0.5%, 0.75% and 1%) on the Lime stabilized Kuttanad Clay are also studied. Section V gives a clear picture about the suitability of stabilizing pavements in Kuttanad region using Lime and Rice Straw.

II. RELATED WORK

J. Bindu, Asst. Professor, College of Engineering Trivandrum, conducted studies on the "Stabilization of Kuttanad clay using cement [9]" and found that cement content of 10 % to 30 % was effective in improving the shear strength of the soil. It was also seen that increase in cement content and curing period resulted in strength gain of the soil which was mainly due to the formation of cementitious products in soil.

H.N. Ramesh (Prof and Chairman, Dept. of Civil Engineering, UVCE, Bangalore), conducted studies on the "Strength Performance of Lime and Sodium Hydroxide Treated – Coir Fibre Reinforced Soil [4]". He found that, the addition of 0.5 % of randomly distributed coir fibres to Black cotton soil reduces the Maximum Dry Density and increases the optimum moisture content.

In the investigation done by S A Naeini and S M Sadjadi,(2008) ,the waste polymer materials has been chosen as the reinforcement material and it was randomly included in to the clayey soils with different plasticity indexes at five different percentages of fibre content (0%, 1%,2%, 3%, 4%) by weight of raw soil [8]. CBR values obtained for this type of soil is around 38% high than the unreinforced soil.

In the experiment, "Soil Stabilization with Fly Ash and Rice Husk Ash [5]", done by Dr. Robert M Brooks, associate professor, civil engineering, Temple University, Philadelphia, stress-strain behaviour of unconfined compressive strength showed that failure stress and strains increased by 106 % and 50 % respectively when fly ash content was increased from 0 to 25 %.

The study "Effect of polypropylene fibre and lime admixture on engineering properties of clayey soil [6]" by Yi Ca and others, Department of Earth Sciences, Nanjing University, China was conducted to investigate and understand the influence of the mixture of polypropylene fibre and lime on the engineering properties of a clayey soil and found that fibre content, lime content and curing duration had significant influence on the engineering properties of the fibre - lime treated soil.

In another research work "Potentials of Rice Husk Ash for Soil Stabilization [7]" by Musa Alhassan Department of Civil Engineering, Federal University of Technology Minna, Niger State, Nigeria, he found that Treatment with RHA showed a general decrease in the MDD and increase in OMC with increase in the RHA content.

The experimental studies were conducted by J. Prabhakar and R.S Sridhar (2002), in Regional Research laboratory (CSIR), Bhopal, India on soil collected from Bhopal, India with sisal fibres as reinforcement [3]. The sisal fibres were added in length of 1 cm, 1.5 cm, 2 cm and 2.5 cm and they were added at different percentages of 0.25, 0.5, 0.75, 1. The shear strength and cohesion were found to increase with the addition of sisal fibre and optimum was reported as 0.75 % of 2 cm length fibre.

III.EXPERIMENTAL STUDY

A. Introduction

Geotechnical properties of the materials used in this project were determined as per Indian standards. The soil tests conducted are Specific gravity, Liquid limit, Plastic Limit, Shrinkage Limit, Hydrometer analysis, Unconfined Compression test, Consolidation test, California Bearing Ratio Test and Compaction test. These tests were conducted on Pure Kuttanad Clay, Pure Lime, and Rice Straw Fibres and on Kuttanad clay with different percentages of Lime and Rice Straw Fibres. Optimum percentages of each material required for soil stabilization were determined.

Unconfined Compression test was required to obtain the optimum percentages of lime and Rice Straw fibre to stabilize the soil. Light compaction test was used to determine the maximum dry density and optimum moisture content of stabilized samples. California Bearing Ratio test had been conducted on stabilized clayey soil with lime and Rice Straw fibres. Specified dosage of lime and Rice Straw fibres were mixed well with the clayey soil for uniformity and homogeneity, before moulding the samples.

B. Materials

The soil used for the study is clay collected from Kuttanad in Alleppey district, Fig 1 (a). The soil was partially air dried before the commencement of the experiments. Quick lime is used in this project, which is known as Calcium oxide (CaO) and it is white in colour Fig 1 (c). The Rice Straw used for the study is collected from Kuttanad region in Alleppey district Fig 1 (b). The Rice Straw was air dried to remove moisture from it.

(a) Kuttanad Clay (b) Rice Straw (c)Lime

Fig. 1 Materials used

C. Preparation of sample

In order to find the effect of lime and Rice Straw fibres on Kuttanad clay, UCC tests, Light compaction tests and California Bearing Ratio (CBR) tests were conducted. The Kuttanad clay was air dried and ground to required fineness. It was then mixed with different percentages of lime (2 %, 4 %, 6 % and 8 %) as in Fig 2 (a).

UCC tests were conducted on these samples after 2 hours. The optimum percentage of the lime corresponding to the maximum unconfined compressive strength was found out. The effect of lime on dry density and moisture content was also found out. CBR test was conducted on the clay with optimum percentage of lime content and corresponding moisture content. The lime stabilized Kuttanad clay was reinforced with different percentages (0.25%, 0.5%, 0.75%, and 1%) of Rice Straw fibres as in Fig 2 (b) and the optimum percentage of fibre corresponding to maximum unconfined compressive strength was determined. The effect of fibre on dry density and moisture content was also found out. CBR test was conducted on the clay with optimum percentage of lime content and different percentages of Rice Straw fibres.

(a) Kuttanad Clay mixed with Lime (b) Kuttanad Clay mixed with Lime and Rice Straw

Fig 2. Preparation of sample

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IV. EXPERIMENTAL RESULTS

Table 1 shows the basic properties of Kuttanad clay used in the study.

Table 1: Properties Of Kuttanad Clay

PROPERTIES OF KUTTANAD CLAY	VALUES
Specific gravity	2.75
Liquid limit (%)	95.8
Flow index	11.4
Plastic limit (%)	35.38
Plasticity Index (%)	60.42
Shrinkage limit (%)	22
Soil classification	MH
Percentage finer of sand (%)	1.6
Percentage finer of silt and clay (%)	93.4
Uniformity coefficient	6.3372
Coefficient of curvature	0.39
Unconfined compressive strength (kg/cm^2)	0.1116
Shear strength (kg/cm^2)	0.0557
Coefficient of consolidation , C_v (cm^2/min)	0.362
Optimum moisture content (%)	29
Maximum dry density (kg/m^3)	1246
CBR value of soil (%)	1.295

The lime used for the study was locally available and the properties of which are given in the Table 2 below. The properties of rice straw fibres used are shown in Table 3.

Table 2: Properties Of Lime

COMPONENTS	AMOUNT (%)
Calcium hydroxide $Ca(OH)_2$	90
Silica	1.5
Ferric oxide	0.5
Magnesium oxide (MgO)	1
Alumina	0.2
Carbon dioxide	3.0

Table 3: Properties Of Rice Straw Fibres

PROPERTIES	VALUES
Average diameter (mm)	2.5
Average Tensile strength (N/mm^2)	12
Fibre density (g/cc)	0.38

A. Effect of lime in UCC And Shear Strength

The Unconfined Compression tests on clay samples with different percentages of lime were conducted and the results obtained are plotted as shown in figure 3.

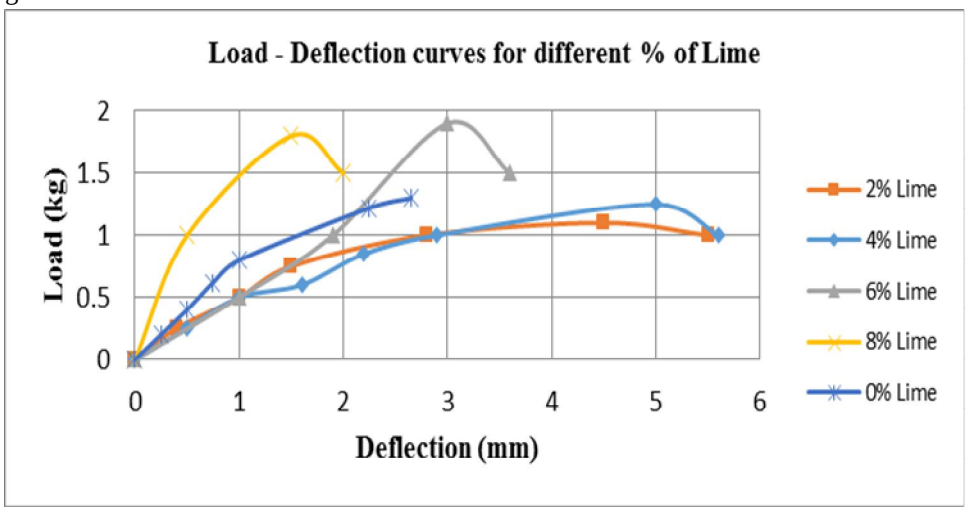

Fig 3 Load – deflection curves for different percentages of lime

From the above figure the maximum UCC strength is obtained for 6% lime and the value of UCC strength is 0.1336 kg/cm².

B. Effect of lime on OMC And Maximum Dry Density

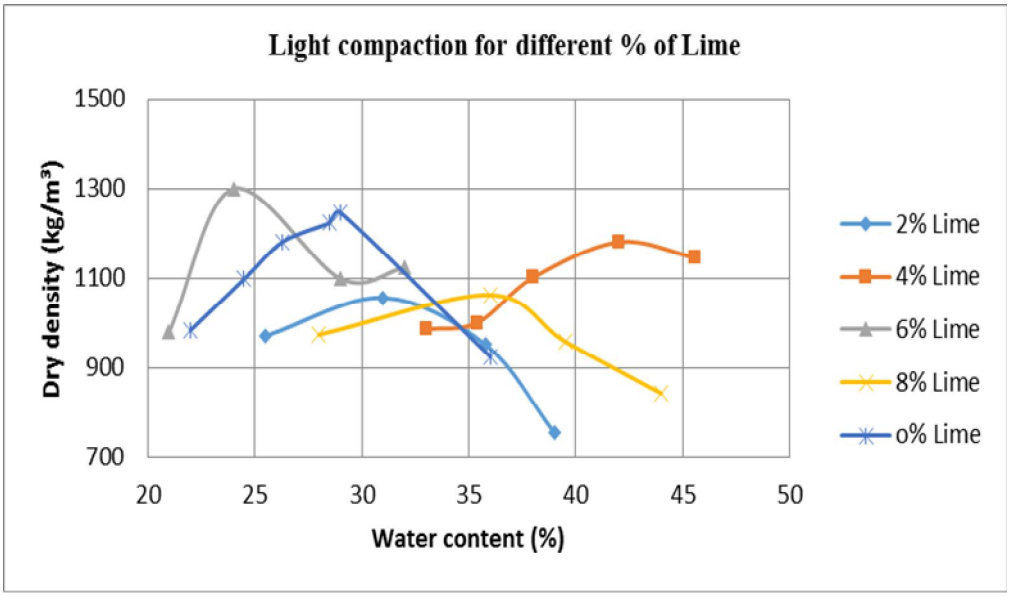

Fig 4 Light compaction for different % of lime

From the Fig 4, the optimum moisture content (OMC) and maximum dry density obtained for optimum lime content of 6% are 24% and 1299 kg/m³ respectively.

C. Effect of rice Straw Fibres in Ucc Strength Of Lime Stabilized Kuttanad Clay

Different percentages of Rice Straw fibres (0.25%, 0.5%, 0.75%, and 1%) are added to the 6% lime stabilized soil and the unconfined compression tests were conducted, as shown in Fig 5.

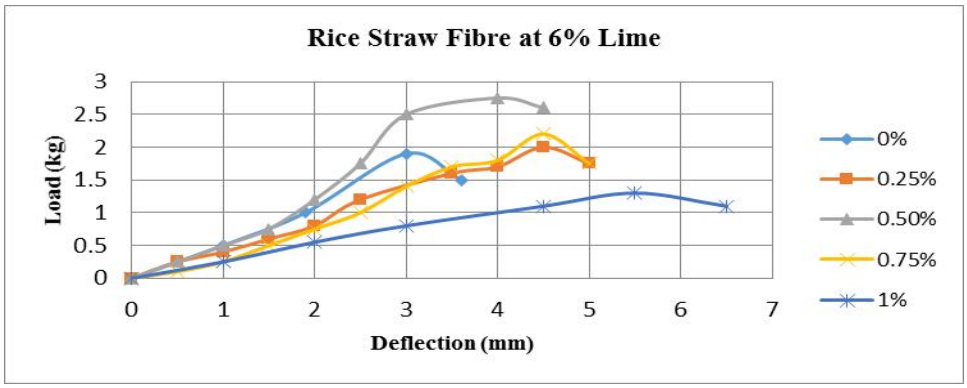

Fig 5. UCC strength of different % of Rice Straw Fibre at 6% Lime

From the above graphs, a maximum UCC strength of 0.2626 kg/cm² is obtained for 6% lime and 0.5% Rice Straw fiber.

D. Effect of rice straw fibres in OMC and maximum dry density of lime stabilized Kuttanad clay

The optimum moisture content and maximum dry density of different percentages of Rice Straw fibre (0.25%,0.5%, 0.75%,& 1%) added to 6% of lime were found out by conducting light compaction.

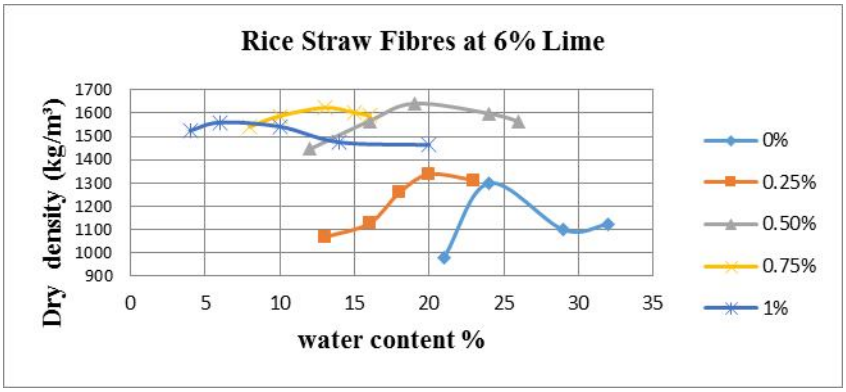

Fig 6. Light compaction for 6 % of lime with different % of Rice Straw Fibres

From the graphs, the maximum dry density of 1641.63 kg/m³and Optimum moisture content of 19% were obtained is for 6% lime and 0.5% Rice Straw.

E. Effect of rice straw fibres in the CBR value of Clay Stabilized With Optimum lime Content

The strength of fibre reinforced- lime stabilized Kuttanad clay to be used as subgrade soil is assessed using California bearing Ratio test that gives the CBR value, which is integral to the process of road design.

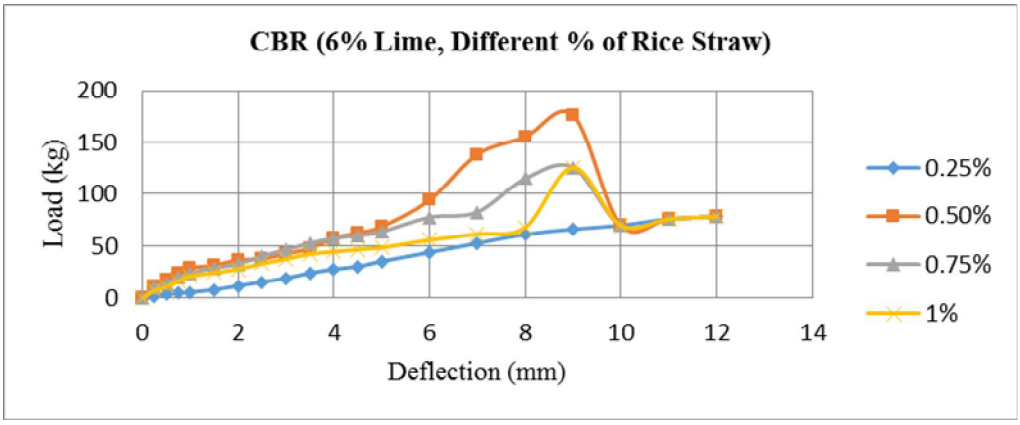

Fig 7 Load – Penetration curve for different % Rice Straw at 6% lime

From the Fig 7, it is clear that the maximum CBR value of 5.095 is obtained for 0.5% Rice Straw at optimum lime content of 6%. The CBR value between 5 and 10 has moderate subgrade strength. The stronger the subgrade (the higher the CBR reading) the less thick it is necessary to design and construct the road pavement, this gives a considerable cost saving.

V. CONCLUSION

The Engineering properties of the Kuttanad clay to be used as a pavement material have improved due to the addition of Rice Straw fibre along with small quantities of lime. The maximum CBR value of 5.095 is obtained for 0.5% Rice Straw at optimum lime content of 6% giving moderate subgrade strength, which can be effectively made use in the unpaved road construction in Kuttanad region. The optimum percentages of lime and rice straw for unconfined compression test are obtained as 6% and 0.5% respectively. The percentage increase in strength obtained for unconfined compressive strength test is found to be 19.7%. Even for a small replacement of Rice Straw fibre we get a high percentage increase in the properties due to the combined effect of lime and Rice Straw fibre. Lime has improved the strength characteristics and changed chemical composition of clay. It also reduced swelling potential of highly plastic clay. The result obtained for Kuttanad clay are satisfactory and the treated soil shows higher increase in strength and gives better results for pavement material.

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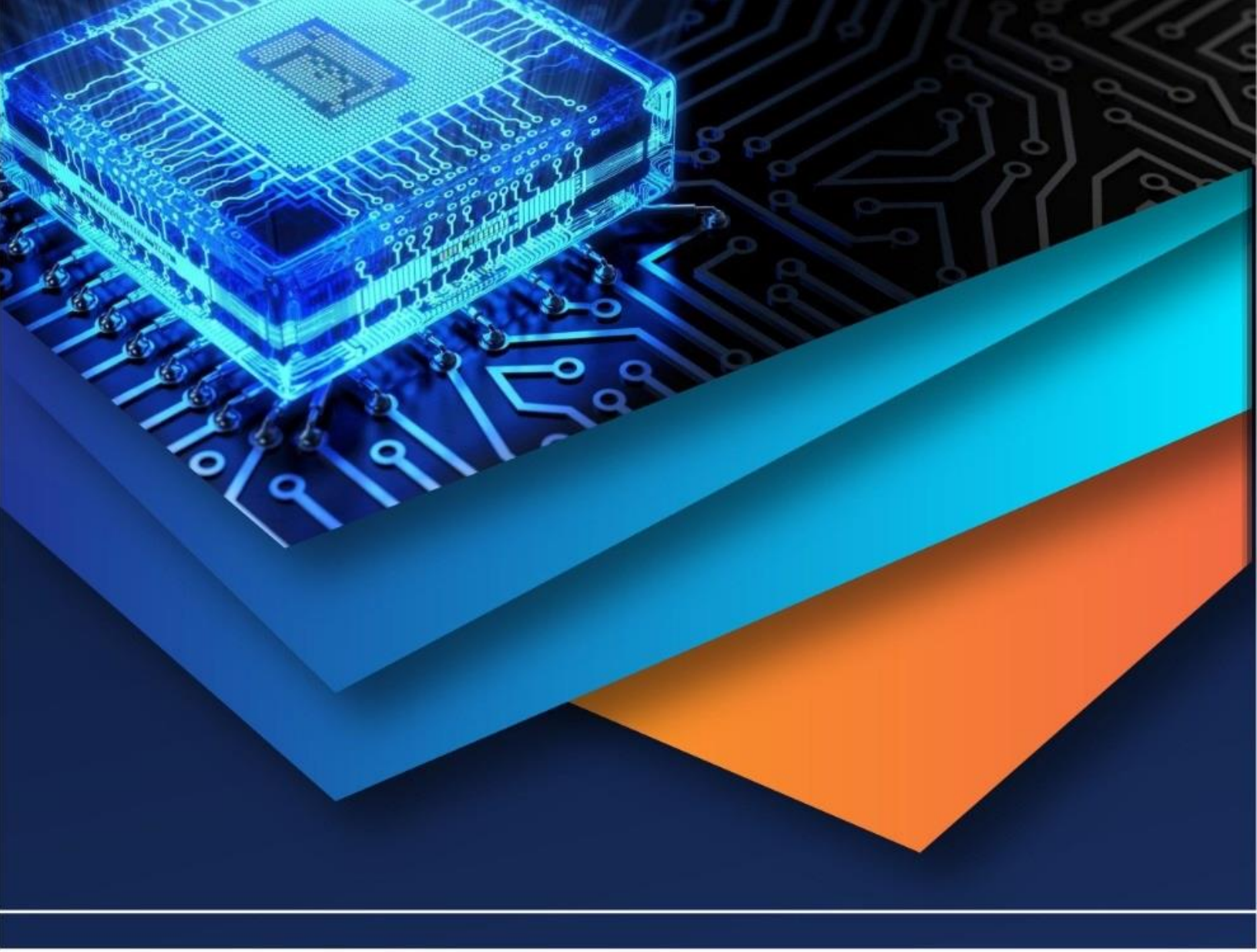

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