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Effect on the Engineering Properties of Black Cotton Soil using Coconut Coir Fiber

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Abstract: ***This research paper represents "Effect on the Engineering Properties of Black Cotton Soil (BCS) by using Coconut Coir Fiber (CCF)". The aim of this paper is to represent the behavior of the black cotton soil when it mixed with the natural fiber (coconut coir fiber). Black cotton soil is largely available in central and western parts of India. It also available in some parts of south India. There are lots of problem associated with black cotton soil i.e. low stability, low bearing capacity, high swelling and shrinkage characteristics of black cotton soil and very low shear strength. Swelling of the black cotton cause due to the excessive amount of water present in the soil which results in increase the volume of the black cotton soil by approximate 2 to 3 times (or up to 200%) of the initial volume of the soil due to this reason black cotton soil have the low bearing capacity. In this research work minimize such kind of problem of black cotton soil by using natural waste material like coconut coir fiber which reduce the swelling, enhance the stability of soil and increase shear strength of black cotton soil. Coconut coir is natural waste material which is biodegradable and also available in south part and coastal regions of India. This research represents the laboratory test results (Unconfined Compressive Strength, California Bearing Ratio (CBR), swell pressure) on black cotton soil mixing with coconut coir fiber in varying percentage (i.e. coconut coir fiber mixed with black cotton soil in the proportion of 0.50%, 1.0%, and 1.50%) and the length of the coir fiber in this study used as 30mm . The Various properties of unmixed black cotton soil and mixed black cotton soil with coconut coir fiber such as maximum dry density, optimum moisture content, and California Bearing Ratio (CBR) are analysed and the results are compared to each other. It has enough strong, resistant to stretching and shrinkage. It has well resistant to abrasion. It also has suitable mechanical properties and good hydraulic properties. It represent as increase in percentage of coconut coir fiber improves the engineering property of black cotton soil.***

Keywords: Black Cotton Soil (BCS), Natural Fiber, Natural Waste Material, Coconut Coir Fiber (CCF), Unconfined Compressive Strength (UCS), California Bearing Ration (CBR).

I. INTRODUCTION

Any structure of the civil engineering (foundation, highways, and railways) which are constructed on land which should have enough bearing capacity to support the whole structure safely because of the all loads i.e. dead loads, live loads etc. are transferred to the foundation of the structure which are laid on the soil base which should be enough strong to carrying all these loads without any failure. So, for overcome from these situation soil is treated which is called soil stabilization. It is not always possible that the required type of soil is available in many cases. Sometimes bearing strength of the soil at desired depth cannot be achieved in that situation we required to treated the soil with suitable material that would be environment friendly, easily available and also cheap in price.

Soil Stabilization is the method of treatment of soil to avoid such kind of problems occurs during construction or later and provide sufficient strength to the foundation of the structure. In the stabilization technics soil is treated with suitable material to enhance the property of the soil. Water absorption capacity of the black cotton soil make it high swelling and high shrinkage characteristics soil which results in failure of the structure or sub-grade in road construction. This occurs because of the montmorillonite clay mineral present in the black cotton soil. The particle of the soil entrapped water in voids and absorbing the water which result in increase in volume of the soil. That's by it is called black cotton soil because it behave like cotton that absorb water and increase its volume 2 to 3 times of the initial volume of the black cotton soil. Black cotton soil occupied land approximately 20% of the whole land area of India. It creates problem in the construction of road or foundation of the structure due to its expansion of the volume of soil when excessive amount of water present in the soil. There are many advantages of stabilization. Stabilization of soil is used to improve the bearing and compressive strength of soil. Soil can be stabilized with many types of material like chemical additives, cement material, natural fiber, artificial fiber, glass fiber, lime etc. There are various types of natural fiber but coconut coir fiber used in this study because it has good strength and durability, also nature friendly which is not cause pollution. Coconut coir fiber is a natural fiber material which is extracted from the outer husk of the coconut. Coconut coir fiber is enough strong, flexible and have good strength. And it is also locally and easily available.

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II. MATERIAL DESCRIPTION

1) *Black Cotton Soil (BCS):* The black cotton soil has the high shrinkage and swelling characteristics due to high water holding capacity of the soil. This soil is generally available in the central and western parts of India. It also found in some part of south India. It covers almost 20% of the entire area of India. Prepared soil sample are shown in figure 1.

Fig. 1 Soil Sample of BCS

2) *Coconut Coir Fiber (CCF):* Elastic property of coconut coir fiber is enough to twist it without failure. Coconut coir fiber is a biodegradable material which would be easily disposed off without harming the environment and it is also nature friendly material. So, it can be used as a stabilization material for the treatment of the black cotton soil. The coconut coir fiber is easily available and it is also cheap in price because it is a waste material which can be used to stabilization of the soil. Length of fiber used in this research is taken as 30mm and having dia. 0.1mm to 0.5mm. Sample of the coconut coir fiber shown in Figure 2.

Fig.2 Coconut Coir Fiber

3) *Physical Properties of Coconut coir Fibre*

Length in Inches	6 to 8
Density (gm/cc)	1.40
Tenacity (gm/tex)	10.0
Breaking Elongation	30%
Diameter in mm	0.1 to 0.5
Modulus of Rigidity	1.8924 dyne/cm
Swelling in Water	5%

Table 1 (source Ravi Shankar 2012)[1]

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4) Chemical Properties of Coconut coir Fiber

Lignin	45.84%
Cellulose	43.44%
Hemi –Cellulose	0.25%
Pectin's and related Compound	3.0%
Water soluble	5.25%
Ash	2.22%

Table 2 (source Ravi Shankar 2012)[1]

Data given in table 1 and table 2 is obtained from source[1].

III. METHODOLOGY

In this research soil sample of black cotton soil is driven from Simritaal – Dabra, Gwalior (M.P.), and bring to the soil testing laboratory of MITS-GWALIOR (M.P.). The soil sample which is used in this study classified as clayey soil and it has high plasticity behaviour (Specific Gravity G_s=2.48 with 78.8% fineness). In the black cotton soil, dominant clay mineral is montmorillonite due to this mineral soil having the high shrinkage and swelling characteristics. The tests performed in the laboratory on virgin black cotton soil are as –Pycnometer test, Atterberg Limit, Free Swell Index (FSI), Sieve Analysis. And the Compaction Test, California Bearing Ratio (CBR), and Unconfined Compressive Strength (UCS) are carried out on the virgin soil sample and treated soil sample with coconut coir fiber. And represents the effect on the various engineering properties of black cotton soil with varying percentage of coconut coir fiber (CCF). Coconut coir fiber (CCF) reinforced in to the soil in the manner of 0.5%, 1.0%, and 1.5% respectively. And all tests are performed at the different percentage of CCF added to the soil sample. Results are studied and compared with varying percentage of CCF mixed with soil sample.

IV. RESULT AND DISCUSSION

A set of experiments (Specific Gravity, Liquid Limit, Plastic Limit, Plasticity Index, Free Swell Index) on the virgin soil sample were conducted in the laboratory as per IS code. And the results and IS code recommendation are shown in the Table 3.

Tests	Results		IS code recommendation
Specific Gravity	2.48		2720-Part 3
Atterberg Limit Liquid Limit w_l Plastic Limit w_p Plasticity Index I_p	 52% 28% 24%		2720-Part 5
Free Swell Index	47.05%		2720-Part 40
Natural Water Content	9%		2720-Part 2
Compaction Test Maximum Dry Density Optimum Moisture Content	 1.64 gm/cm^3 16%		2720-Part 7
Grain Size Distribution	Gravel	0%	2720-Part 4
	Sand	21.2%	
	Silt and Clay	78.8%	

Table 3 Engineering Properties of the Black Cotton Soil without CCF

In the laboratory, the liquid limit and plastic limit found as 52% and 28% respectively. From the result soil sample has been classified as highly compressible clay with 78.8% fineness. Soil sample have natural water content as 9% and free swell index is to be found as 47.05%. Specific gravity of the soil sample is to be found as 2.48.Grain size distribution is calculated by using wet sieve analysis test as per IS code.

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1) *Standard Proctor's Test on the soil with varying percentage of CCF:* - The compaction test of the black cotton soil is carried out by using proctor's test (as per IS-2720-part 7-1980) to understand the compaction characteristics of the virgin soil and compared with after stabilization of the soil. The results are shown in Table 4 and Figure 3.

Tests	BCS + 0%CCF	BCS + 0.50%CCF	BCS + 1.0%CCF	BCS +1.50%CCF
Optimum Moisture Content (OMC)	16	17	19	20
Maximum Dry Density (MDD)	1.64	1.63	1.62	1.60

Table 4 OMC and MDD of the BCS with Varying Percentage of CCF

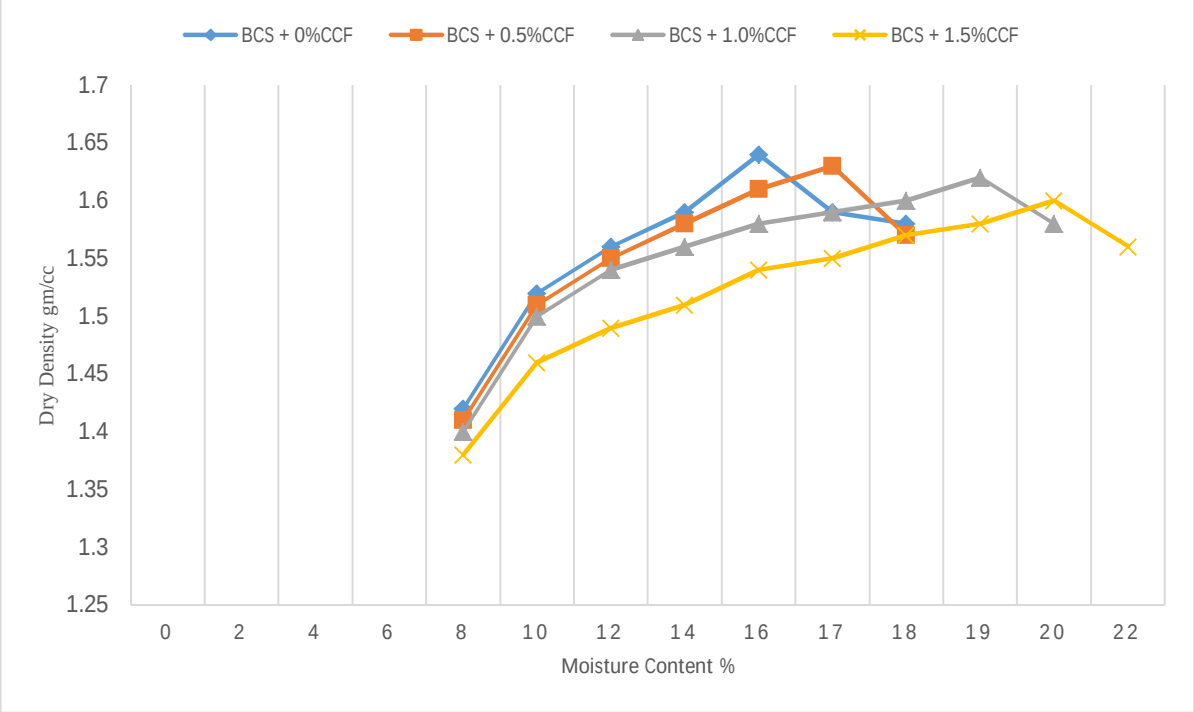

Fig. 3 OMC and MDD of the BCS with varying percentage of CCF

From the result, in the compaction test coconut coir fiber (CCF) increasing the value of OMC from 16% to 20% and decreasing the value of MDD from 1.62 gm/cm^3 to 1.60 gm/cm^3 with 0% to 1.5% of CFF respectively. According to Hejazi[2], Water absorption of the soil increases with increase in percentage of coconut coir fiber, which causes the water trapped between the soil particles. Decreasing in value of MDD due to the presence of coconut coir fiber which interferes the bonding between the soil particles. Presence of CCF in soil doesn't allow the rearranging of soil particles and weak the bond between soil particles.

2) *Unconfined Compressive Strength of soil with varying percentage of CCF:* - The unconfined compressive strength test is conducted in the laboratory as per IS: 2720-Part 10 (1991). UCS is the maximum compressive strength of the soil that can be bear by soil under zero confining zone. It is also defined as UCS is the load per unit area at which the soil sample fails in compression. The UCS test were performed on the virgin soil and on treated soil. And the result are shown by graph in figure 4.

Test	BCS + 0%CCF	BCS + 0.5%CCF	BCS + 1%CCF	BCS + 1.5%CCF
Unconfined compressive strength (UCS) in KN/m^3	130	138	147	**162**

Table 5 UCS of BCS with varying percentage of CCF

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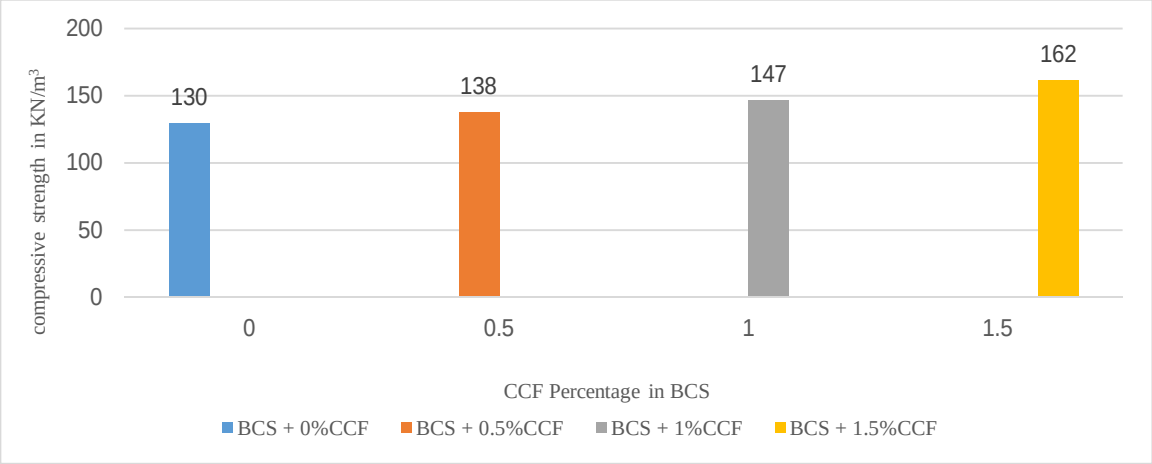

Fig. 4 Unconfined Compressive Strength of BCS with varying percentage of CCF

From the results it is seen that coconut coir fiber (CCF) increasing the value of compressive strength with increasing the percentage CCF in soil sample. It gives the highest value of compressive strength at 1.5% of CCF added to soil sample. The compressive strength of untreated soil sample found as 130 KN/m^3 which increased up to 182 KN/m^3 with 1.5% of CCF mixed in BCS. It found that compressive strength of soil sample is increased as 40% of the untreated soil sample of BCS.

3) *California Bearing Ratio (CBR) of soil with varying percentage of CCF:* - The CBR test is performed in the laboratory as IS 2720-16 (1987). This method is developed by the California state highway department of USA for the evaluation of subgrade strength of roads and pavement. The empirical curves are obtained by result of this test are used to determine the thickness of pavement and its component layers. This is the mostly used method for the design of flexible pavement. CBR values are calculated for penetration of 2.5 mm and 5 mm for soaked CBR results are produced after 4 day of soaking. Graphical and tabulation representation of results are given in figure 5 and table 6. Respectively.

Test	BCS + 0%CCF	BCS + 0.5%CCF	BCS + 1%CCF	BCS + 1.5%CCF
2.5mm	2.27	2.63	2.94	**3.20**
5mm	2.12	2.58	2.78	3.05
CBR Value %	2.27	2.63	2.94	**3.20**

Table 6 Variation in CBR of BCS with varying Percentage of CFF

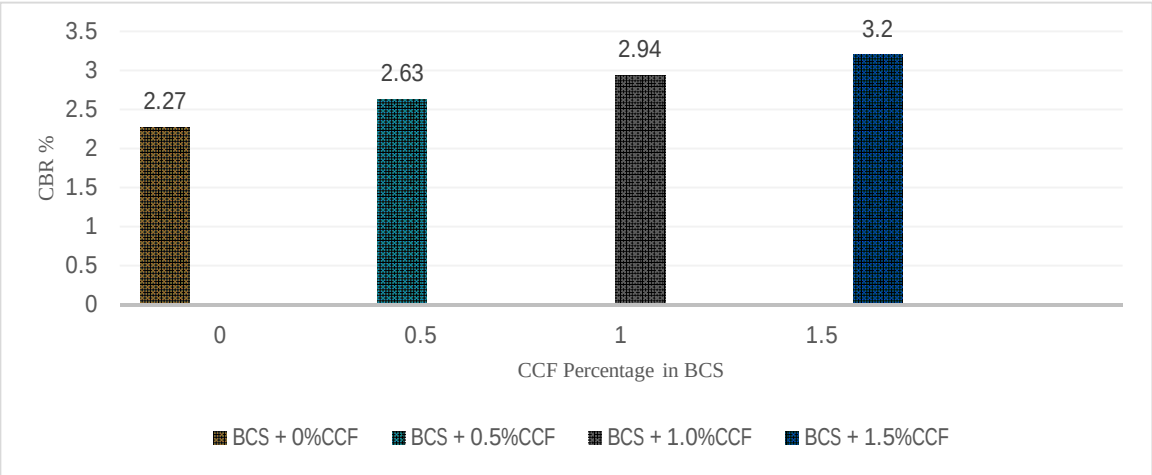

Fig. 5 Variation in CBR of BCS with varying Percentage of CFF

From the results CBR percentage of black cotton soil increases form 2.27% to 3.2% with 1.5% of CCF mixed with virgin soil sample.

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V. CONCLUSIONS

In this study coconut coir fiber (CCF) reinforced to the black cotton soil sample in the proportion of 0.5%, 1.0%, 1.5%. From the study of laboratory test results it has conclude that

A. In the compaction test it has found that

1) Increase in the percentage of CCF from 0% to 1.5% in soil sample, the value of OMC increases from 16% to 20% respectively. Which is about 25% of initial value of OMC. The value of OMC increases due to the CCF because of water absorption capacity of coir.

2) With increase in percentage of CCF from 0% to 1.5% in soil sample, the value of MDD decreases from 1.62 gm/cm^3 to 1.60 gm/cm^3 which is about 1.23% of initial value of MDD. The reason of decreasing value of MDD is specific gravity of CCF is lesser than soil sample. Fiber interferes the bonding of soil particles.

B. In the UCS test it has found that the value of compressive strength of soil sample comes out as 130 KN/m^3, 138 KN/m^3, 147 KN/m^3, and 162 KN/m^3 with respect to 0%, 0.5%, 1.0%, and 1.5% increase in percentage of CCF in soil sample. It gives the highest value (162 KN/m^3) of compressive strength at 1.5% of CCF mixed with soil sample. It is increasing about 24.62% of initial value of soil sample.

C. The CBR percentage increases from 2.27% to 3.2% with increase in percentage from 0% to 1.5% of CCF in soil sample respectively. CBR of treated soil sample with 1.5% of CCF increases about 40.96% of the CBR of the untreated soil sample.

From the above results it has concluded that CCF is a good material for the stabilization of soil. It is a totally natural waste material, which is non-toxics, zero CO_2 emission to environment and easily available. It is also cheap in price which reduce cost the stabilization of soil.

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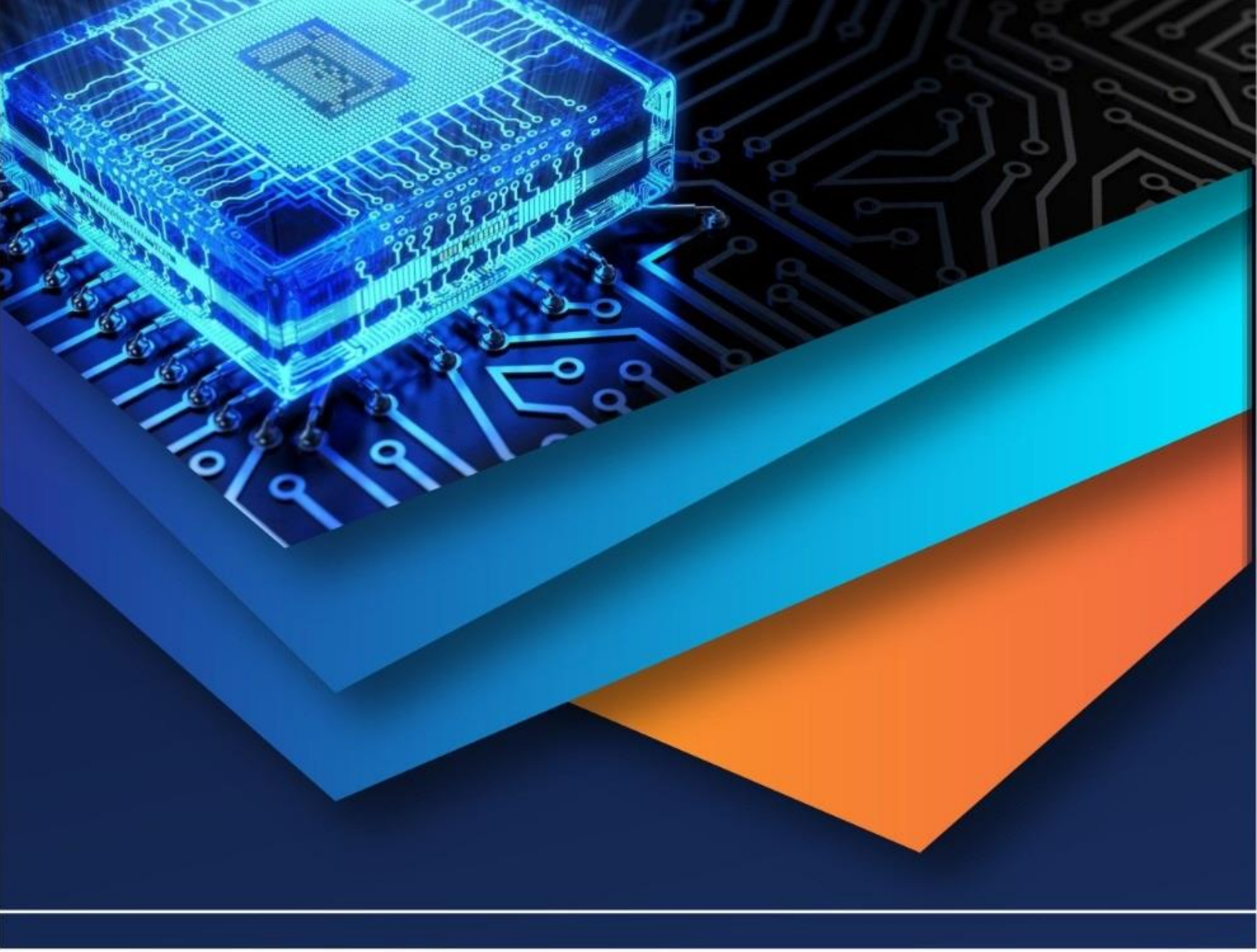

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