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Geotechnical Characteristic of Compacted Sand Bentonite Mixture

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Abstract: Sand and bentonite mixture is generally used as a liner or backfill material at waste disposal sites and construction of hydraulic barriers. Bentonite is added to sand to achieve a higher compaction density and lower shrinkage. Permeability and strength are important properties of sand-bentonite mixtures and are often required for the design of the liner/barrier of the containments. A review of the literature showed that most of the past research work has focused on studying the influence of bentonite on the various geotechnical properties of sand–bentonite mixtures. In this study, the permeability, and strength characteristics of sand–bentonite mixture is investigated to support recommendation for a cost-effective liner material with locally available soil. Locally available Narmada sand of Jabalpur, Madhya Pradesh (India) was mixed with different proportions of sodium bentonite. A series of standard tests such as Modified Compaction test, Unconfined Compression Strength (UCS) test and Permeability test for strength and hydraulic conductivity characteristics, were conducted on different of sand-bentonite mixtures. The mixtures were formed by mixing local sand, with (0%, 5%, 10%, 15%, 20% and 25%) by dry of sodium bentonite. The investigations are presented to show the influence of bentonite clay on compaction, Atterberg limits, FSI, UCS, and permeability of Narmada sand by increasing the bentonite content 5% by weight each time. It was found that there is significant improvement in MDD and OMC of sand-bentonite mixture. This study focuses on the effect of bentonite content on strength and permeability, which are two important requirements of hydraulic liner material, of sand-bentonite mixtures.

Keywords: Geotechnical properties, Sand-Bentonite mixture, Hydraulic conductivity, UCS.

I. INTRODUCTION

A. General

For the past several decades, mixing sand with an adequate amount of clay/bentonite has been a common practice for creating mixtures as construction material used in a variety of engineering applications, such as hydraulic barriers and waste containments. The combination of mixing sand and bentonite are able to provide very low permeability because of the ability of bentonite to swell and then fill the voids between sand particles. Another benefit of the mixture is low compressibility which is provided by sand framework. Furthermore, the mixture is less susceptible to frost damage compared to natural clays with low shrinkage potential in terms of wetting or drying processes which lead to better volume stability and higher strength. The sand-bentonite mixture is an economical solution for the geo-technical applications in places which are covered mostly by sandy soils. For design purposes, permeability and strength characteristics of the nominated materials should be examined in order to select the suitable and economical ratio which meets the requirements. Srikanth and Mishra (2016) worked on geotechnical characteristic of sand–bentonite mixture and the role of particle size of sand. Proia, Croce and Modoni et al. (2016) carried an experimental investigation on compacted sand-bentonite mixtures and Shaker and Tamer Y. Elkady (2016) also carried an investigation of the Hydraulic efficiency of sand-natural expensive clay mixtures. In this study, Sand was mixed with bentonite, as binding material, at 5,10,15, 20 and 25 percentages (dry weight bentonite/dry weight GW sand) to obtain less permeable liner material. Some Environmental agencies suggested specifications for liner material in which the coefficient of hydraulic conductivity (cm/s) was put as (10-6 <k < 10-8).

B. Objectives of Present Study

1) Determine the basic properties of Narmada Sand and Sodium bentonite.
2) To study the effect of different proportions of bentonite clay on the compaction characteristics of Narmada sand.
3) To study the effect of varying proportions of bentonite clay on shear strength parameters of Narmada sand by unconfined compression.

4) To study the effect of different proportions of bentonite clay on Hydraulic conductivity of Narmada sand by Falling Head permeability test.
5) To recommend a specific sand bentonite mixture composition which can produces permeability to meet the hydraulic barrier design requirements and suitable strength.

II. MATERIALS USED AND METHODOLOGY

A. Sand

In the present study the sand sample were obtained from bank of Narmada river Jabalpur district of Madhya Pradesh state of India. The sand of this region is GW as per IS classification. The various properties of sand are tested in the laboratory and results are as given in table2.1.

Table-2.1: Basic properties of Narmada sand

Properties of Sand	Values
Soil type as per IS: 1498-1970	GW
Specific Gravity	2.84
Fine Content (<75µ),%	6.37
Coefficient of uniformity, Cu	6.32
Coefficient of curvature, Cc	2.35
Plasticity Index	-
Effective size of particle, D10 (mm)	0.212
Maximum Dry Density (g/cc)	1.96
Optimum Moisture Content	5.70

B. Bentonite

The bentonite used for the project work was Sodium bentonite which is naturally occurring hydrated aluminum silicate clay. It exhibits extremely high swelling and water absorbency properties. Bentonite used in this study is sodium bentonite purchased from the market of Jabalpur in Madhya Pradesh.

Table-2.2: Basic Properties of Bentonite

Properties	Values
Soil type as per IS: 1498-1970	CH
Colour	Cream
Specific Gravity	2.80
Liquid Limit (%)	210
Plastic Limit (%)	41.52
Plasticity Index (%)	168.48
Shrinkage Limit (%)	16
Free Swell Index (FSI %)	510

III. EXPERIMENTAL WORK

Tests on the sand and bentonite samples with different proportion of bentonite were performed in two stages.

In the first stage, geotechnical characteristics of the sand samples and bentonite samples were determined by conducting grain size analysis, specific gravity test, and consistency limits test as per Indian Standards.

In the second stage, geotechnical properties of sand and bentonite samples with different proportions of bentonite were determined. The sand was mixed with different percentages of bentonite (5, 10, 15, 20, and 25%) by dry weight of total sample. Series of Free swell index (FSI) test, standard compaction test, UCS test and the permeability test were conducted to determine geotechnical properties of sand and bentonite mixes.

IV. RESULT AND DISCUSSION

Table 4: Variation of various parameters with different percentage of bentonite

S.N	SAMPLE	EXPERIMENTAL RESULTS						
		LL (%)	PL (%)	PI (%)	FSI (%)	OMC (%)	MDD (g/cc)	UCS (KN/m2)
1	Sand+0%Bentonite	-	-	-	-	5.70	1.96	-
2	Sand+5%Bentonite	21.18	NP	-	-	9.38	2.01	100
3	Sand+10%Bentonite	31.21	NP	-	20	9.06	2.04	279
4	Sand+15%Bentonite	45.72	NP	-	60	10.23	2.05	300
5	Sand+20%Bentonite	56.85	NP	-	70	17.38	1.86	178
6	Sand+25%Bentonite	60.94	29.02	31.92	140	18.28	1.85	118

A. *Atterberg Limits*

Representative samples of the soil were taken to determine Atterberg limits (plastic and liquid limits) by using the size fraction passing through 0.425 mm sieve.

1) *Liquid limit (LL):* Casagrande apparatus was used to determine the liquid limit. The liquid limit of Bentonite clay was found to be 210% which is very high. Bentonite used in this research have very high liquid limit.
2) *Plastic limit (PL):* The plastic limit was determined with the thread-rolling method. The plastic limit of bentonite is found out to be 41.52.The mixture shows plasticity after about 20% of bentonite content in it.
3) *Shrinkage limit (SL):* The shrinkage limit is obtained by Mercury dish experiment. The shrinkage limit of bentonite was found to be 16%.

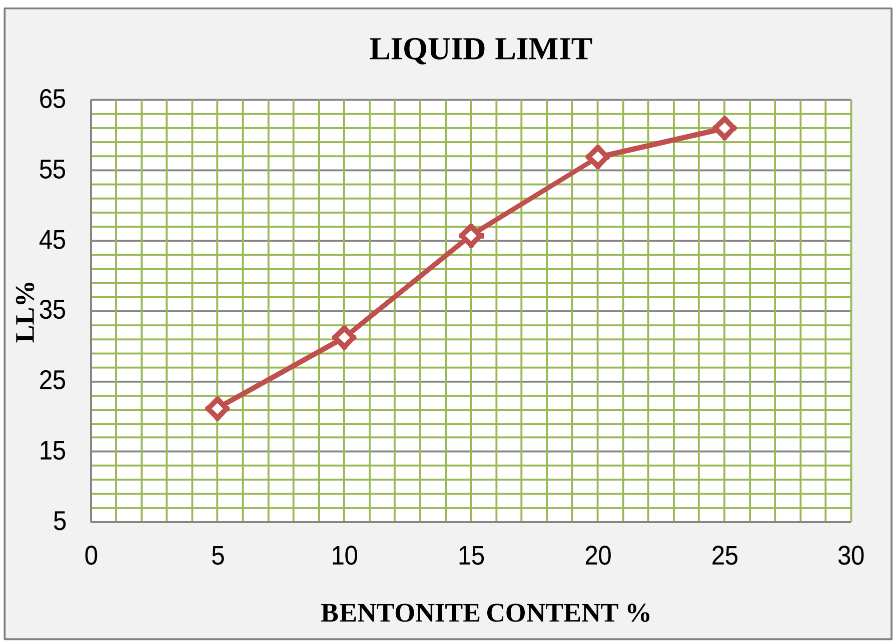

Figure1: Effect of Sand-bentonite mixture on LL values

B. *Free swell index (FSI)*

Free swell or differential free swell, also termed as free swell index, is the increase in volume of soil without any external constraint when subjected to submergence in water. The formula used is

$$FSI = \frac{[Vd - Vk]}{Vk} \times 100$$

Where, Vd = volume of soil specimen read from the graduated cylinder containing distilled water
Vk = volume of soil specimen read from the graduated cylinder containing kerosene.

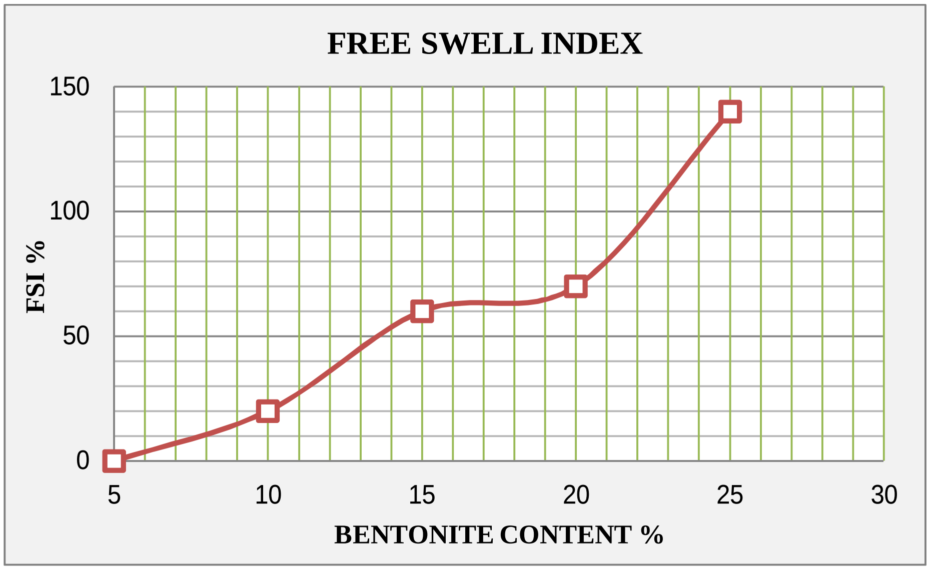

Figure 2: Effect of sand-bentonite mixture on FSI values

C. Unconfined Compressive Strength

This test was performed in accordance with IS 2720: Part 10. The results on the effect of varied content of Sand-Bentonite mixture on Unconfined Compressive strength for a maturing period of 1 day are summarized and presented in the Table. It was found that the changes in UCS were significant up to 15% bentonite content after 1 day of maturing. Further increase in Bentonite content UCS values get reduces.

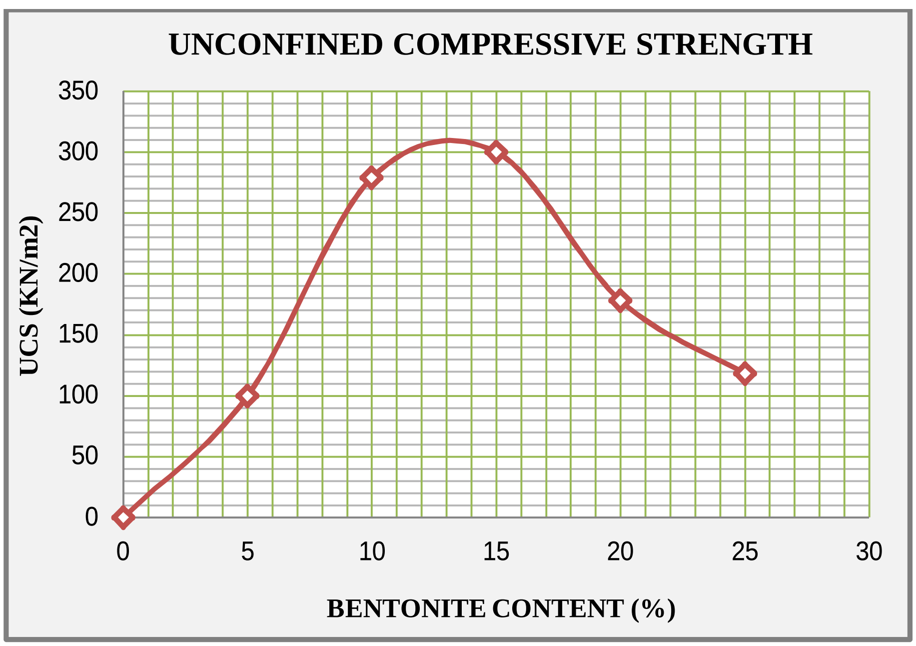

Figure3: Effect of sand-bentonite mixture on UCS value

D. Compaction Characteristics

Heavy compaction test was carried out on specimens as per IS 2720 (Part 8) 1980. The compaction curves for Sand-Bentonite mixture was obtained and the OMC and MDD values are given in Table 4.

These OMC and MDD values obtained from laboratory compaction test provide a reference point while estimating the actual water content of the field-compacted soil liner. The variation of MDD and OMC of the compacted Sand-Bentonite mixtures are presented in the Figure 4 and 5.

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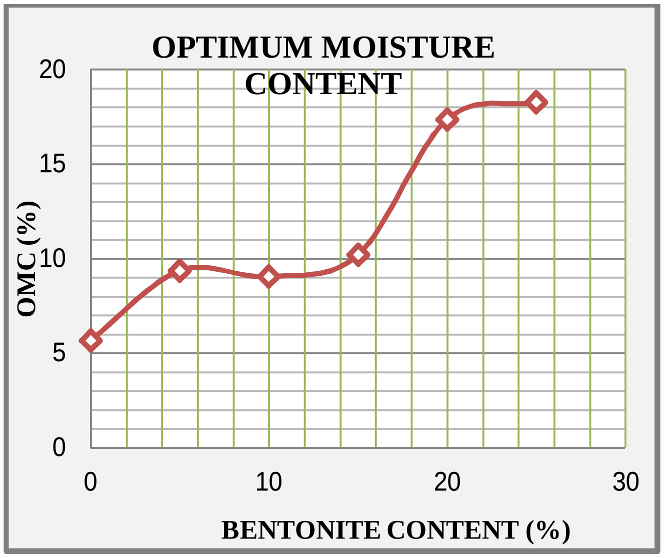

Figure4: Variation of Optimum moisture content with bentonite content

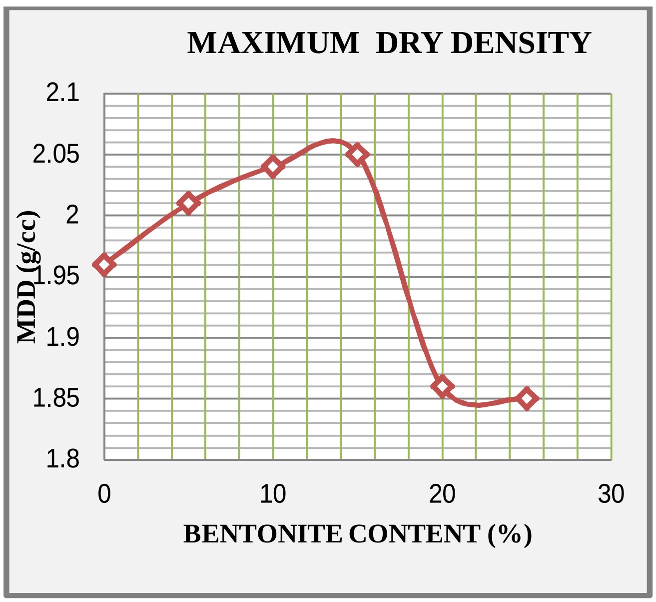

Figure5: Variation of Maximum dry density with bentonite content

E. Permeability Characteristics (IS: 2720- Part 17, 1986)

The permeability of Sand-Bentonite mixtures was measured by Falling Head Test method, after their compaction at optimum moisture content.

Formula used: The coefficient of permeability has been determined by the relation.

$$K = 2.303 \frac{aL}{(At)} \log_{10} \frac{h1}{h2}$$

K = Coefficient of permeability in cm/sec. at test temperature
a = Inside cross sectional area of stand pipe in cm2
A = Cross sectional area of soil sample
L = Length of soil sample in cm
h_1 =Initial head in cm
h_2= Final head in cm
t = Time interval in seconds in which the head drop from h_1 to h_2

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Table 4: Variation of Coefficient of permeability with different percentage of bentonite

Bentonite (%)	Coefficient of Permeability of Sand-Bentonite Mixture(cm/sec)
0	1.73×10^{-3}
5	5.37×10^{-4}
10	5.02×10^{-5}
15	3.34×10^{-6}
20	9.58×10^{-7}
25	3.57×10^{-8}

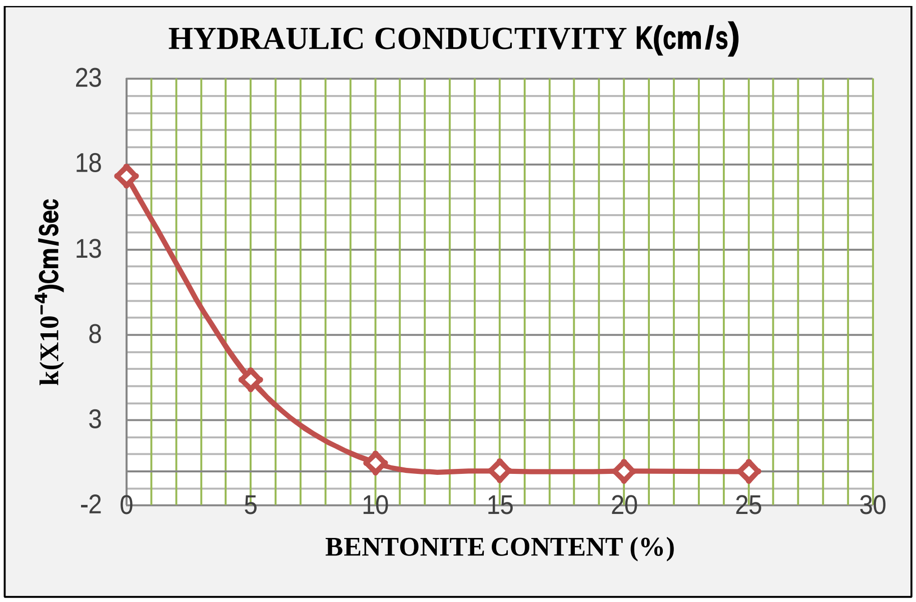

Figure6: Effect of sand-bentonite mixture on hydraulic conductivity

V. CONCLUSION

A. Based on the findings of the Present Investigations, the Following Conclusion Can be Drawn.

1) With increase in the Bentonite content, the maximum dry density (MDD) of the mixture is increased up to 15% further addition in Bentonite content up to 25% MDD values get decreased and the optimum moisture content (OMC) is increased up to 25%.
2) An increase in Bentonite content Liquid limit, Plastic limit increases. At 25% mixture induced plasticity which led to better bonding between particles upon compaction.
3) Unconfined compressive strength (UCS) also increases from 100 to 300 KN/m2 for 5% to 15% Bentonite respectively, further increase in Bentonite content from 15% to 25% UCS value of mix get decreased and attained a value of 118 KN/m2 at 25% Bentonite content.
4) The hydraulic conductivity decreased from 1.73×10^{-3}cm/sec without bentonite to 3.57×10^{-8} cm/sec sand with 25% Bentonite. When Bentonite added to sand, due to its very small size it occupies the pore space present between the Individual sand grains and once the Bentonite comes in contact with water, it starts to swell and fill all Void spaces resulting in decrease in the hydraulic conductivity of the mixture.

Based on the above test results it can be recommended that Sand mixed 20% bentonite proportion is an optimum mix that can be safely used as a cover or liner at waste disposal sites as per the design criteria clays with permeability between $10^{-6} < k < 10^{-8}$ cm/sec is considered for landfill liner.

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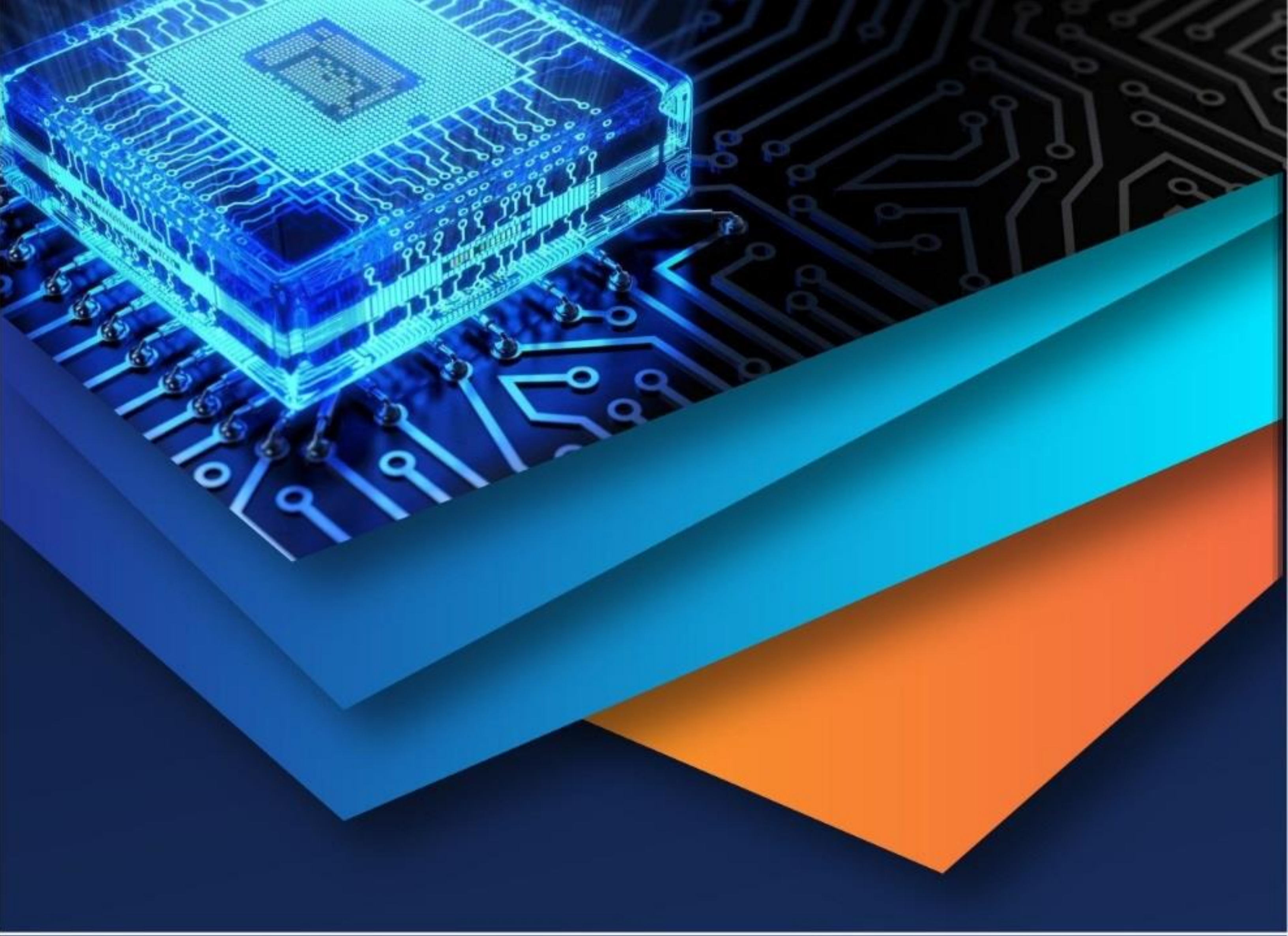

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