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Stabilization of Expansive Soil using Dismantled Class III Bricks, Lime and Iron Dust

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Abstract: Soil plays an important role in the construction industry. In India, various types of soils can be used for construction work specially the Black Cotton soil also known as the expansive soil that covers one-fifth of land area which contains the clay mineral montmorillonite results high swelling and shrinkage characteristics.
This type of soils has highly compressible, low shear strength and bearing capacity. Soil stabilization is the method to enhance the geotechnical properties of the soils. Various admixtures or materials like cement, lime, marble dust, fly ash, geo-polymers etc. can be used as stabilizing materials. In this research, brick dust(5%,10%&15%), lime(5%&10%) and iron dust(5%&10%) by weight are used as stabilizing agents mixing in all possible combinations simultaneously that stabilizes the black cotton soil by increasing their shearing and bearing strength as well as reducing the swelling and shrinkage properties of the soil.
Keywords: Soil Stabilization, Brick Dust, Lime, Iron Dust, Black Cotton Soil, Free Swell Index, CBR value

I. INTRODUCTION

Soil stabilization is a technique for improving the soil properties by blending or mixing the materials. Soil stabilization can be utilized on roadways, site development projects, airports, highways, parking areas and many other situations where the sub-soils are not suitable for construction. Stabilization can be used to treat a wide range of sub-grade materials, varying from expansive clays to granular materials.

This process is accomplished using a wide variety of additives, including lime, fly ash, cement, brick dust, cement kiln dust(CKD), marble dust, lime kiln dust(LKD), brick kiln dust(BKD), geo-polymers etc.

Soil stabilization is the process of improving the engineering properties of the soil and thus making the soil more stable. It is required when the soil available for construction is not suitable for the intended purpose.

In its broadest sense, stabilization includes compaction, pre-consolidation, drainage and many other such processes. However, the term stabilization is generally restricted to the processes which alter the soil material itself for improvement of its properties.

Stabilization is mainly used to reduce the permeability and compressibility of the soil mass in earth structures and to increase its shear strength.

It is also required to increase the bearing capacity of foundation soils. The principle of soil stabilization is used for controlling the grading of soils and aggregates in the construction of base and sub-base.

Stabilization means the improvement in the properties of poor soils by three different methods:

1) *Mechanical Stabilization:* Where suitable soil materials are available, mechanical stabilization may prove to be simplest and a cheap method of constructing bases for pavements and improving sub-grades. Mechanical treatment or 'stabilization' is based on the principles of-
   a) Controlled grading of soil
   b) Proper compaction
2) *Chemical Stabilization:* A number of admixtures or materials other than soil have been tried to improve the physical properties of soils. These include lime, cement, bitumen, industrial wastes, such as molasses from sugar industry and lignin from paper industry, etc.
3) *Geo-textiles:* Geo-textiles are permeable synthetic fabrics which can be used to improve soils. They are currently used in many civil engineering works including pavements, embankments, retaining structures, reservoirs, canals, dams, bank protection and coastal engineering.

II. OBJECTIVE OF RESEARCH

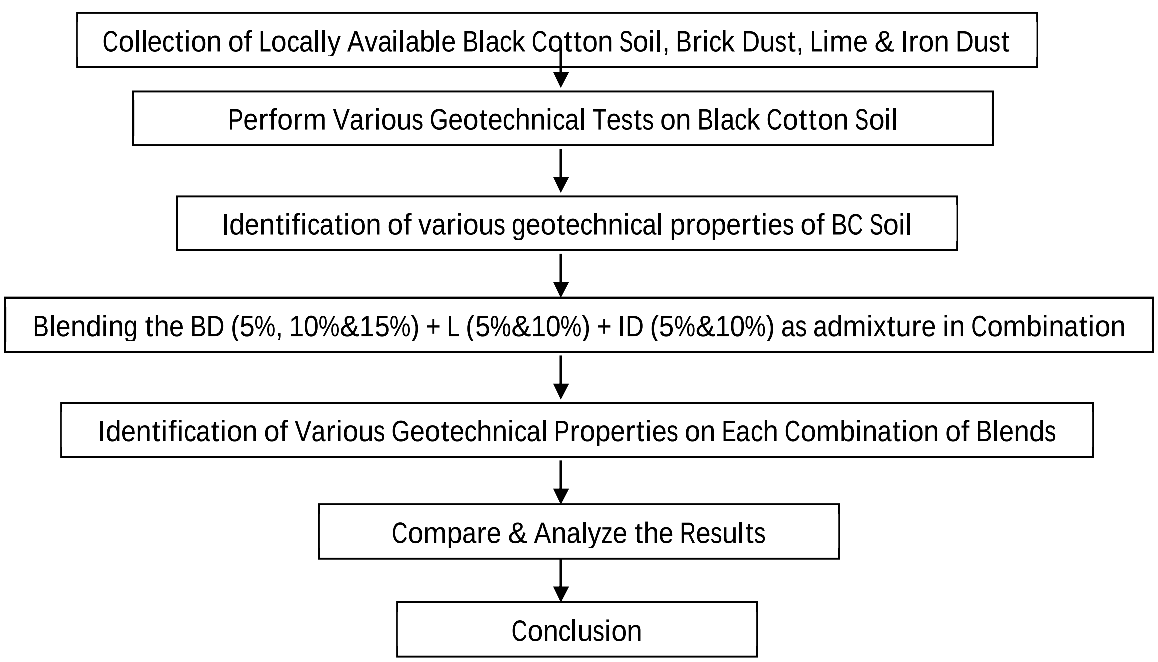
Objectives of this research are given below

A. The prime objective of soil stabilizing is to improve the CBR (California Bearing Ratio) value of in-situ soils.
B. The second objective is to prevent the storage of water so the permeability increases and reduce the swelling & shrinkage properties of the soil.
C. The third purpose is to preserve the natural or constructed strength of a soil by reducing the holding capacity of surface water.
D. The reduction of construction waste and industrial waste which helps to make the eco-friendly environment.
E. Cost effective utilization of suitable stabilizing agent as admixtures like lime, brick dust, iron dust etc.

III. SOIL AND MATERIALS USED

1) *Black Cotton Soil:* In India, about one-fifth of the land area include the states of Andhra Pradesh, Madhya Pradesh, Uttar Pradesh, Rajasthan, Gujarat, Maharashtra, Karnataka and Tamil Nadu. Black cotton soils are clays of high plasticity. They contain essentially the clay mineral montmorillonite. The soils have high shrinkage and swelling characteristics. The shearing strength of the soils is extremely low.
2) *Class III Bricks:* These bricks are ground-molded and they are burnt in clamps. These bricks are not very hard and they have rough surfaces with irregular and blunt edges. These bricks give dull sound when they are struck together. Dismantled condition bricks can be used in the form of brick dust.
3) *Lime:* Lime is a calcium-containing inorganic material in which carbonates, oxides and hydroxides predominate. These materials are still used in large quantities as building and engineering materials.
4) *Iron Dust:* Iron is the second most metallic element in the earth's crust and accounts for 5.6% of the lithosphere. The usage of large quantities of iron in the present days is resulting in the generation of large amount of Iron waste in the form of dust. This iron dust can be collected in the process of surfacing by the surface grinder from the industries.

IV. PROPOSED METHODOLOGY



a) *Step1:* Soil sample collects from the locally available Black cotton soil near district Gwalior (M.P.), Brick dust can be formed by collecting the dismantled class III bricks from construction demolish waste, Lime from the stores and Iron dust from the local industries.
b) *Step2:* Various Geotechnical Tests for finding the different physical properties are defined as:

i) *Specific Gravity (Gs):* It can be defined as the ratio of unit weight of soil solids to the unit weight of water. It is used in finding critical hydraulic gradient, stability analysis of slopes
ii) *Liquid Limit (LL):* It may be defined as the minimum moisture content at which the soil is still in liquid state but having a small shearing strength against flowing.
iii) *Plastic Limit (PL):* The water-content boundary beyond which a soil can be rolled into a thread approx. 3 mm in diameter without crumbling.
iv) *Plasticity Index (PI):* The difference between the numerical value of Liquid Limit & Plastic Limit
v) Classification of soil by sieve and sedimentation analysis– Dry Sieve Analysis - Dry sieve analysis is carried out on particles coarser than 75 micron.
vi) *Sedimentation Analysis:* Sedimentation analysis is used only for the soil fraction finer than 75 microns.
vii) *Standard Proctor Test for OMC & MDD:* This method used to determine the soil compaction properties, specifically, to determine the optimal water content at which soil can reach its maximum dry density.
viii) *Permeability (Variable Head) Test (K):* The ease with which water can flow through a saturated soil is known as permeability.
ix) *Differential Free Swell Index (FSI):* The degree of shrinkage is expressed as the ratio of difference between the original volume at its normal moisture content and the final constant volume.
x) *CBR Test (soaked & un-soaked):* The California bearing ratio (CBR) is a penetration test for evaluation of the mechanical strength of natural ground, sub-grades and base courses beneath new carriageway construction. The CBR rating was developed for measuring the load-bearing capacity of soils used for building roads.

c) *Step3:* Various Physical Properties of Black Cotton Soil as given in Table-1:

Various Physical Properties Of Black Cotton Soil			
Properties	Value	Properties	Value
Specific Gravity	2.60	Optimum Moisture Content	16.00%
Liquid Limit	42.67%	Maximum Dry Density	1.680 gm/cc
Plastic Limit	25.60%	CBR soaked	0.882
Permeability	1.414×10^{-7} cm/s	CBR un-soaked	1.282
Differential Free Swell	44.44%	Plasticity Index	17.07%

Table-1

Some other properties of soil and admixture as:
Classification of Soil on the basis Fig-1
Of Atterberg Plasticity Chart = CI
Specific Gravity of Brick Dust = 2.50
Specific Gravity of Lime = 2.32
Specific Gravity of Iron Dust = 3.33

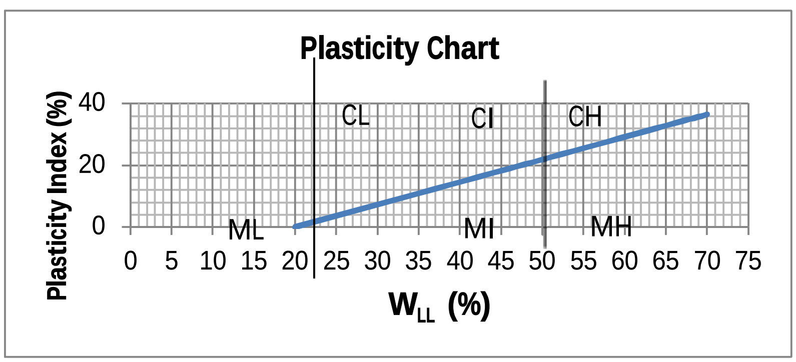


Fig-1 Plasticity Chart for classification of soil

d) *Step4:* Mixing the Brick Dust (5%, 10% & 15%), Lime (5% & 10%) & Iron Dust (5% & 10%) with the BC soil by weight in all different combinations forms various blends as listed below:
i) Soil +BD (5%) + L (5%) + ID (5%)
ii) Soil +BD (10%) + L (5%) + ID (5%)
iii) Soil +BD (15%) + L (5%) + ID (5%)
iv) Soil +BD (5%) + L (10%) + ID (5%)
v) Soil +BD (10%) + L (10%) + ID (5%)

vi) Soil +BD (15%) + L (10%) + ID (5%)
vii) Soil +BD (5%) + L (5%) + ID (10%)
viii) Soil +BD (10%) + L (5%) + ID (10%)
ix) Soil +BD (15%) + L (5%) + ID (10%)
x) Soil +BD (5%) + L (10%) + ID (10%)
xi) Soil +BD (10%) + L (10%) + ID (10%)
xii) Soil +BD (15%) + L (10%) + ID (10%)

e) *Step5:* The various geotechnical properties can be obtained in the Table-2 & Table-3 below:

S. No.	Blend with proportion	Gs	LL (%)	PL (%)	PI (%)
1	Soil +BD (5%) + L (5%) + ID (5%)	2.77	37.96	29.03	8.93
2	Soil +BD (10%) + L (5%) + ID (5%)	2.89	37.82	28.20	9.62
3	Soil +BD (15%) + L (5%) + ID (5%)	2.94	34.76	26.43	8.33
4	Soil +BD (5%) + L (10%) + ID (5%)	2.76	38.06	28.57	9.49
5	Soil +BD (10%) + L (10%) + ID (5%)	2.80	41.12	30.00	11.12
6	Soil +BD (15%) + L (10%) + ID (5%)	2.88	41.96	30.95	11.01
7	Soil +BD (5%) + L (5%) + ID (10%)	2.85	38.98	29.03	9.95
8	Soil +BD (10%) + L (5%) + ID (10%)	2.91	34.92	28.57	6.35
9	Soil +BD (15%) + L (5%) + ID (10%)	2.88	38.87	27.27	11.6
10	Soil +BD (5%) + L (10%) + ID (10%)	2.71	38.75	26.98	11.77
11	Soil +BD (10%) + L (10%) + ID (10%)	2.82	38.14	29.03	9.11
12	Soil +BD (15%) + L (10%) + ID (10%)	2.94	36.56	29.62	6.94

Table-2

S. No.	Blend with proportion	OMC (%)	MDD (gm/cc)	K (x10^{-7}cm/s)	FSI (%)
1	Soil +BD (5%) + L (5%) + ID (5%)	16.20	1.720	3.202	38.10
2	Soil +BD (10%) + L (5%) + ID (5%)	17.00	1.754	4.126	33.33
3	Soil +BD (15%) + L (5%) + ID (5%)	17.20	1.776	5.590	25.00
4	Soil +BD (5%) + L (10%) + ID (5%)	17.00	1.768	4.840	31.58
5	Soil +BD (10%) + L (10%) + ID (5%)	16.00	1.772	5.992	25.00
6	Soil +BD (15%) + L (10%) + ID (5%)	16.00	1.797	6.920	23.81
7	Soil +BD (5%) + L (5%) + ID (10%)	16.00	1.802	5.510	27.27
8	Soil +BD (10%) + L (5%) + ID (10%)	15.50	1.820	6.401	19.05
9	Soil +BD (15%) + L (5%) + ID (10%)	17.00	1.804	7.186	22.72
10	Soil +BD (5%) + L (10%) + ID (10%)	16.00	1.784	6.637	33.33
11	Soil +BD (10%) + L (10%) + ID (10%)	17.00	1.795	7.306	30.00
12	Soil +BD (15%) + L (10%) + ID (10%)	16.00	1.767	7.928	28.57

Table-3

CBR soaked & un-soaked values for Optimum Blend BD (10%), L (5%) & ID (10%) with or without ID(10%) as in table-4:

S. No.	Blend with proportion	CBR Value at 2.5 mm penetration	
		Soaked	Un-soaked
1	Soil +BD (10%) + L (5%)	1.683	3.406
2	Soil +BD (10%) + L (5%) + ID (10%)	3.005	6.172

Table-4

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f) *Step6:* Comparison & Analysis of the results of various blends with the plain Black Cotton Soil

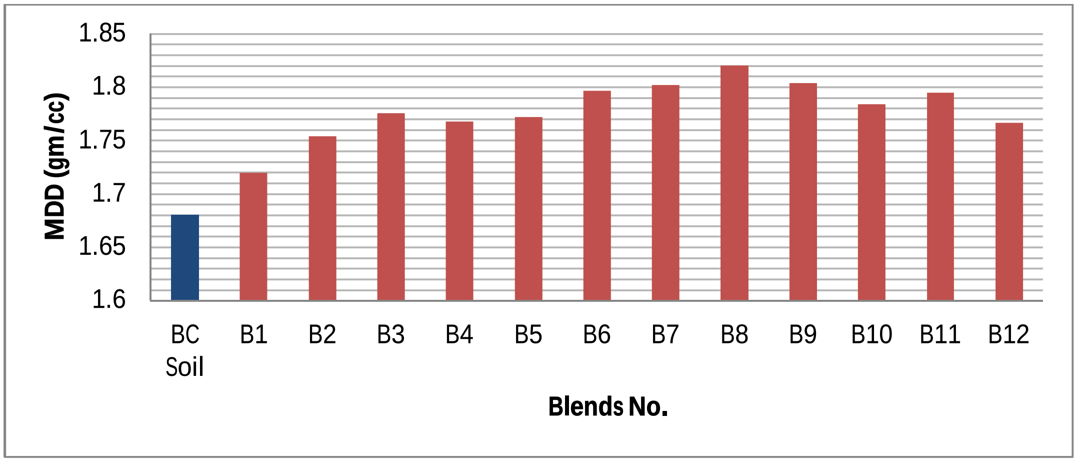

Fig-2 Chart showing the variation in Maximum Dry Density for plain soil & various mix proportions

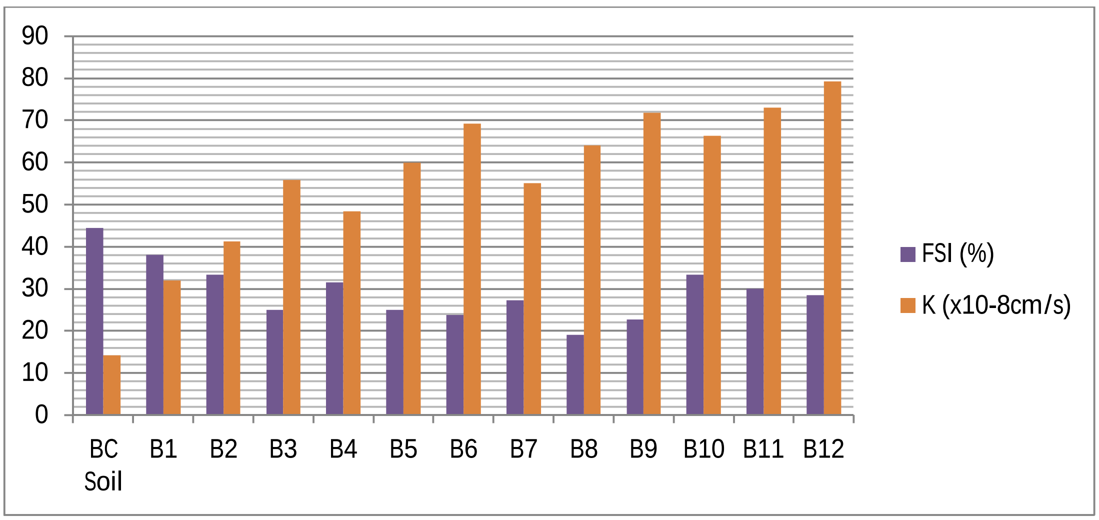

Fig-3 Chart showing the variation in Free Swell Index & Permeability for plain soil & various mix proportions

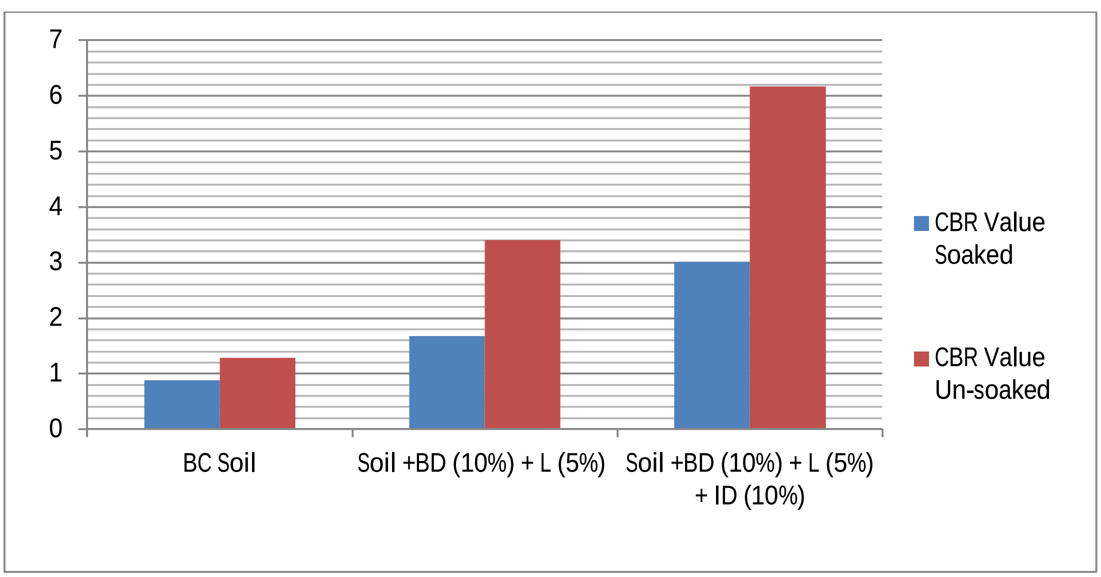

Fig-4 Chart showing the variation in CBR value at 2.5 mm penetration

V. CONCLUSION

The analysis of the results indicates that the mixture of Soil with Brick Dust (10%), Lime (5%) & Iron Dust (10%) seems to be good option for the stabilization of the Black Cotton Soil. It is clearly visible that the Maximum Dry Density (MDD) of this mixture is maximum in all combinations and the values increases from 1.680 gm/cc for plain BC soil to 1.820 gm/cc as well as Optimum Moisture Content (OMC) also reduces. The other physical properties of the soil like Free Swell Index (FSI) reduce from 44.44% for plain soil to 19.05 %, Permeability (K value) increases and Plasticity Index reduces from 17.07 for plain BC soil to 6.35 for Optimum Blend. The CBR values increases in soaked condition from 0.882 for plain BC Soil to 1.683 and in un-soaked condition from 1.282 for plain BC Soil to 3.406 when the 10% Iron Dust is not added in soil only the 10% Brick Dust and 5% Lime is added to the soil. While the 10% Iron Dust also mixed with the BC Soil, 10% Brick Dust and 5% Lime, the CBR values also increases in soaked condition from 0.882 for plain BC Soil to 3.005 and in un-soaked condition from 1.282 for plain BC Soil to 6.172. Hence the CBR value increases upto the 3-5times by the soil stabilization using Brick Dust, Lime & Iron Dust as 10%, 5% & 10% respectively.

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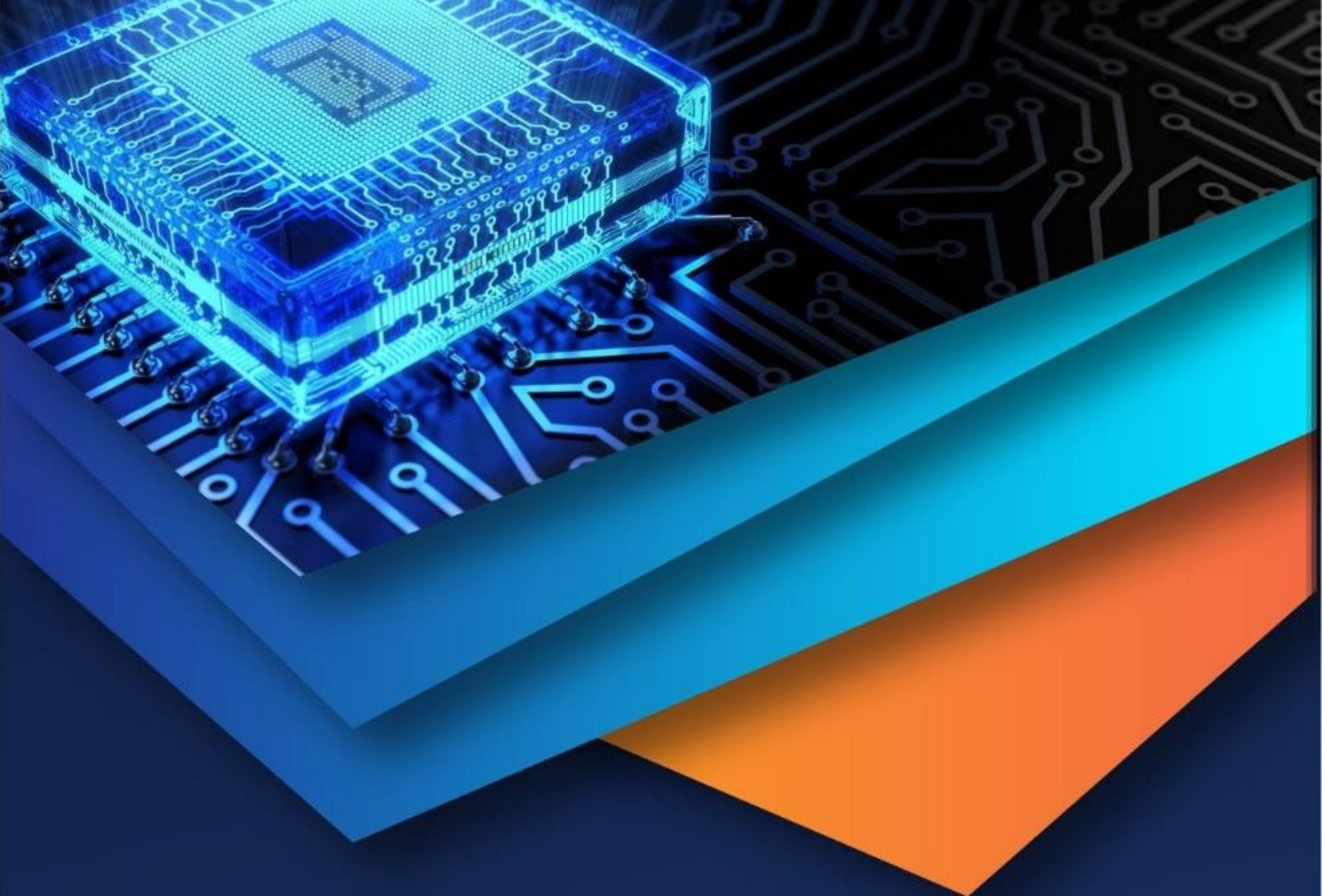

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