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The Improvement of Engineering Properties of Expansive Soil using Waste Glass Powder (WGP) and Quick Lime

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Abstract: ***This study was carried out with an intention to observe any sign of improvement of expansive clayey soil due to the addition of Waste Glass Powder (WGP) with it. In this laboratory work clayey (BC) type soil has been chosen. The reason behind choosing clay is that it has many problems. The main problem is that it undergoes consolidation settlement due to the application of long-term loading. Another problem is it shrinks significantly if it is dried and expands significantly, if it absorbs moisture than exerts much pressure on the substructure. Quick Lime and Waste Glass powder is chosen to check the improvement because waste glass powder is cohesionless material and also contains silica, lime etc. Addition of cohesionless material to the cohesive soil means it will lesser the consolidation settlement and expansive nature of soil and Lime provides binding property. To investigate the traditional methods of analysing, the effect of additives on soil has been adopted i.e., conducting several tests of untreated soil and soil treated with waste glass and lime with varying percentage and then comparing the results obtained. The tests that were carried out in this study are Compaction test (Proctor test), Consolidation test (unconfined compression test). MDD and Unconfined compressive strength increases with the addition of glass powder and lime with oven dried expansive soil.***
Keywords***: Black cotton soil (BCS), Waste glass powder (WGP), Quick Lime, Engineering properties, Optimum moisture content (OMC), Maximum Dry Density (MDD), UCS test.***

I. INTRODUCTION

In India, an area about one-six is occupied by black cotton soil. The area covers mostly the Deccan Trap plateau, between 73°80" East Longitude and 15° to 24° North Latitude. That means these soils are predominant in Deccan trap plateau region, i.e., in states of Andhra Pradesh, Western Madhya Pradesh, Gujarat, Maharashtra, Northern Karnataka, Tamil Nadu and even some on the river banks is Black cotton soil which is expansive in nature.

Expansive soil is prone to large volume changes (swelling and shrinking) that are directly related to changes in water content. Soils with a high content of expansive minerals can form deep cracks in drier seasons or years, such soils are called vertisols. Expansive soils with high content of clay minerals (montmorillonite and bentonite) are found and so, they cannot be used as foundation layers or as a construction material. Different methods are adopted to stabilize these types of soils to suit the specifications of construction fields. Waste Glass powder and Quick Lime were used to study the effects on the geotechnical properties of expansive soil.

Waste Glass powder primarily contains silicon dioxide (SiO_2), calcium oxide (CaO), & Sodium oxide (Na_2O) which increase the bearing capacity of soil, while Quick lime is inorganic mineral, contains calcium oxide (CaO) & calcium hydroxide ($Ca(OH)_2$), which gives bond between soil & waste glass powder. Waste Glass can be collected from municipal solid waste (MSW) and Glass manufacturing/recycling industries, and crushed in powdered forms for used as a stabilizing waste material to overcome the loads on disposal lands and environment.

The main objective of this paper is to determine the improvement in engineering properties of expansive soil under varying percentage of waste glass powder (0% to 30%) and Quick lime (0% to 6%).

II. MATERIALS AND PROPERTIES

1) *Black Cotton Soil:* The black cotton soil used in this study was collected from village Piparia, near khamaria, Jabalpur Madhya Pradesh. The latitude and longitude of the site are 23.213939 and 80.036789. The black cotton soil collected from the site at 1.5-2.0 m depth is brought to the laboratory for testing purpose. The properties of the BC soil collected from the site tabulated below -

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Table 1 Properties of black cotton soil

s.no.	Particulars	Observation
1.	Specific gravity	2.276
2.	Liquid limit	58.73%
3.	Plastic limit	22.24%
4.	Plasticity index	36.49%
5.	Passing 75µ sieve	78.171%
6.	Differential Free soil	50.91%

2) *Waste Glass Powder (WGP):* The waste glass powder is brought form Glass Manufacturing industry, Bhopal, MP. Million tons of waste glass is being generated annually all over the world. Once the glass becomes a waste it is disposed as landfills, which is unsustainable as this does not decompose in the environment. Glass is principally composed of silica. Use of milled (ground) waste glass in concrete as partial replacement of lime could be an important step toward development of sustainable (environmentally friendly, energy-efficient and economical) infrastructure systems. In this study waste glass powder and lime used for improvements of engineering property of expansive soil and also solve the disposal problems. The properties of Waste Glass Powder are tabulated in table 2 and 3 given as -

Figure1. Waste Glass powder (GP)

Figure2. Quick lime in powder form

Table 2 Physical properties of Waste glass Powder

S.NO.	PARTICULARS	PERCENTAGE
1.	Type	Powder
2.	Specific gravity	2.612
3.	Passing 75µ sieve	98%

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Table 3 Chemical properties of waste glass powder

S.NO.	PARTICULARS	PERCENTAGE	
		(a)	**(b)**
1.	Silicon dioxide ($SiO_{2)}$	74%	71.21%
2.	Aluminioum oxide ($Al_2O_{3)}$	1.3 %	1.91%
3.	Ferric oxide ($Fe_2O_{3)}$	0.57%	0.45%
4.	Calcium oxide (CaO)	10.5%	13.3%
5.	Magnesium oxide (MgO)		2.4%
6.	Sodium oxide (Na_2O)	13 %	10.1%
7.	Potassium oxide (K_2O)		
8.	Manganese oxide (MnO)		
9.	Another accumulated component	0.63%	0.63%
Source: Canacki Hanifi et al. 2016[(a)] Rizgar A. Blayi et al. 2020[(b)]			

3) Quick LIME: Quick Lime purchased from local market of Jabalpur, MP. The main benefits of using lime to stabilize clays are provide bond strength between waste glass and soil, also improved workability, increased strength, and volume stability. Lime increases the strength of clayey soil by reducing shrinkage and swell characteristics.

III. TESTING METHODOLOGY

The various tests can be conducted in the geotechnical laboratory to characterize the engineering properties of plain black cotton soil and stabilized soil. Following tests were performed in the laboratory as per the relevant IS codes:

A. Proctor test (IS: 2720 PART- VII)-1980.
B. . Unconfined compressive strength test (IS: 2720 PART-X)-1991.

IV. SAMPLE PREPARATION

This work presents an investigation of the effect of waste glass powder (WGP) and Quick Lime on strength and engineering properties of expansive soil and in this research work lime is used as a stabilizer. The samples are prepared as -

A. The black cotton soil, lime and WGP are oven dried separately.
B. The oven dried black cotton soil, lime (0%, 4%, and 6%) and (0%, 10%, 20%, and 30%) are mixed in proportions by weight to form various mixes.
C. The formed dry mixes are being blended together with water in order to get a homogeneous blend as per the requirement of test.
D. In these blended soil samples geotechnical test performed as per the IS specifications.

The OMC, MDD and UCS value of different samples containing varying percentage of WGP (0%, 10%, 20%, 30%) and black soil was found out from which Optimum WGP percentage was determined. Then again prepare same samples with fixed percentage of lime (0%, 4%, 6%) treated soil and effects on engineering properties like- OMC, MDD and UCS value was evaluated.

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V. RESULTS AND DISCUSSION

The laboratory tests are conducted in the Geotechnical laboratory, Jabalpur engineering college, Jabalpur, MP India. Based on experimental work, numerous tests were executed on the various samples with varying percentages of WGP and lime. The effect of WGP and lime inclusion on OMC-MDD relationship, and UCS values were considered. The outcomes are presented below table -

TABLE 4: OMC-MDD and UCS value of soil sample with lime and varying percentage of WGP

Soil + (%) WGP + (%) LIME	Maximum Dry Density (gm/cc)	Optimum Moisture Content (%)	UCS value (KN/m^2)
BCL0WGP0	1.560	24.54	113.24
BCL0WGP10	1.596	23.67	124.67
BCL0WGP20	1.640	22.77	141.65
BCL0WGP30	1.682	21.27	151.942
BCL4WGP0	1.578	23.21	133.739
BCL4WGP10	1.612	20.15	162.912
BCL4WGP20	1.665	19.65	194.82
BCL4WGP30	1.720	18.09	206.04
BCL6WGP0	1.618	22.30	140.29
BCL6WGP10	1.635	19.38	174.73
BCL6WGP20	1.736	18.39	255.60
BCL6WGP30	1.730	17.96	223.90

1) BCL0WGP0 – Black Cotton Soil +0% Lime + 0% WGP
2) BCL4WGP0 – Black cotton soil + 4% lime + 0% WGP
3) BCL6WGP0 - Black cotton soil + 6% lime + 0% WGP
4) BCL0WGP10 – Black cotton soil + 0% Lime + 10% WGP
5) BCL0WGP20 – Black cotton soil + 0% Lime + 20% WGP
6) BCL0WGP30 – Black cotton soil + 0% Lime + 30% WGP
7) BCL4WGP10 – Black cotton soil + 4% lime + 10 % WGP
8) BCL4WGP20 - Black cotton soil + 4% lime + 20% WGP
9) BCL4WGP30 – Black cotton soil + 4% lime + 30% WGP
10) BCL6WGP10 – Black cotton soil + 6% lime + 10% WGP
11) BCL6WGP20 – Black cotton soil +6% lime + 20% WGP
12) BCL6WGP30 – Black cotton soil + 6% lime + 30% WGP

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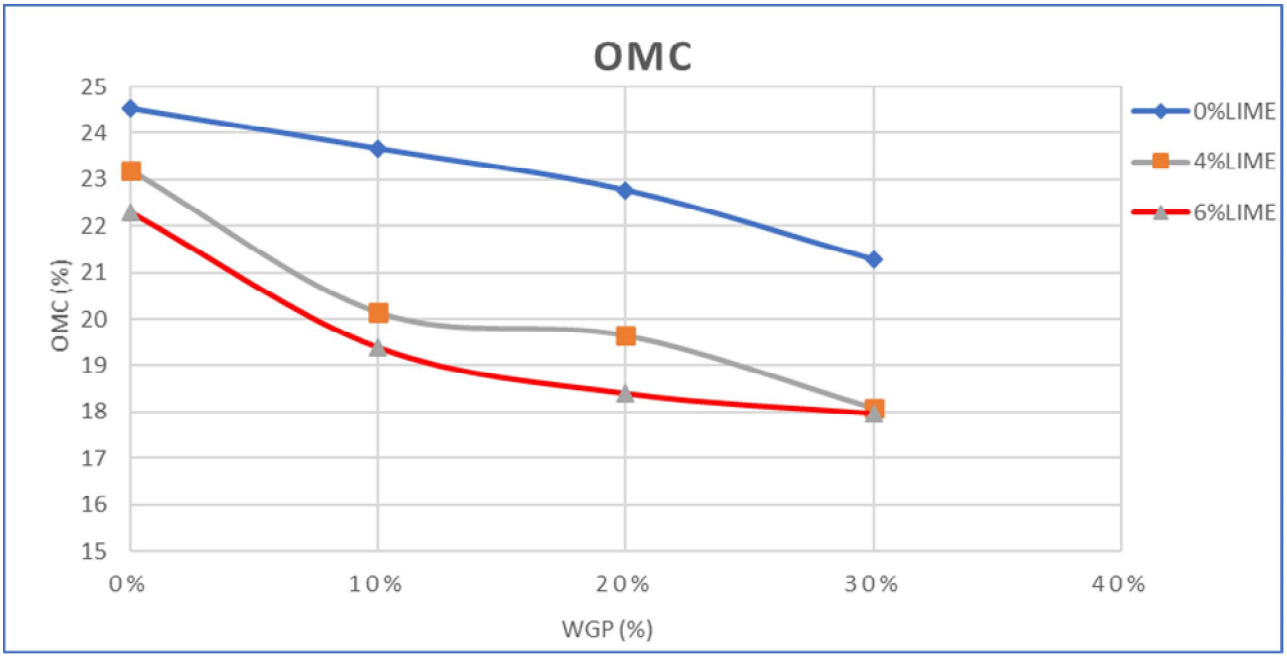
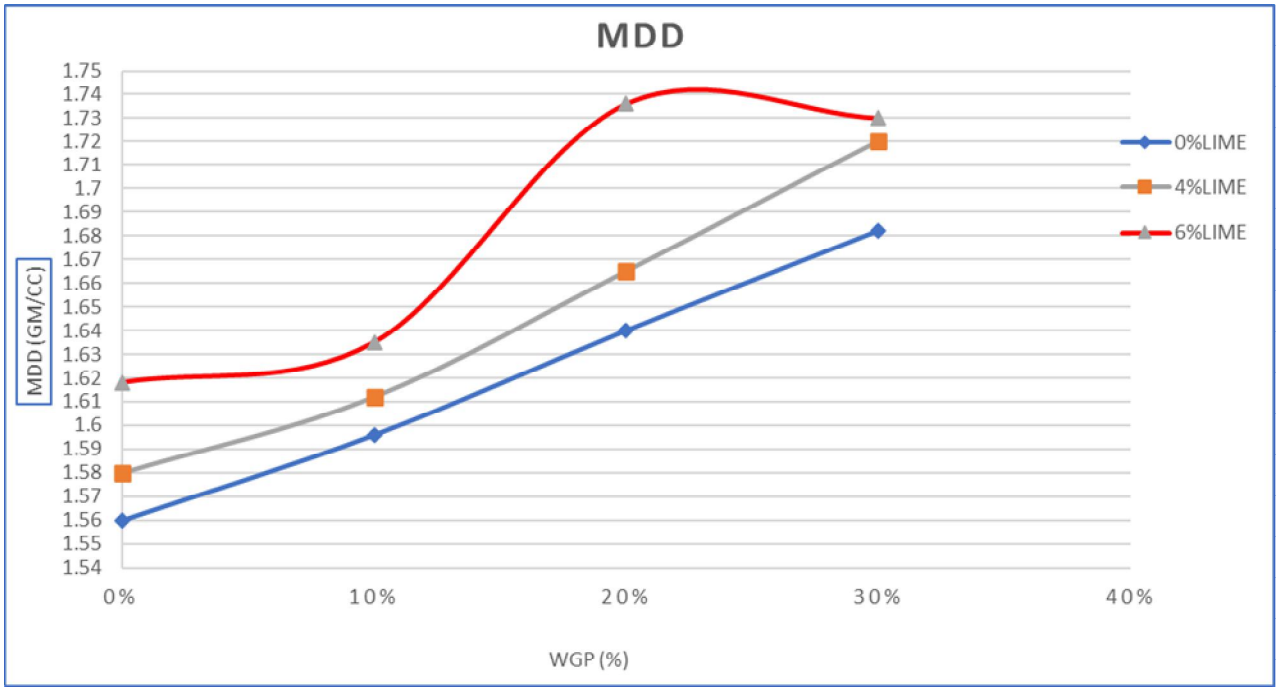
a) Compaction Test: It is observed in Table 2 and 3 and Graph 1 and 2 that with the inclusion of WGP and lime, the MDD increased throughout addition of WGP with and without lime. The OMC of plain BC soil 22.96% was reduced 17.19% on addition of 30% WGP and 6% lime.

Graph 1: Figure 1 Variation of Optimum moisture content of soil in different percent of WGP



b) Maximum Dry Density: Due to addition of WGP and lime the MDD value of plain black cotton soil 1.560 gm/cc was increases 1.682 gm/cc, 1.720 gm/cc and 1.730 gm/cc at 30% of WGP and 0%, 4% and 6% of lime.

Graph 2: Figure 2 Variation of maximum dry density of soil in different percent of WGP



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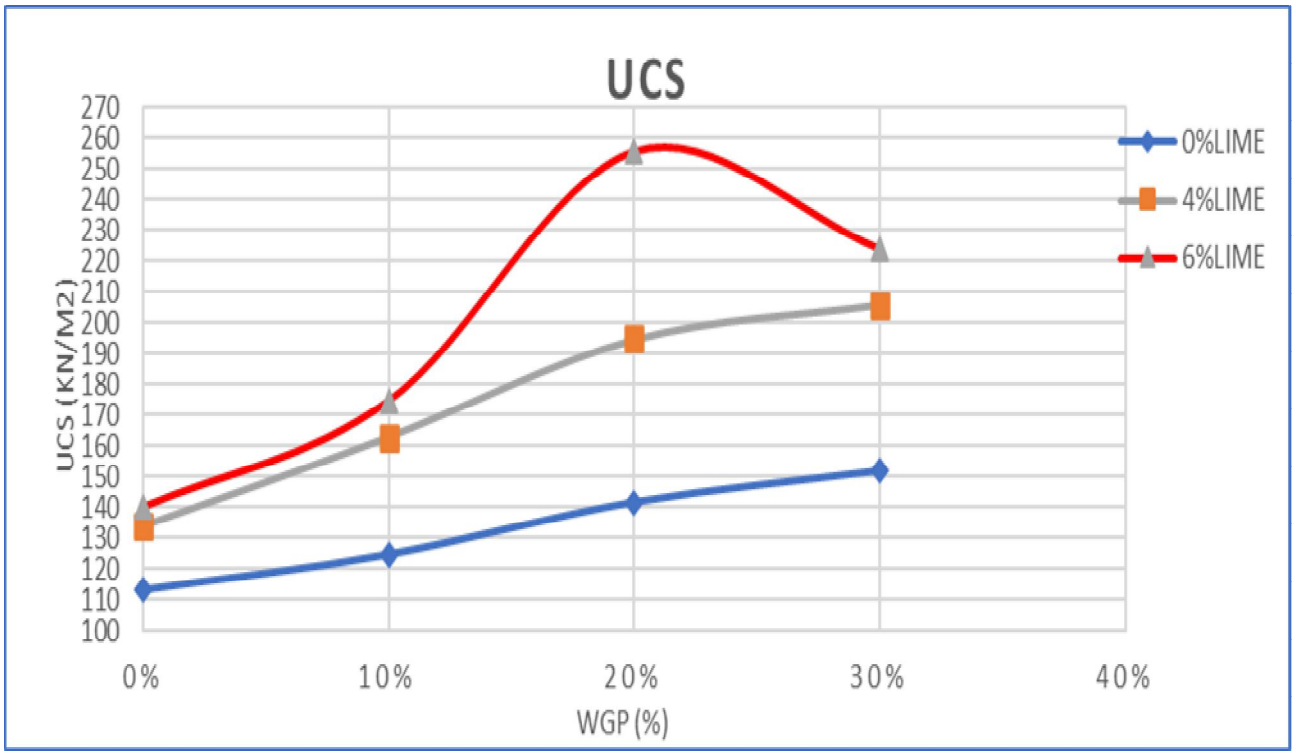
c) Unconfined Compressive Strength: The UCS value of soil 113.24 KN/m^2 was increases 255.60 KN/m^2 with the addition of 20% WGP and 6% lime.

Graph 3: Figure 3 Variation of unconfined compressive strength of soil in different percent of WGP



VI. CONCLUSION

From the above experimental results, following conclusions can be drawn:

A. On this research work and conclude that addition of Waste Glass Powder and quick Lime are suitable for improvement of Engineering properties of BC Soil.

B. The disposal of Waste Glass material may be used as stabilizing material instead of dumping in a land and causing environmental problems.

C. By performing experiment at varying percentage of Glass Powder and Lime, it is concluded that Maximum proctor density and UCS of expansive soil is achieved at 20% of Waste Glass Powder and 6% of Lime in Expansive soil.

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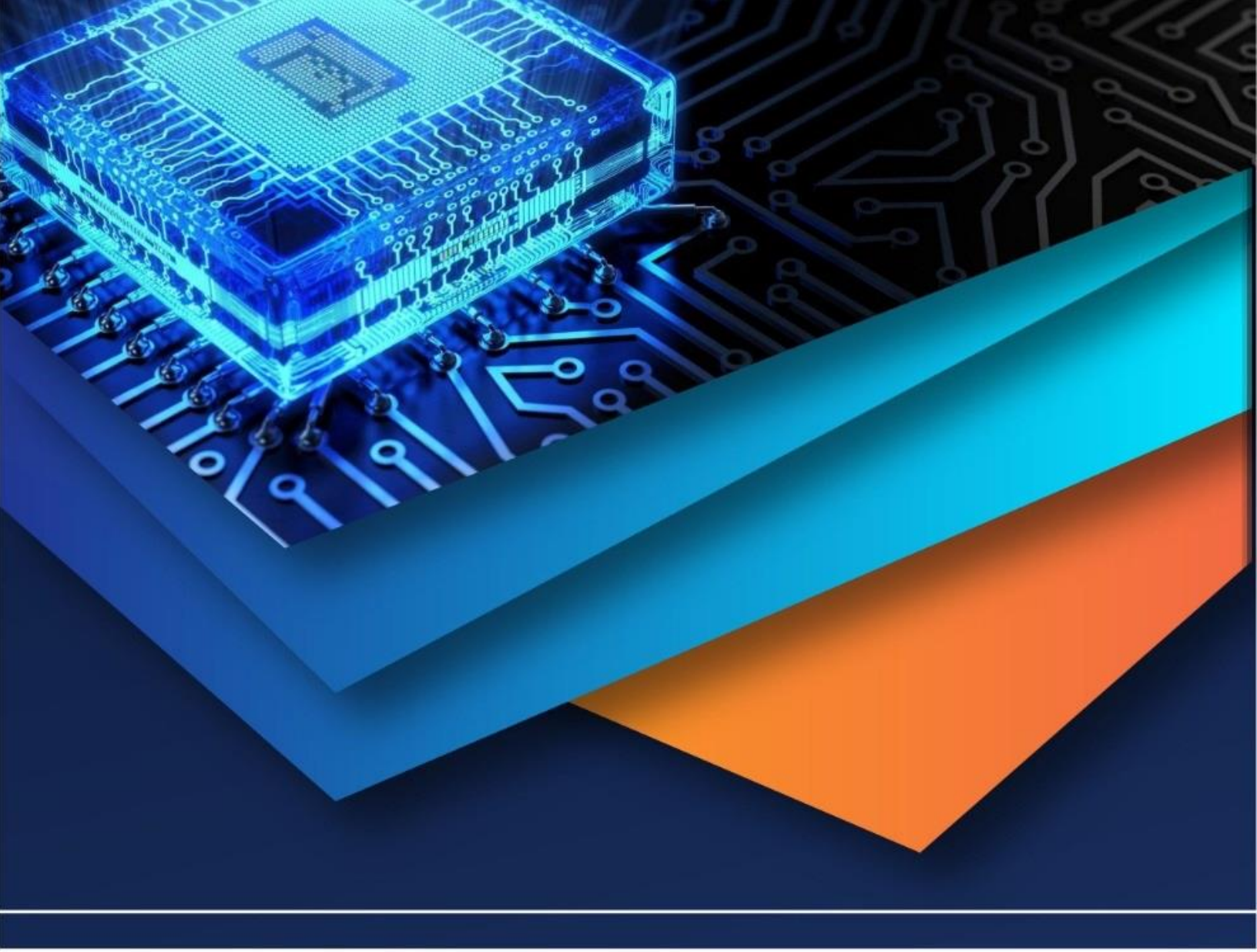

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