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Effect on the Strength Properties of Soil using Ground Granulated Blast Furnace Slag and Sodium Sulphate

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Abstract: Stabilization aims at improving the strength of soil increasing the resistance of soil against softening (due to water) by bonding the soil particles together. These improvements through stabilization include increasing the weight bearing capacities, tensile strength and the overall performances of soils.
In the present study, the potential of GGBS along with Sodium Sulphate to stabilize clayey soils has been evaluated. The GGBS is a material obtained by quenching molten iron slag (a by-product of iron) from a blast furnace in water or steam. The main objectives of this research were to investigate the effect of GGBS and Sodium Sulphate on the engineering properties (liquid limit, plastic limit, optimum moisture content, maximum dry density, compaction etc.) of the soil and to determine the engineering properties of the stabilized soil. GGBS was added in the percentages of 10%, 15%, 20% & 25% while as the Sodium Sulphate was added in percentages of 1%, 2% & 3% by the weight of soil. Considerable changes in the index properties and compaction characteristics were observed which are explained based on a series of experimental results. The addition of GGBS and Sodium Sulphate to the optimum values, increases the strength of mixtures. The maximum dry density was also found increasing with the addition of GGBS and Sodium Sulphate.
Keywords: Clay Soils, Stabilization of Soil, GGBS, Sodium Sulphate, Compaction characteristics.

I. INTRODUCTION

Soils are advanced mixtures of minerals, water, air, organic matter, and innumerable organisms that are the decaying remains of once-living things. It forms the at the surface of the land i.e. it is the skin of earth. The particles that frame soil are classified into three terms by size– sand, silt, and clay. Sand particles are the biggest and clay particles the tiniest. Most soils are a combination of the three. The relative percentages of sand, silt, and clay are what offer soil its texture.

For the construction of any structure, the role of soil is very crucial. It acts as a medium of load transfer as the soil is in direct contact with the structure and hence for any analysis of forces acting on structure, it is necessary to consider the aspect of stress distribution through soil, as stability of structure itself depends on soil properties. Construction of civil engineering structures on expansive soils, however, pose a major risk to the structure in itself, because of the greater degree of instability in these kinds of soil. Now-a-days a lot of construction work is being undertaken throughout the world in the case of highways as well as buildings, both commercial and residential. Very often the available soil is not suitable for construction purposes due to its changing behaviour caused by various factors. Therefore, there's a necessity to go for appropriate technique of low value construction followed by a method of stage development of the roads, to satisfy the growing wants of road traffic. the development may be significantly diminished by choosing native materials as well as native soils for the development of the lower layers of the pavement like the sub-base course and subgrade soil. If the soundness of the native soil isn't adequate for supporting the wheel masses, the properties square measure improved by soil stabilization techniques. The stabilization is the best way to improve the soil used as a foundation for construction of various types of structures. In the present study we have used The stabilization is the technique improving the engineering properties of weak soil by using various stabilizing agents is called soil stabilization.

In this paper utilization of industrial by-products as suitable admixture to enhance the geotechnical properties of clayey soils is presented. Hence an attempt has been made to improve the strength and behaviour of clayey soil using GGBS a by-product of iron ore and Sodium Sulphate in this work. Various tests are carried out according to the IS standards and the different test results have been evaluated.

II. LITERATURE REVIEW

J.Vijaya Chandra (2017) The effect of Granulated blast furnace slag on black cotton soil was determined in this investigation. The soil was replaced with granulated blast furnace slag in different proportion of 10, 20, 30% and 40% by dry weight of soil. The MDD of the soil increased from 15.7kN/m3 to 16.8kN/m3 upon increasing the percentage of GBFS replacing the soil. The OMC of the soil blended with GBFS increased slightly with slag percentage. Free swell index of the soil was found to be decreased by 44% for 30% of slag replacement and thereby degree of expansiveness also decreased. The angle of internal friction showed a considerable improvement from 2° to 14° when GBFS replaced the soil by 30%. The decrease in cohesion occurred from 55kpa to 42kpa when

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30% GBFS replaced the soil. The CBR value (soaked and unsoaked) showed a drastic improvement when 30% GBFS replaced the soil. The increase in CBR value for soaked (CBR from 1.9% to 11.5%) and for unsoaked (7.6% to 17.5%).

Kshipra Kapoor (2017) The main objective of the present study is to improve various engineering properties of the soil by using waste material Ground Granulated Blast Furnace Slag(GGBS) as an alternative to lime or cement. This paper includes the evaluation of soil properties like unconfined compressive strength test and California bearing ratio test. The soil sample was collected from Lalru and addition to that, different percentages of GGBS (0%, 6%, 12 %, 18 % and 24%). was added to find the variation in its original strength. Based on these results CBR test was performed with the GGBS percentages (0%, 6%, 12 %, 18 % and 24%).It is observed that with increase of slag, more stability of soil is achieved as compared to using lime alone. C B R value for soaked and unsoaked increases with increases in percentage of GGBS that show the densification of soil takes place and more suitable for pavement thickness.

Khalifa Harichane (2017) The effect of Sodium Sulphate (0-6% by dry weight of soil) on the behavior of the grey clayey soils and red clayey soils stabilized with lime (L) (0-8%), natural pozzolana (NP) (0-20%) was investigated. The soil specimens were subjected to testing of direct shear strength after 7, 30, 60, and 120 days of curing period. At short curing period and for any content of Na2SO4, there was a gradual increase in shear strength and the shear parameters. However, at any curing periods, the shear strength and shear parameters of both stabilized clayey soils on curing with 2% Sodium Sulphate are still higher than that of the L and/or L-NP treated the same soils without Sodium Sulphate. The degradation of two stabilized clayey soil specimens after 30 days of curing and the gradual reduction of their cohesions and shear strengths can be explained by the formation of ettringite due to the presence of a high content of Na2SO4.

Dayalan j (2016) This study briefly describes the suitability of the local fly ash and ground granulated blast furnace slag (GGBS). In this present study, different amount of fly ash and GGBS are added separately i.e. 5, 10, 15 and 20% by dry weight of soil are used to study the stabilization of soil. It is observed that with the increases of fly ash and GGBS percentage, optimum moisture content goes on decreasing while maximum dry density goes on increasing, hence compact ability of soil increases and making the soil denser and hard.

The maximum optimum moisture content of 14.8% is reached at 10% of fly ash and of 13.7% is reached at 10% of GGBS. This showed that the optimum value based on OMC is 10%. The CBR value increase with increase in amount of fly ash and attained maximum value at 15% and again decreases.

Ashish Kumar Pathak (2014) Soil is mixed with GGBS and their engineering properties were determined. The experimental setup and the test procedure have been planned in such a way that it takes into account all the related aspects. Soil with various amounts of GGBS added to determine the effect on compressive strength of soil and the effect on shear parameter of soil with 0 % to 25% by dry weight of soil. C B R value for soaked and unsoaked increases with increases in percentage of GGBS that show the densification of soil takes place and more suitable for pavement thickness.

Dr.H.N.Ramesh (2013) Shedi soil was collected from shedigudda near Mangalore, Karnataka State, India by open excavation from a depth of 2 m below natural ground level. It was air-dried and pulverized in a ball mill after separating the pebbles. This pulverized soil was passed through 425-micron sieve, used for the investigation. With the addition of 1% Sodium Sulphate to Shedi soil, optimum Neyveli fly ash mixtures the liquid limit decreases on immediate testing. However, there was increase in liquid limit with curing up to 7days and remains almost constant with further curing. Maximum dry density and optimum moisture content increases with the addition of 1% Na2SO4. This indicates the improvement in strength of soil for immediate testing with the addition of 1% Na2SO4.

Laxmikant Yadu (2013) The paper evaluated the potential of Granulated Blast Furnace Slag to stabilize a soft soil. Soft soil samples were collected Tatibandh-Atari Chattisgarh. Different amounts of GBS, i.e, 3, 6, 9 and 12% were used to stabilize soft soil. The performance of GBS stabilized soils was evaluated using physical and strength performance tests namely, plasticity index, specific gravity, free swelling index, compaction, swelling pressure, California bearing ratio (CBR). The liquid limit, plastic limit and plasticity index of the raw soil were found 46%, 29%&17% respectively.

The results indicate that the use of GBS to the soft soil significantly improves the physical and the strength properties of soil. MDD increased while OMC decreased with the addition of GBS. There is significant reduction in the swelling behaviour of the soil. Based on the strength tests, optimum amount of GBS was determined as 9%. Soaked CBR and UCS values increased about 400%and 28% respectively by the addition of optimum amount of GBS.

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III. MATERIALS AND METHODOLOGY

A. Clayey Soil

Clay refers to present materials that are composed primarily of fine-grained minerals. It's a finely grained natural rock that mixes one or a lot of clay minerals with traces of metal oxides (Al2O3, MgO etc). These soils produce swelling after they are exposed to water and shrink once water is squeezed out. These changes cause failure to the civil infrastructure. Clay soil is reddish brown in color, has small particles and small pores between them. Clay soil tends to stay together causing water to fill up the air spaces. Clay are compressible, i.e. if a moist mass is subjected to compression, moisture and air may be expelled resulting in the reduction in volume.

B. Ground Granulated Blast Furnace Slag

GGBS is produced as a by-product during the manufacture of iron. This material is obtained by heating iron ore, limestone and coke in a blast furnace at a temperature of about 1500 degree Celsius. A molten slag is produced at the end of this process and this slag is then allowed to pass through high pressure water jet. This results in quenching of the particles which results in formation granules of size lesser than 5mm in diameter. The particles are further dried and ground in a rotating ball mill to form a fine powder, known as ground granulated blast furnace slag cement. It is found that working with GGBFS is easy as it has greater mobility characteristics. This is due to its fineness and the particle shape of the GGBFS particles. These also possess a lower relative density. The main constituents that are found in abundance in according to the percentages present in GGBS are CaO (30%-50%), SiO2 (28%-40%), Al2O3 (8%-24%) & MgO (1%-18%).

Table 1 Physical Properties of GGBS

Property	Value
Physical form	Off White Powder
Bulk Density(kg/m3)	1200
Specific Gravity	2.9
Specific Surface(m^2/kg)	425-470

C. Sodium Sulphate

It is also produced from by-products of chemical processes such as hydrochloric acid production. In 1625, Johann Rudolf Glauber discovered the sodium sulphate from Austrian spring water, there so the hydrate form is known as Glauber's salt. Due to its medicinal properties, he named it as salt mirabilis (miraculous salt). The crystals were used as a general purpose laxative. Glauber's salt was also used as a raw material for the industrial production of soda ash.

Table 2 Properties of Sodium Sulphate

Molecular Formula	Na_2SO_4
Molecular Weight	142.04gm/mole (anhyd), 322.20gm/mole (decahyd)
Appereance	White crystalline solid
Melting Point	8840 C (anhydrous), 32.40C (decahydrate)
Density	2.664gm/ml (anhydrous), 1.464gm/ml (decahydrate)

IV. METHODOLOGY

In the present study, GGBS and Sodium Sulphate were used as the additives to stabilize clayey soil. GGBS was added in percentages of 10%, 15%, 20%, 25% while as Sodium Sulphate was mixed in 1%, 2% & 3% respectively by dry weight of soil. The properties of the blended mix were evaluated in the laboratory and compared to obtain an optimum value of GGBS and Sodium Sulphate content for stabilizing the clayey soil.

V. TESTS INVOLVED

The following tests are to be conducted on virgin soil as well as soil containing different proportion of Sodium Sulphate and Granulated Blast Furnace Slag to determine the various parameters proposed in the objectives;

A. Unconfined Compression Test - IS 2720, Part 10 1991
B. California Bearing Ratio Test – IS 2720, Part 16 1979

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VI. RESULTS AND DISCUSSIONS

A. *Unconfined Compression Test*

The UCS tests were conducted on clayey soil and blended material in accordance with IS:2720 (Part 10)-1991. The test is widely used for evaluating the strength of the stabilized soil and the effectiveness of stabilization. The compressive load per unit area is termed as Unconfined Compression Test. This test is used to determine the shear parameters of soil.

The variations in the values of UCS with the increase in percentages of GGBS and Sodium Sulphate from 0%-25% and 0%-35 respectively are tabulated in Table 3.

Table 3 Variations in the values of UCS of various mix proportions at different curing periods

Soil : GGBS :Sodium Sulphate	UCS (kg/cm^2) 3days curing	UCS (kg/cm^2) 7days curing	UCS (kg/cm^2) 28days curing
100:0:0	0.94	0.94	0.94
89:10:1	0.87	1.33	1.47
84:25:1	1.25	1.52	1.63
79:20:1	1.43	1.59	1.69
74:25:1	1.55	1.64	1.73
88:10:2	1.62	1.77	1.81
83:15:2	1.76	1.86	1.96
78:20:2	1.82	1.94	2.24
73:25:2	1.74	1.82	1.98
87:10:3	1.67	1.76	1.84
82:15:3	1.54	1.65	1.73
77:20:3	1.49	1.53	1.62
72:25:3	1.31	1.48	1.55

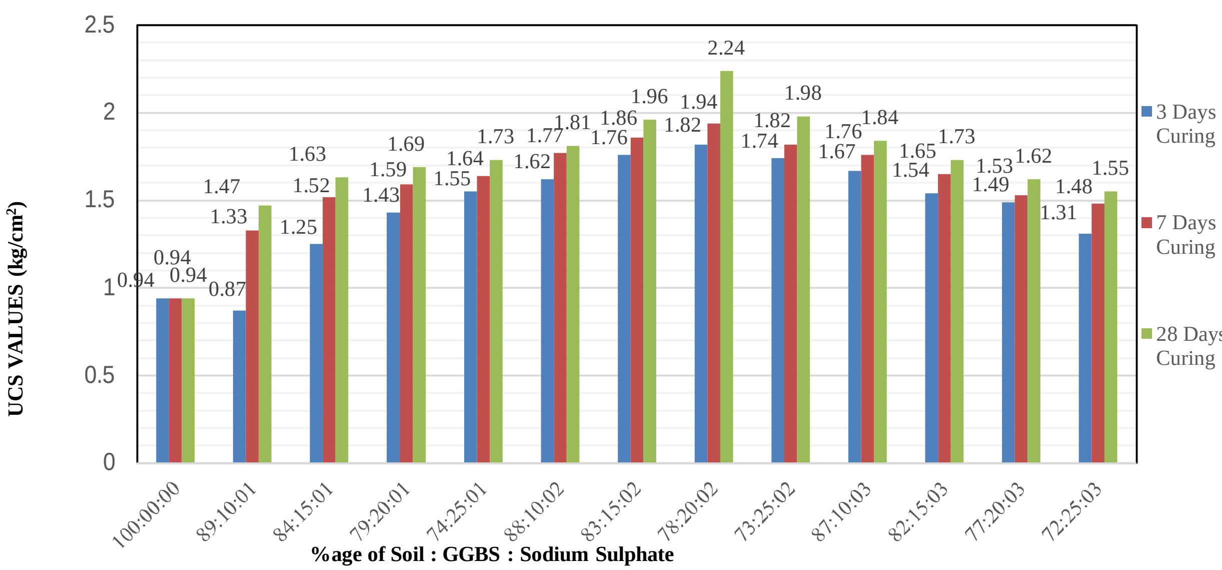

Fig 1 Various proportions of Soil, with varying percentages of GGBS and Sodium Sulphate treated together

When different proportions of soil samples are treated with different amounts of GGBS and Sodium Sulphate, then up to optimum value, the unconfined compressive strength values attain the maximum value. But after the optimum value, the readings show a gradual decrease. The highest value of UCS is reached at the mix of 78% of soil, 20% of GGBS and 2% of Sodium Sulphate. The increase in the values of UCS is because of the formation of cementitious compound between CaOH present in the soil and the pozzolana present in GGBS. While as the decrease in the values of UCS is due to the excess amount of GGBS, which weakens the bonds formed between cementitious compounds formed and the soil.

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B. California Bearing Ratio Test

The test was performed as per IS 2720(Part 16): 1979. This test is used to evaluate the mechanical strength of road sub-grades and base courses. In this test, the pressure that is required to penetrate a soil sample is measured using a plunger of standard area. After the measurement of this pressure, it is then divided by the pressure required to achieve an equal penetration on a standard crushed rock material. Thus, CBR test is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min.

The variations in the values of CBR with the addition of GGBS and Sodium Sulphate are tabulated in Table 4.

Table 4 California Bearing Ratio Test Results for various mix proportions

Soil : GGBS : Sodium Sulphate	CBR
100:0:0	3.83
78:20:2	17.89
73:25:2	16.77

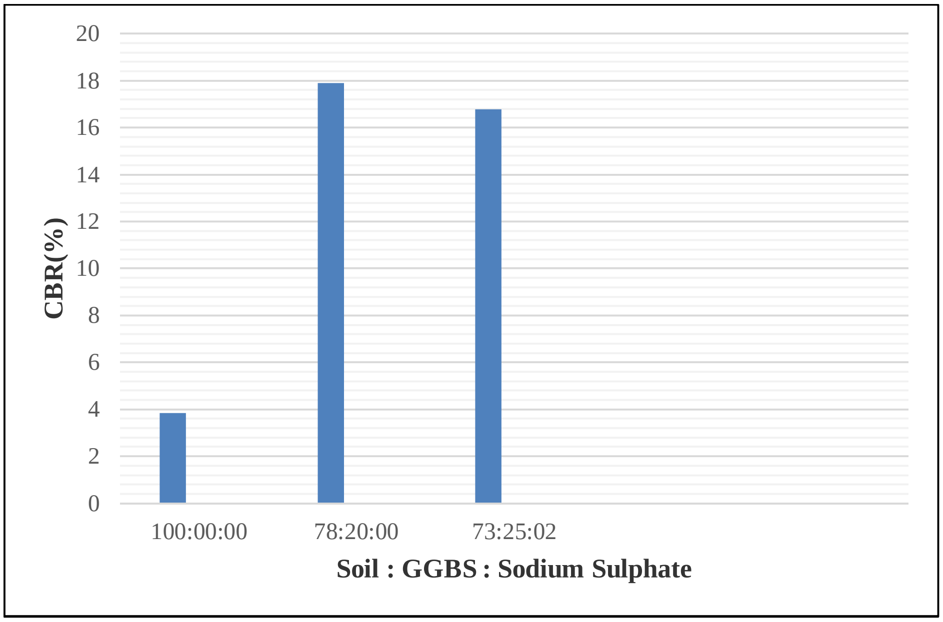

Fig 2 Various proportions of Soil, with varying percentages of GGBS and Sodium Sulphate treated together

When different proportions of soil samples are treated with different amounts of GGBS and Sodium Sulphate, the CBR values start increasing. But after the optimum value, the readings show a gradual decrease. The highest value of CBR is reached at the mix of 78% of soil, 20% of GGBS and 2% of Sodium Sulphate. The increase in the values of CBR is because of the formation of cementitious compound between CaOH present in the soil and the pozzolana present in GGBS. While as the decrease in the values of CBR is due to the excess amount of GGBS, which weakens the bonds formed between cementitious compounds formed and the soil.

VII. CONCLUSIONS

A. The compressive strength of soil from UCS test increases from 0.94 kg/cm2 with addition of GGBS and Sodium Sulphate till it becomes maximum i.e. 1.82 kg/cm2 for optimum mix (78% soil, 20% GGBS, 2% Sodium Sulphate) and then goes on decreasing. The same pattern is observed for 7days and 28days curing periods.

B. With the increases of GGBS percentage compressive strength increases that means arrangement of soil particles are very closely, which reduces the voids.

C. The CBR value is found to increase from 3.83% with the increase in the value of GGBS and Sodium Sulphate till it attains maximum value of 17.89% for optimum mix (78% soil, 20% GGBS, 2% Sodium Sulphate)

D. C B R value increases with increases in percentage of GGBS that show the densification of soil takes place and more suitable for pavement thickness.

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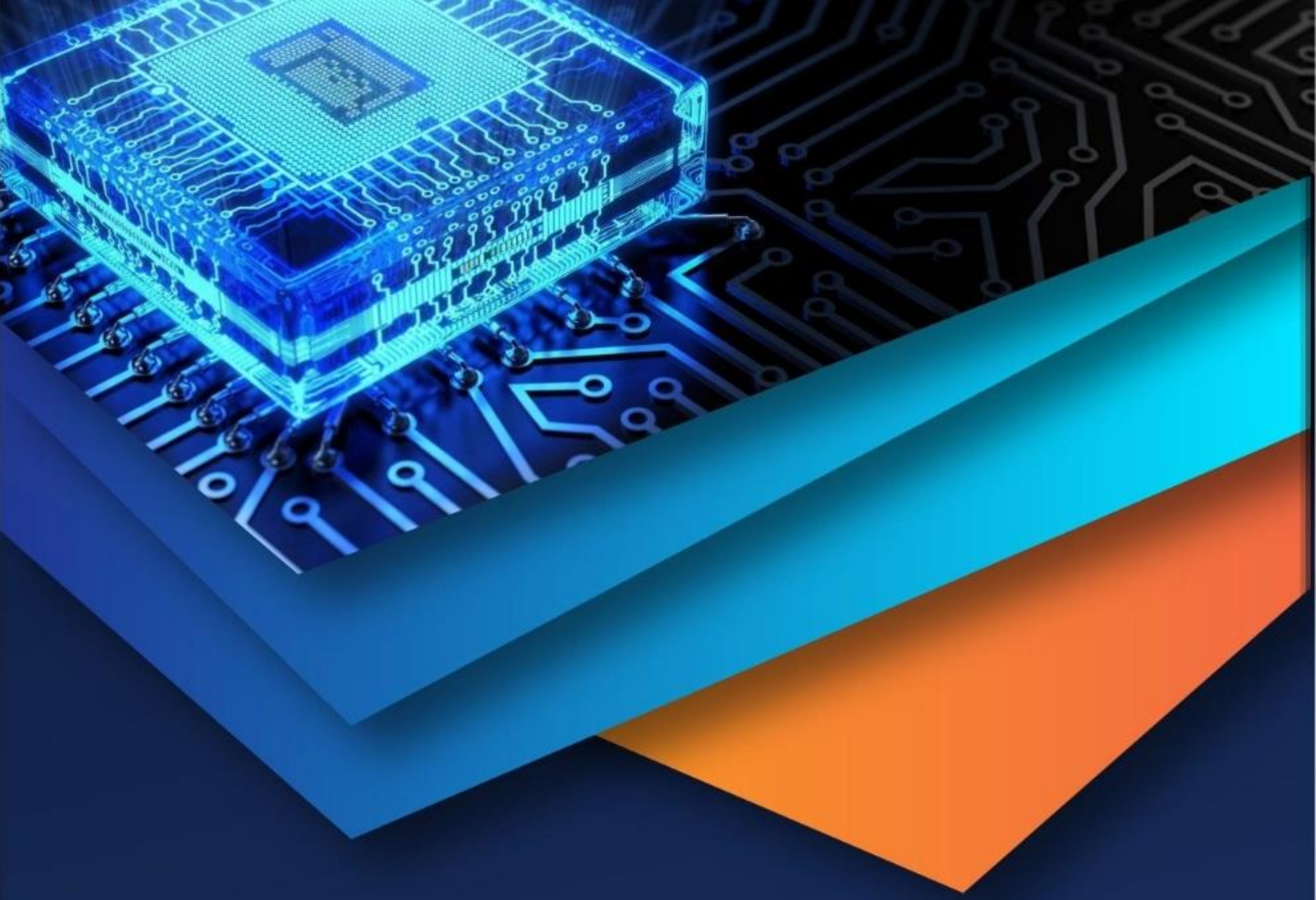

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