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Analysis of Chemical Stabilizer on the Behavior of Expansive Soil

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Abstract:** Rapid growth in industrialization and urbanization in developing countries like India, leads to increasing scarcity of land which forces us to utilize the available land even though it is problematic. Problematic soils are those having low bearing capacity, high compressibility and high swelling/shrinkage and as such they are not suitable for any geotechnical application. In most geotechnical engineering projects, increase in concentration of Red mud, Maximum dry density of mixture increases. The mix containing 30% Red Mud + 67% Soil + 3% Fly Ash has good bearing strength characteristics. The bearing strengths of Red Mud were increased to 7.354% on addition of Red Mud and Fly Ash in the ratios of 30% and 3% respectively. With increase in concentration of red mud, California bearing ratio increase up to a fixed concentration of Red mud. With increase in percentage concentration of Red Mud, Optimum moisture content of the mixture (Red Mud + Fly Ash + Soil) increases. With increase in concentration of Red mud, Maximum dry density of mixture increases.

I. INTRODUCTION

Expansive soils are known as one of the problematic soils. These soils are residual deposits formed from basalt or trap rocks. They contain essentially the clay mineral montmorillonite, which is the most unstable clay mineral, thus the soils have shrinkage and swelling characteristics upon change in water content.

The climatic conditions exist in arid and semiarid areas where evaporation exceeds precipitation and also where there is poor leaching and drainage is more conducive for the formation of expansive soils. The major clay mineral present in the expansive soil is montmorillonite. It belongs to smectite group minerals. High pH, high electrolyte content and the presence of more Mg^{2+} and Ca^{2+} than Na^+ and K^+ are more favourable conditions for the formation of montmorillonite mineral. It is a three sheet mineral with 2:1 silica:alumina structure. It consists of an octahedral sheet (This sheet structure is composed of magnesium or aluminium in octahedral coordination with oxygens or hydroxyls) sandwiched between two silica sheets (This sheet structure is composed of silica tetrahedral interconnected in a sheet structure. Three of the four oxygens in each tetrahedron are shared to form a hexagonal net). The structure of montmorillonite is replacement of every sixth aluminium by a magnesium ion. Montmorillonite mineral has this composition. Charge deficiencies resulted from isomorphous substitution are balanced by exchangeable cations located between the unit cell layers and on the surfaces of particles. The arrow showed in the chemical formula of Montmorillonite indicates the source of the charge deficiency, which is 0.66 per unit cell for Montmorillonite. Sodium shown in the formula indicates that it is a balancing cation. The interlayer bond in montmorillonite is by van der Waals forces and by cations that balance charge deficiencies in structure, which is weak and easily separated by cleavage or adsorption of water or other polar liquids. The basal spacing is variable and is ranging from about 9.6 Å to complete separation. The shape of montmorillonite is equidimentional flakes. The thickness of particles ranges from 1-nm unit layers upward to about 1/100 of the width. The cation exchange capacity ranges from 80-150 meq/100g. Specific gravity ranges from 2.35 to 2.7. The primary specific surface area (The surface area exclusive of interlayer zones) ranges from 50-120 m^2/g. The secondary specific surface that is exposed by expanding the lattice so that polar molecules can penetrate between layers ranges between 700 – 840 m^2/g.

Presence of Montmorillonite mineral makes the soil unsuitable either as a load bearing material or as a Construction chemical. These soils typically exhibit moderate to high plasticity, low to moderate strength and high swell-shrink characteristics[20,60,5,11,2,52]. Expansive soils are commonly found in many parts of the world particularly in arid and semi-arid regions of Australia, Canada, China, India, Israel, South Africa and the United States.

Soil stabilization aims at improving strength of soil and reducing settlement and volume change of soil[61]. Compaction and drainage are the simplest stabilization methods. The other stabilization method is by improving gradation of particle size and further improvement can be achieved by adding binders to the weak soils[57]. Soil stabilization can be accomplished by several methods. All these methods can be grouped into two broad categories (FM 5-410). They are (1) mechanical stabilization and (2) chemical stabilization.

A. Mechanical Stabilization

If soil stabilization is achieved through physical process by altering the physical nature of native soil particles by either induced vibration or compaction or by incorporating other physical properties such as barriers and nailing, then this method of stabilization is known as mechanical stabilization.

B. Chemical Stabilization

In chemical stabilization method, soil stabilization depends mainly on chemical reactions between the stabilizer added and mineral present in the soil. The chemical used for stabilisation is known as cementitious material and the mineral present in the soil is referred as pozzolanic material.

Through soil stabilization, unbound materials can be stabilized with cementitious materials like cement, lime, fly ash, bitumen etc. The stabilized soils generally have a higher strength, higher permeability and lower compressibility than the unstabilised soil. The important properties of soil which are of interest to geotechnical engineers are strength, compressibility, permeability, volume stability, and durability[28,61]. Laboratory studies on stabilized soil will enhance the knowledge on the choice of binders and amount of binders to be used for improving the properties of soil.

Though various methods are available to improve the performance of poor quality soils, the choice of a particular method depends mainly on the type of soil to be improved, its characteristics and degree of improvement desired in a particular application. Among the various ground improvement techniques chemical stabilization is most preferred in improving the engineering properties of expansive soils. In addition, chemical stabilization is one of the most economical techniques to improve the engineering behaviour of expansive soils. This method is used in road (highway, railway and runway) construction to improve sub-bases and sub-grades, for embankments, as soil exchange in unstable slopes, as backfill for bridge abutments and retaining walls, as canal linings and for improvement of soil beneath foundation slabs[3,4].

II. REVIEW PREVIOUS WORK

Sabat et al[58] studied the combined effects of two industrial wastes, bagasse ash and lime sludge on compaction characteristics, unconfined compressive strength (UCS), soaked California bearing ratio (CBR) and swelling pressure of expansive soil. Effects of molding water content and compaction delay on soaked CBR of bagasse ash, lime sludge stabilized expansive soil has also been discussed. The materials used in the experiments are expansive soil, bagasse ash and lime sludge. The geotechnical properties of expansive soil used in this study are: sand size- 18%, silt size- 26%, clay size- 56%, specific gravity- 2.6, liquid limit- 60%, plastic limit- 32%, shrinkage limit-11%, swelling pressure- 128 kN/m^2, OMC-21%, MDD- 16.1 kN/m^3, UCS- 58 kN/m^2 and Soaked CBR- 1.98%. Different samples/mixes of expansive soil- bagasse ash-lime sludge were prepared, in which the amount of bagasse ash was varied from 0 to 16 percent by dry weight of soil in steps of 4 percent and lime sludge from 0 to 20 percent by dry weight of soil in steps of 4 percent. Each sample was cured for 7 days before conduction of any tests. The soaked CBR tests were conducted after soaking the samples for 4 days. The different samples for CBR, UCS and swelling pressure prepared at its corresponding moisture content and dry density. To study the effect of molding water content on soaked CBR, different sample (having optimum proportion of bagasse ash and lime sludge) were prepared by compacting it at MDD (corresponding to OMC value) but having different molding water content i.e. at OMC, dry and wet (90%, 92.5%, 95%, 97.5%, 100%, 102.5%, 105%, 107.5%, 110%) of OMC.

Based on results it is noticed that

1) The addition of bagasse ash to expansive soil decreases the MDD and increases the OMC of the expansive soil irrespective of the percentage of addition of bagasse ash.
2) The UCS and soaked CBR are observed to have maximum values corresponding to the mix having proportion of soil 76%, bagasse ash 8% and lime sludge 16%. The optimum proportion of soil: bagasse ash: lime sludge is found to be 76:8:16.
3) The swelling pressure goes on decreasing with addition of both bagasse ash and lime sludge. The swelling pressure of expansive soil having bagasse ash 8% and lime sludge 16% is found to be 18 kN/m^2, which will not create problem to flexible pavements.
4) The variation in molding water content reduces the soaked CBR value of the bagasse ash, lime sludge stabilized expansive soil substantially, hence the bagasse ash, lime sludge stabilized expansive soil should be compacted.

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Gandhi[16] carried out work on stabilization of expansive soil with varying percentage of bagasse ash. Bagasse is the matted cellulose fibre residue from sugarcane that has been processed in a Sugar mill. Utilization of industrial and agricultural waste products in the industry has been the focus of research for economic, environmental and technical reasons. Sugarcane bagasse is a fibrous waste product of the sugar refining industry.

a) Various tests like Liquid Limit, Plastic Limit, Plasticity Index, Shrinkage Limit, Free Swell Index and Swelling Pressure performed.
b) The percentage of bagasse ash is kept as 0%, 3%, 5%, 7% and 10% respectively and all the tests are conducted.
c) The results show that when the percentage of furnace ash is increased in the soil sample, all the properties decrease.

Negi et al[47] studied the feasibility of using Silica fume as soil stabilization material. Silica fume also referred as micro-silica is a product resulting reduction of high purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferro-silicon alloy. Silica fume rises as an oxidized vapour. It cools, condenses and is collected. It is fine grey coloured powder sometime similar to Portland cement or some fly ashes. In this paper the effect of Silica fume on engineering characteristics of expansive clay like black cotton soil has been presented. In soil, Silica fume is mixed on percentage basis i.e. 0%, 5%, 10%, 15% and 20% by weight of dry soil. Compaction Test, California bearing ratio test, unconfined compressive strength test, differential free swell test were conducted on BC soil and Silica fume mixes.

III. METHODOLODY

To achieve the objectives, methodology of the proposed research work has been framed and shown as flow chart in Figure 3.1. The stabilizers chosen for this study are Construction chemical, Terrazyme, Phosphogypsum, Lime, Copper slag, Red mud, Rice Husk Ash and Geopolymer. Soil chosen for this study is high plastic clay. Variables considered are percentage of stabilizer and period of curing. Various tests are conducted to evaluate index and engineering Properties of stabilized soil

The tests included in the index properties of virgin soil and soil mixed with admixtures are as follows

1) Specific gravity (IS 2720 Part III -1980)[22]
2) Grain size distribution (IS 2720 Part IV - 1985)[23]
3) Liquid limit (IS 2720 Part V - 1985)[25]
4) Plastic limit (IS 2720 Part V - 1985)[26]
5) Shrinkage limit (IS 2720 Part VI - 1972)[27]
6) Differential free swell index (IS 2720 Part XL -1977)[24]

The grain size distribution curve of the soil-1 used in the proposed investigation is presented in Figure 3.11. The colour of the soil is grey in dry state and black in wet state. The properties of the soil-1 are given in Table 3.1. The specific gravity of natural soil-1 is 2.72. The soil-1 composed of 2% gravel fractions, 19% sand fractions, 8% silt fraction and 71% clay fraction.

The soil-1 exhibited liquid limit and plastic limit of 68% and 27% respectively. The plasticity index of the soil is 41% and its shrinkage limit is 10%. Based on IS soil classification system, the soil is classified as Clay of High plasticity (CH). The soil-1 exhibited differential free swell index of 60%. As per IS 2911 part III 1980 for free swell index of 60%, the soil-1 is classified as high swelling soil. Further the plasticity index and shrinkage limit values of the soil-1 also confirm its high swelling quality. Figure 3.12 shows the standard Proctor compaction curve for soil-1. The soil-1 showed a maximum dry unit weight of 16.1kN/m^3 at an optimum moisture content of 19.22% for Standard Proctor energy. The permeability of CH group soil when compacted is known as impervious, the shear strength when compacted and saturated is poor. The compressibility when compacted and saturated is poor. Since the CH group soil is not exhibiting suitable engineering properties, there is a need to improve its behaviour and chemical stabilization is one of the famous techniques.

PARTICLE SIZE(mm)	Percentage Finer
0.001	60
0.01	70.23
0.1	78
1	80
10	90

Table 3.1 Grain Size Distribution Curve of Soil-1

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Water Content (%)	Dry unit weight(KN/M3)
5	13.7
10	14.2
15	15
20	16.2
25	15.3
30	13
35	12

Table 3.2 Standard Proctor Compaction curve for soil-1

Table 3.2 Properties of Soil - 1

Properties	Value
Specific Gravity	2.72
Gravel (%)	2
Sand (%)	19
Silt (%)	8
Clay (%)	71
Liquid limit (%)	68
Plastic limit (%)	27
Plasticity index (%)	41
Shrinkage limit (%)	10
Differential Free swell index (%)	60
IS Soil classification group symbol	CH
Optimum Moisture Content (%)	19.22
Maximum Dry unit weight(kN/m^3)	16.1
Swell classification	High

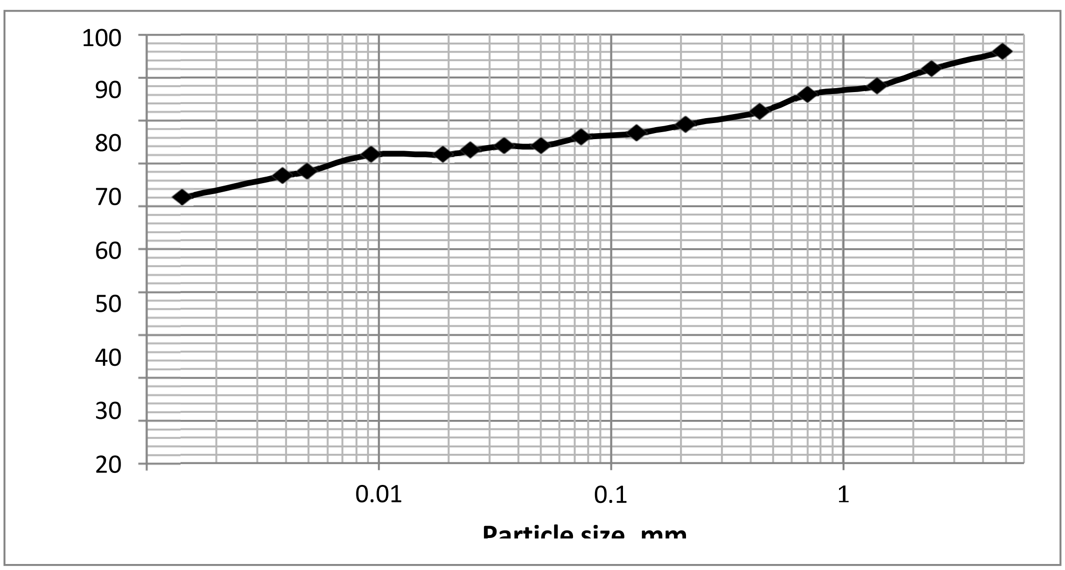

Figure 3.11 Grain Size Distribution Curve of Soil-1

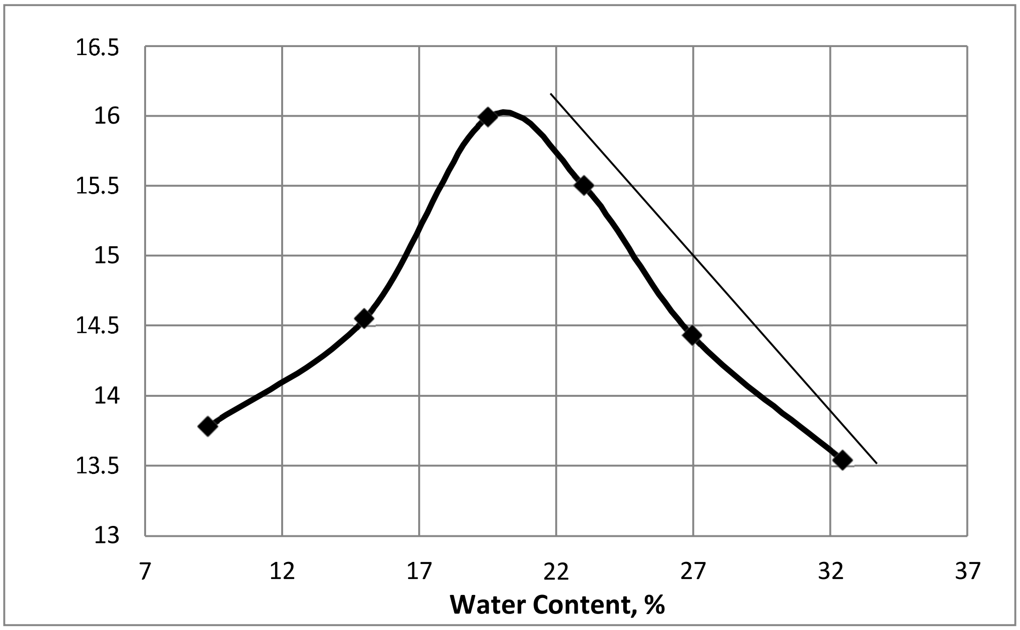

Figure 3.12 Standard Proctor Compaction curve for soil-1

A. Soil - 2

The soil-2 is examined for its index and engineering properties as per IS specifications and the test results are tabulated in Table 3.2. From the index property test, it is observed that the specific gravity of soil-2 is 2.67. The grain size distribution curve of soil-2 is shown in the Figure 3.13. The soil-2 composed of 0.3% gravel, 4.7% of sand, 23% of silt and 72% of clay. The soil-2 showed liquid limit of 66%, plastic limit of 34%, plasticity index of 32%, shrinkage limit of 13% and differential free swell index of 100%. As per Indian standard soil classification system, the soil-2 is classified as clay of high compressibility (CH).

PARTICLE SIZE(mm)	Precentage Finer
0.001	65
0.01	70
0.1	85
1	90
10	99

Table 3.1 Grain Size Distribution Curve of Soil-1

Water Content (%)	Dry unit weight(KN/M3)
5	14
10	15
15	15.2
20	15.6
25	15
30	12
35	11

Table 3.2 Standard Proctor Compaction curve for soil-1

axial strain *10^-3	Axial stress (Kn/m^2)
5	5.2
10	7
15	10.2
20	12
25	20
30	40.34
35	45.23
40	50.12
45	52.13
50	55
55	60.33
60	90.23
65	100.34
70	110
75	120.45

Table Stress – Strain relationship of Soil - 2

Table 3.2 Properties of Soil - 2

Properties	Values
Specific gravity	2.67
Gravel fraction, %	0.3
Sand fraction, %	4.7
Silt fraction, %	23
Clay fraction, %	72
Liquid limit, %	66
Plastic limit, %	34
Plasticity index, %	32
Shrinkage limit, %	12.8
Differential Free swell index, %	100
IS Soil Classification Group Symbol	CH
Optimum moisture content, %	20.6
Maximum dry unit weight, kN/m^3	15.36
Swell classification	High
Unconfined compressive strength, kN/m^2 (at γ_d = 15.36 kN/m^3 & w = 20.6 %)	170.97

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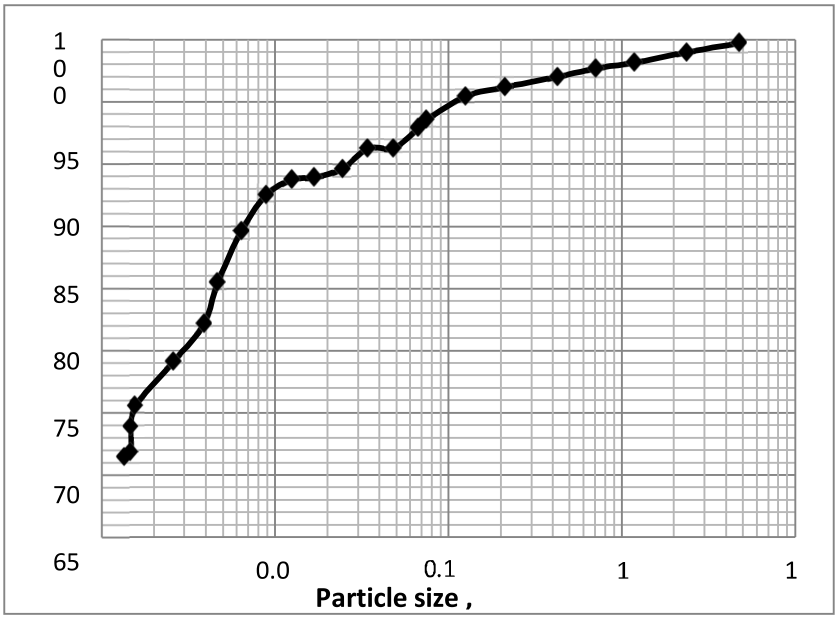

Figure 3.13 Grain Size Distribution Curve of Soil-2

The compaction curve for soil-2 obtained through standard Proctor compaction test is shown in Figure 3.14. The soil exhibited standard Proctor maximum dry unit weight of 15.36 kN/m^3 and Optimum Moisture Content of 20.6 %.

IV. CONCLUSION

Addition of Construction chemical and Terrazyme does not show much variation in liquid limit and plastic limit with increase in percentage and curing period. However Phosphogypsum shows significant variation. The reduction in plasticity characteristics has been attributed to the suppression of double layer thickness caused by cation exchange of high valence ions whereas plasticity characteristics of soil treated with lime increased significantly at higher curing period. This may be due to the fact of flocculated particle will have higher water holding capacity. Present study mainly concentrated on improving the plasticity characteristics and strength of high plastic clay. There is a scope to extend this study by focussing the effect of different chemicals on the swell-shrink characteristics, consolidation characteristics and permeability characteristics of expansive soil.

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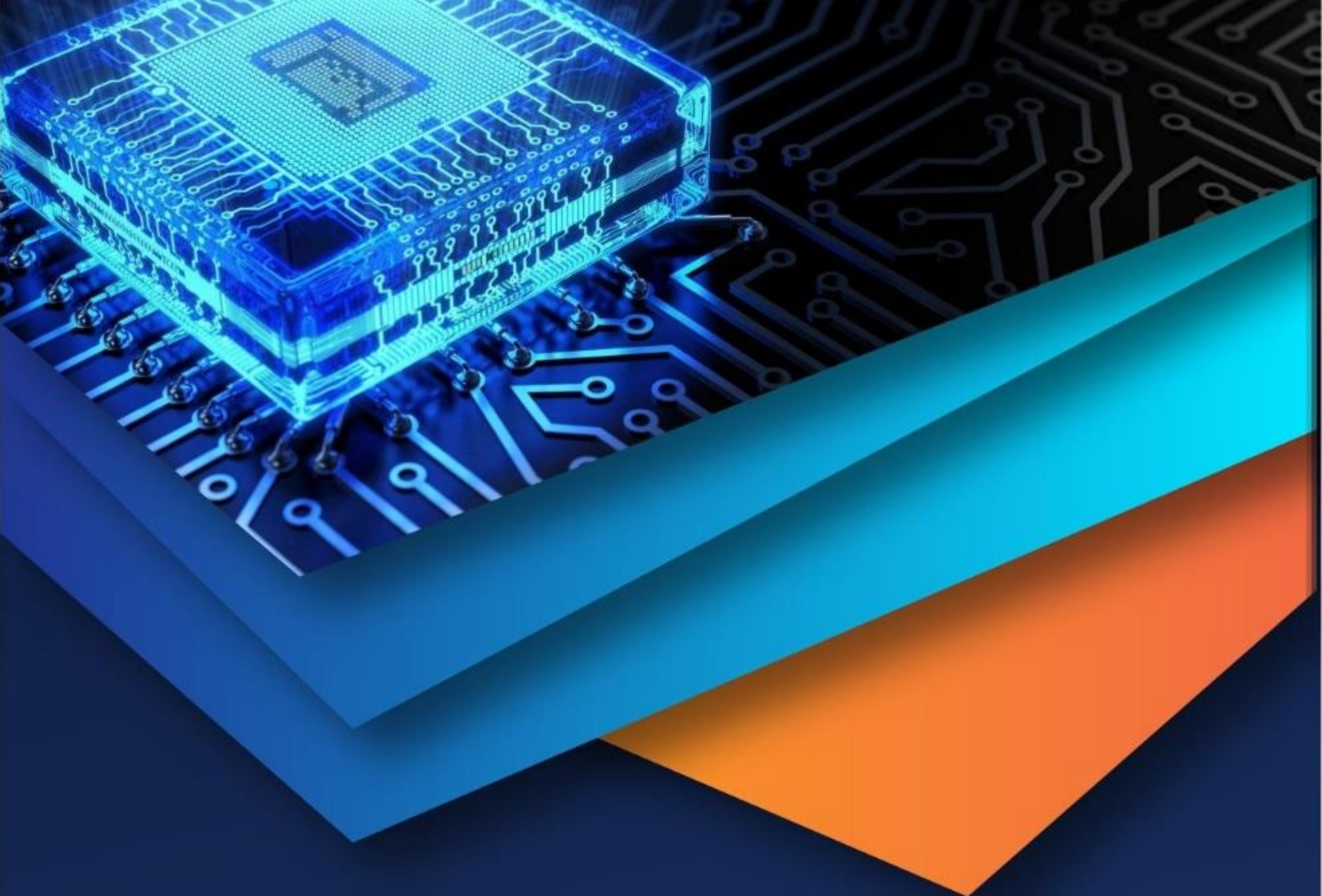

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