iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** V **Month of publication:** May 2025

DOI: https://doi.org/10.22214/ijraset.2025.70586

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

Utilization of Low CBR Soil for Flexible Pavements for Low Volume Roads with Robosand Stabilization

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Abstract: Many rural areas in developing countries like India lack adequate and affordable access to transport infrastructure and services. The problem is more persistent in low volume and low CBR value sub-grades. The objective of this project is to evaluate the required flexible pavement for very low volume traffic roads with very low CBR values with practically very low traffic of not more than 30-40 vehicles mostly comprising passenger cars where the level of serviceability is very high.

The IRC recommended pavement composition is for unpaved gravel roads in rural areas with low volume traffic. There are various disadvantages associated with construction of the road using gravel like dust generation, and gravel loss over a period of time due to passage of vehicles and inaccessibility during rains and the quality of serviceability is unsatisfactory. Problems with sub grade having low CBR values are stability and large deformations or settlements.

A project has been taken up where the CBR of sub grade soil is less, the soil is improved by mechanical stabilization with an additive of robosand. The emphasis of the project is 'Utilization of low CBR soil for flexible pavements for low volume roads with robosand stabilization'.

The addition of robosand has improved the sub soil condition in achieving higher CBR value. Locally available soils mixed with crushed robosand serve as effective reinforcement in soft soils for different sub-grade resulting in technically better sub-grade as well cost economy in savings of aggregate material and also reducing carbon foot print.

Keywords: CBR, flexible pavement, Subgrade, Robosand, IRC recommendations.

I. INTRODUCTION

Rural road connectivity is a key component of rural development, since it promotes access to economic and social services, thereby generating increased agricultural productivity, non- agriculture employment as well as non agricultural productivity, which in turn expand rural growth opportunities and real income through which poverty can be reduced.

The Ministry of Rural Development (MORD), Government of India has decided to develop various rural roads under Pradhan Mantri Gram Sadak Yojana (PMGSY). The PMGSY has set up a programme to achieve all weather connectivity to all the habitations with population more than 500 (250 for hilly areas) by the end of tenth five year plan i.e. by 2007. Gravel roads are important components of the road transportation network throughout the world which have not yet been paved. In many developing countries, more than 75% of the road network consists of gravel and earth roads. Aggregate surfaced roads are referred to as unpaved roads. Gravel pavement will not only carry traffic loads but will also be resistant to shear deformation and wear i.e. they have to be of sufficient strength and durable The CBR test is a way of putting a figure on the inherent strength, the test is done in a standard manner to compare the strengths of different subgrade materials, and the CBR values are used as a means of designing the road pavement required for a particular strength of subgrade. The stronger the subgrade (the higher the CBR reading) the less thick it is necessary to design and construct the road pavement, this gives a considerable cost saving. Conversely if CBR testing indicates the subgrade is weak (a low CBR reading) a suitable thicker road pavement is to be adopted to spread the wheel load over a greater area of the weak subgrade in order that the weak subgrade material is not deformed, causing the road pavement to fail. The CBR in spite of its limited accuracy still remains the most generally accepted method of determining subgrade strength, and as such this information, along with information on traffic flows and traffic growth is used to design road pavements.

II. STUDY AREA

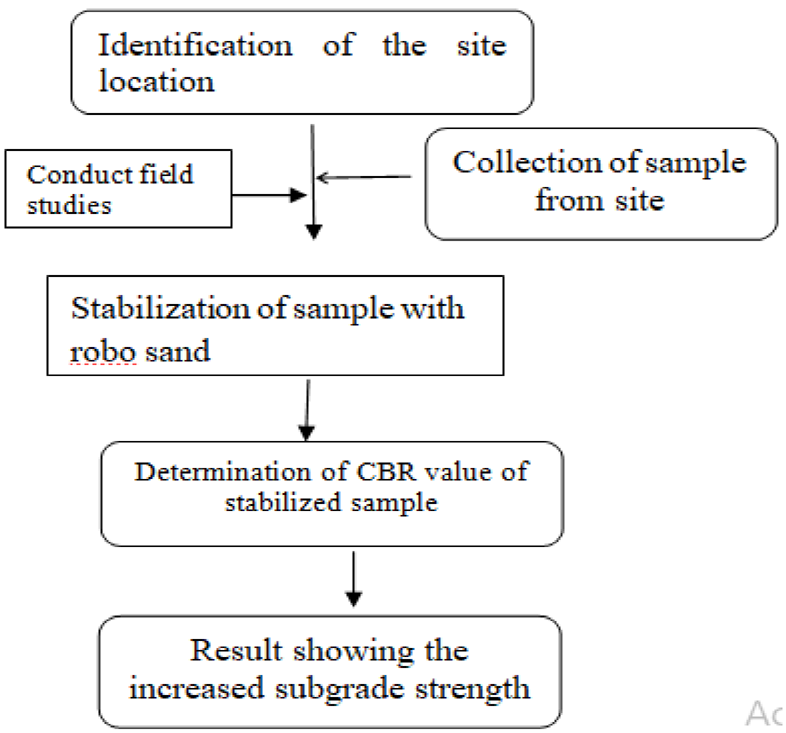
The proposed road falls in the proposed campus of College of Engineering at Sulthanpur, JNTUH in Pulkal Mandal, district of Medak in Telangana State. Medak district coordinates are between 17°27'and 17°79' Northern latitude and 78°27' and 79°35' Eastern longitude. Geologically the District is covered by Classified Granite Rocks, the district has a mean maximum temperature of 40˚C and a mean minimum temperature of 26˚C. The average annual rain fall is 873 mm. Manjira, a perennial tributary of River Godavari with its tributaries of Haldi (Pasupuyeru) and Kundlair drains the district. The important rock types are Peninsular Gneissic complex, Dharwar supergroup associated with Younger intrusives of Achaean age separated unconformably with overlying Basaltic flows of late Cretaceous to early Eocene age with sub-Recent to Recent alluvium along the stream courses.

III. OBJECTIVES

The main objectives of the study are listed below:

1) To improve the sub-grade strength by stabilizing the sub soils with soil-robo sand in low CBR conditions
2) To evaluate and compare the performance of the stabilized sub-grade.
3) For best results of engineering properties of soil reinforced with robosand, it is recommended to use 20% robosand

IV. METHODOLOGY



V. RESULTS AND DISCUSSION

A. Black Cotton Soil

In this section, the results for various tests such as standard proctor tests, CBR tests, UCS tests, Atterberg limit tests, and Free swell index tests performed on natural soil. Dry sieve analysis is performed on dry soil to determine the percentages of coarse grained soil and hydrometer analysis is conducted on the soil sample to determine the percentages of silt and clay. It is observed that the percentage of soil passing through 0.075 mm is more than 50%, so soil is classified as fine grained soil. As per IS 1498-1970 soil classification system, it is observed that the given soil is classified as Silty Sand and having some percentage of clay. Particle size distribution of given soil is depicted. To find maximum dry unit weight and Optimum moisture content of silty sand, Standard Proctor compaction test is performed.

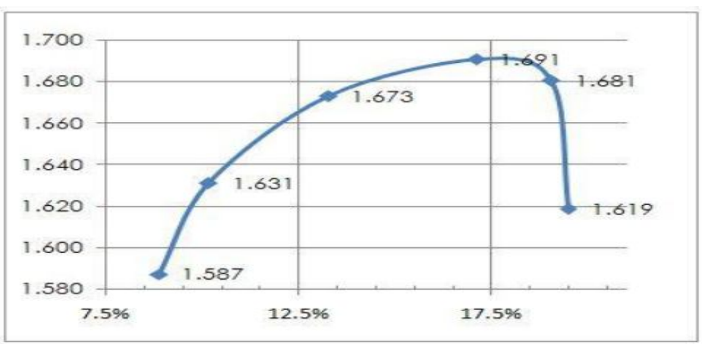
It is found that MDU and OMC values of silty sand are 1.69 KN/m^3 and 17.105% respectively shown in table 1. To perform CBR test, natural soil sample is tested for CBR machine and CBR value is noted as 7.02%, which is very low and it requires improvement by means of admixtures like robosand. The following sub section discusses the results for soil reinforcement with various plastic contents and strip sizes.

Fig.1 Low CBR black cotton soil.

B. Compaction Test MDD & OMC For (0%0 Robosand)

Table.No:1compaction results for low CBR natural soil

DRY DENSITY (KN/m^3)	MOISTURE CONTENT (%)
1.587	8.861%
1.631	10.169%
1.673	13.253%
1.691	17.105%
1.681	19.048%
1.619	19.481%



Graph.1 Moisture content versus Dry density.

(Compaction curve for low CBR natural soil)

MAXIMUM DRY DENSITY	1.691 (KN/m^3)
OPTIMUM MOISTURE CONTENT	17.105 (%)

C. Compaction Test

Compaction curves for different percentages of robosand are shown in graph 2. A graph is drawn between moisture content and dry density for different percentages of robosand(5, 10, 15, 20%), optimum values of dry unit weight and moisture content are shown in graph12.

Based on the data obtained in Table 2, it is observed that MDU for natural soil is found out to be equal to 1.691 KN/m^3. It increases to 1.699 KN/m^3 at 5% robosand and then to 1.727 KN/m^3 at 20% robosand. If the plastic content is further increased to 25 and 30% respectively, then the MDU value reduces. It can be concluded that, there is considerable increment in maximum dry unit weight of soil up to 20% robosand. After which there is reduction in MDU. In case of OMC, the effect is just reverse. Therefore, 20% of robosand by mass of the soil is considered to be the optimum value where maximum dry unit weight and optimum moisture content is achieved.

Table. No:2 MDD & OMC for varying percent of robosand.

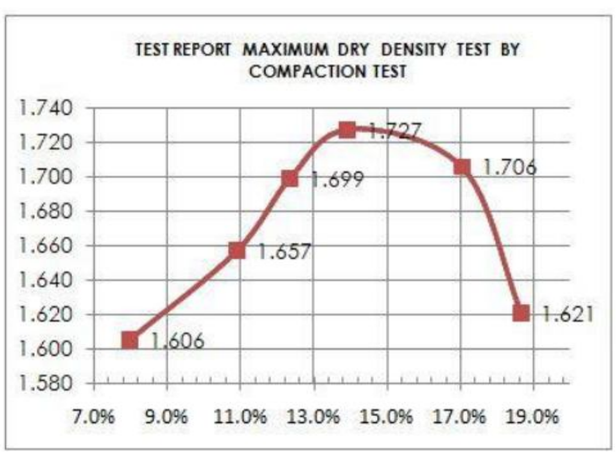
DRY DENSITY (KN/m^3)	MOISTURE CONTENT (%)
1.587	8.861%
1.631	10.169%
1.673	13.253%
1.691	17.105%
1.681	19.048%
1.619	19.481%

Decrease in MDU for higher percent of robosand is attributed to the fact that as weight of robosand are increased, volume of solid fraction of soil does not make a very good bonding with robosand. This phenomenon is also attributed to the fact that void spaces between soil grains get completely filled up by the robosand particles for higher percent. . Also, the robosand can homogeneously mixed with soil grains under different compactive efforts. This helps in further packing of soil grains with robosand together. In this way, compaction test on admixture soil with robosand yields higher maximum dry unit weight (MDU) and lower optimum moisture content (OMC).

D. Compaction Test MDD & OMC for 20% of Robosand

Table.3 Compaction results for 20% of robosand.

MAXIMUM DRY DENSITY	1.727 (KN/m^3)
OPTIMUM MOISTURE CONTENT	13.924 (%)



Graph.2 Compaction curve for 20% of robosand.

E. California Bearing Ratio (CBR) Test

Un-soaked CBR Test are conducted for each percentage of robosand and results are shown in Table 3. It is clearly observed that addition of robosand in soil increases CBR value considerably. If soil with robosand is used as subgrade material in pavement construction, the thickness of sub grade can be reduced substantially. The reduction in pavement thickness directly leads to reduction in cost of the construction of pavement. Maximum CBR values are observed to occur at 20% of robosand of natural soil by mass as shown in table. The decrease in CBR values above 20% of robosand. Beyond this limit, the strength and MDU of soil plastic matrix is observed to decrease. This type of soil can be termed as over admixture soil with robosand.

It is observed that sub grade thickness for natural soil is around 55 cm for heavy traffic condition (55 KN wheel load) for CBR value of 7.02% and it reduces to 20 cm for the same traffic condition for 20% plastic having CBR value of 12.5%. It implies that reduction in pavement thickness from 55 cm to 20 cm, quantity of aggregate materials and soil

ROBOSAND (%)	CBR VALUES (%)
0	7.02
5	9.83
10	10.61
15	11.82
20	12.50
25	12.13
30	11.98

Table.3 CBR Values for varying percent of robosand

F. Unconfined Compressive Strength (UCS) Test

Unconfined compressive strength test are conducted for each percentage of robosand and results are shown in Table 4. It is clearly observed that addition of robosand in soil increases UCS value considerably.

Maximum UCS values are observed to occur at 20% of robosand of natural soil as shown in below table. The decrease in UCS values above 20% of robosand. Beyond this limit, the strength of a soil mixed with robosand is observed to decrease. This type of soil can be termed as over admixture soil with robosand.

In the highway construction industry especially for pavement base material, cement treated material is a conventional method that had been applied. Other than that, there is various types of base can be used such as, robosand, cement kiln dust, reclaimed asphalt pavement, fly ash, and mine tailings. The usage of this various material can improve the unconfined compressive strength (UCS) of the base it terms of the strength. It was found that the UCS is the important properties to indicate the durability of the base.

ROBOSAND (%)	UCS (KPa)
0	95.02
5	140.23
10	143.55
15	144.07
20	149.06
25	134.50
30	128.91

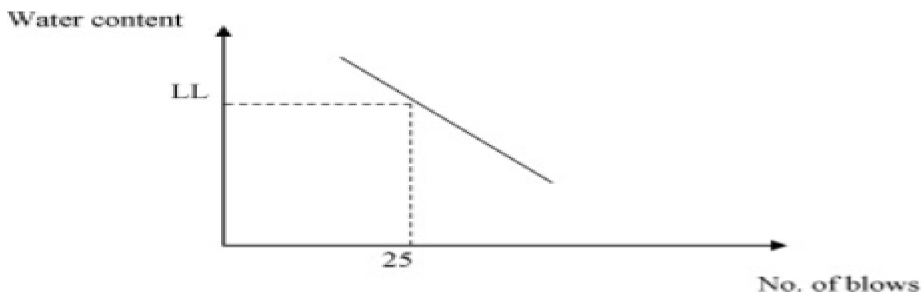
Table.4 UCS Values for varying percent of robosand.

G. Atterberg Limits Test

1) Liquid Limit Test

Liquid limit test are conducted for each percentage of robosand and results are shown in Table 5. It is clearly observed that addition of robosand in soil decreases liquid limit value considerably. Minimum liquid limit values are observed to occur at 20% of robosand of natural soil as shown in below table. The increase in liquid limit values above 20% of robosand. Beyond this limit, the strength of a soil mixed with robosand is observed to decrease, and swelling potential, shrinkage, compressibility may increases.

A high liquid limit normally indicates a high compressibility and a high shrinkage/swelling potential. A high-plasticity index I_p generally results in a low shear strength. A low I_p means that a soil used as foundation will change significantly in consistency even with a small change in water content.



Graph.3 liquid limit graph.

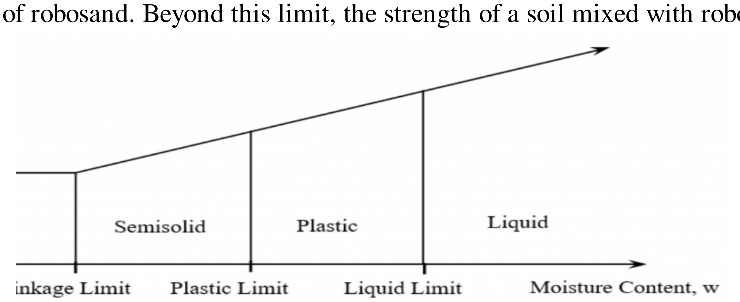
Table.6 Liquid limit values for varying percent of robosand.

ROBOSAND (%)	LIQUID LIMIT (%)
0	45.33
5	44.45
10	43.23
15	43.01
20	41.75
25	42.11
30	42.98

2) Plastic Limit Test

For each percentage of robosand, Plastic limit test are conducted and results are shown in Table 7. The percentage moisture content at which a soil changes with decreasing wetness from the plastic to the semi- solid consistency or with increasing wetness from the semi-solid to the plastic consistency. The plastic limit is the lower limit of the plastic state. A small increase in moisture above the plastic limit will destroy the cohesion of the soil.

Minimum Plastic limit values are observed to occur at 20% of robosand of natural soil as shown in below table. The increase in plastic limit values above 20% of robosand. Beyond this limit, the strength of a soil mixed with robosand is observed to decrease.



Graph.4 Atterberg limit test stages.

Table.5 Plastic limit values for varying percent of robosand.

ROBOSAND (%)	PLASTIC LIMIT (%)
0	25.15
5	25.01
10	24.74
15	24.61
20	24.50
25	24.67
30	24.82

3) Plasticity Index

The PI is defined as the range of moisture contents over which the soil deforms plastically. The PI is thus defined to be the difference between the LL and the PL

$$PI = LL - PL$$

The PI thus is a measure of the plasticity of a soil. As such, the PI determines the amount and type of clay present in a soil. In general,

- Soils with a high PI tend to be clay,
- Those with a lower PI tend to be silt, and
- Those with a PI near zero tend to have little or no silt or clay (fines) present.

ROBOSAND (%)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)
0	45.33	25.15	20.18
5	44.45	25.01	19.44
10	43.23	24.74	18.49
15	43.01	24.61	18.40
20	41.75	24.50	17.25
25	42.11	24.67	17.44
30	42.98	24.82	18.16

Table.6 Plasticity Index values.

H. Free Swell Index Test

For each percentage of robosand, Free swell index test are conducted and results are shown in Table 9.

Minimum free swell index values are observed to occur at 20% of robosand of natural soil as shown in below table. The increase in free swell index values above 20% of robosand. Beyond this limit, the strength of a soil mixed with robosand is observed to decrease, and shrinkage, compressibility, swelling potential may increases.

V_d = Volume of soil specimen read from the graduated cylinder containing distilled water.

V_k = Volume of soil specimen read from the graduated cylinder containing kerosene.

Free swell index = [Vd - Vk] / Vk x 100%

ROBOSAND (%)	0	5	10	15	20	25	30
V_d	19.00	18.832	18.633	18.045	17.233	17.305	17.411
V_k	10	10	10	10	10	10	10
FREE SWELL INDEX	90	88.32	86.33	80.45	72.33	73.05	74.11

Table.7 Free swell Index values.

VI. CONCLUSION

From the experimental works carried out, following conclusions can be made regarding the aspect of strength improvement of soil due to mixing of robosand. From the results and discussions of Standard Proctor Test on admixture soil, the maximum dry unit weight (MDU) is observed to be maximum at 20% robosand. MDU values starts to decrease for higher percentage of robosand(above 20% respectively). It is also observed that, OMC values show just opposite trend of MDU values for admixture soil. From the results of CBR Test, addition of robosand in percentages increases the CBR value from 7.02 (Natural soil) to 9.83 (for 5% robosand), 10.61(for 10% robosand), 11.82 (for 15% robosand), and 12.50 (for 20% robosand). Beyond the limit of 20% robosand, CBR values start showing decreasing pattern. It means that the thickness of sub-base can be reduced to about 30 cm and this directly leads to saving in pavement construction cost.

To determine the Unconsolidated, Undrained strength of a low CBR soil the Unconfined Compressive Strength test was carried out for all the 5%, 10%, 15% and 20% fraction mixtures of robosand and the strength is ranging between 140.233 KPa to 149.06 KPa. The free swell index FSI was determined and found to be ranging between 86.33% to 72.33% for the fractions of robosand mixtures between 10% to 20%. Similarly, the Optimum Moisture Content and Maximum Dry Density test were carried out to determine the degree of compaction and the results varied between 18% - 16.5% and 1.58-1.64 for the fractions of robosand mixtures between 10% to 20%.

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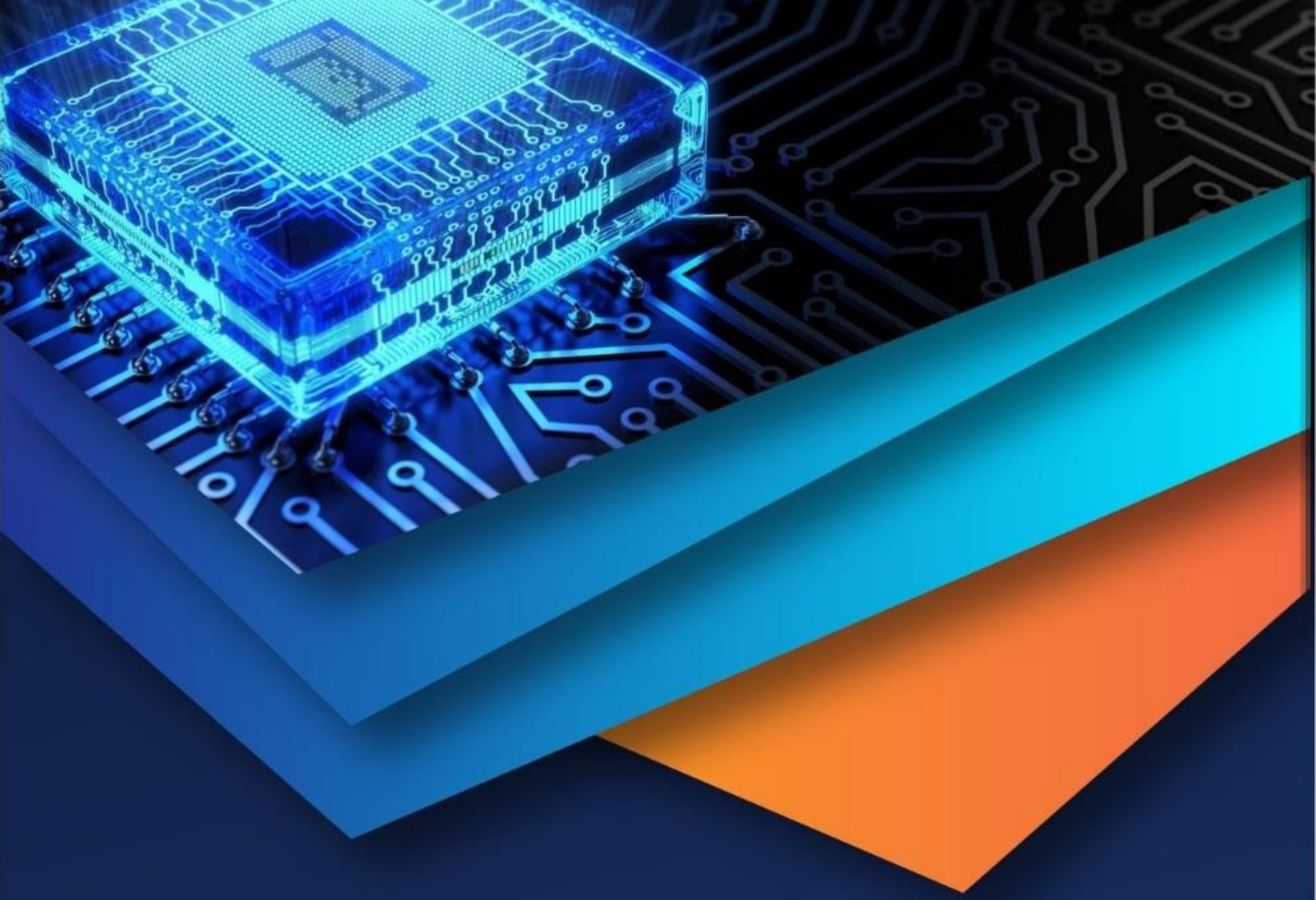

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