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The Study of Effects of Aggregates on C.B.R. Value

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Abstract: In engineering practice, the earth construction requires the compaction of the existing subgrade by improving the density and strength of the data. All types of earth structures, i.e., highways, pavements, etc., rest directly on the soil beneath them. The safety of these entities depends upon the strength/bearing capacity of the soil over which these are constructed. Therefore, a proper analysis of the soil properties and the design of their compression parameter become necessary to ensure that these structures remain stable and are safe against unequal settlements. To determine the suitability of any soil type for use as subgrade, subbase, or base material, one of the parameters generally used is the California bearing ratio (C.B.R.). The coarse aggregates available as a reinforcing material can enhance soil properties and increase its C.B.R. value. This paper will study the effects of coarse aggregates on the C.B.R. value, determine suitable size range of aggregates with their percentage, and their application for the earth structures.
Keywords: Soil, CBR, Aggregate, Compaction, pavement.

I. INTRODUCTION

California Bearing Ratio (CBR) test is a type of test developed by '**California Division of Highways'** in 1929. The test is used for evaluating the suitability of subgrade and the materials used in subbase and base courses. The test results have been correlated with the thickness of various materials required for pavements. CBR is frequently used as a test value for civil engineers, particularly those who are in pavement construction, to access the stiffness modulus and shear strength of the subgrade. It is actually an indirect measure, which represents the strength of crushed rock as a percentage value. Usually, the pavement engineers design the thickness of the pavement to be laid on the subgrade use the CBR values.

The thickness of the pavement will be more for the subgrades having a lesser value of CBR and vice versa. Different types of soils give different values of CBR even though these were compacted to the same amount of energy and rate of penetration. To enhance the strength of sub-grade soil, several techniques like compaction, mechanical/electrical/thermal stabilization, the addition of geotextile, geo-synthetic, fly ash, or randomly distributed discrete fibers are used. In the present study, the variation in CBR value or sub-grade strength of soil is carried out due to the addition of coarse aggregates. The review of literature is carried out for the improvement to the CBR value by various technologies.

A. Problem Statement

The deformation or distress in highway pavement is mainly due to weak subgrade. If the subgrade is weak or not well compacted, then various distresses will occur on both the types of rigid and flexible pavement, and it will also ruin the appearance of pavement. Some common distress occurs due to weak subgrade on the rigid and flexible pavement, as follows. Because of all these distresses, the life and serviceability of pavements get reduced.

1) *Rigid Pavement:* Unequal settlement at joint, Imperfect riding quality, Pumping is apparent, Localized structural failure
2) *Flexible Pavement:* Rutting, Shallow depressions, Settlement, Potholes.

II. LITERATURE REVIEWS

1) Ref. [1] Srivastava, Naeini did the study on the CBR Value of Sandy Subgrade Blended with Coarse Aggregate. They reported that the CBR of the soil increases when the geotextile layer intercepts the pressure bulb generated due to the application of the applied load. Further, by using geotextile in layers, increased failure stresses can reduce the thickness of road pavement. Its inclusion in soils leads to decreased penetration and deformation, thus improving the stress distribution of the soil sample.
2) Ref. [2] Jain, Mathur both observed that with the addition of 4% discrete natural fiber in the sand at a density of 16.60 KN/m3, there is a 114% and 80% increase in the CBR value of soil both in unsoaked and soaked conditions. At the same time, the direct shear test indicates that there is an increase in the cohesion of the soil.

3) Ref. [3], [6] Pandian, Amu, Modak, Mehta studied the California Bearing Ratio with wood ash/ fly ash/ lime.

a) While working on soil, fly ash mixes, Pandian reported that with the addition of 20% fly ash in black cotton soil, the CBR value of black cotton could be improved, while the CBR of fly ash can be improved with the addition of 30% black cotton soil. The study also indicates that the low value of CBR of black cotton soil or fly ash is due to a poor gradation; thus, the gradation and the compacted strength can be significantly improved by mixing the two materials in proper proportions.

b) Amu observed that up to 60% stabilization, the CBR value increases, and beyond that, it starts decreasing. At 60% stabilization, the CBR value obtained was highest at 110.73% for lime and 92.26% for wood ash. The CBR values of soil samples were found better when stabilized with lime and when stabilized with wood ash, the maximum dry density of the soil sample was found better.

c) Modak studied the combined effect of lime and fly-ash in black cotton soil and concluded that increasing the percentage of lime and fly ash in black cotton soil (CBR) and maximum dry density (MDD) values are also increases.

d) Mehta stabilized black cotton soil using lime. The CBR value of the lime stabilized clayey soil was improved due to a decrease in the plastic behavior of the soil. A review of the literature reveals that most of the work has been carried out using either fly ash/geotextile/lime or rice husk ash as a reinforcing material to enhance the CBR value of the soil, and very few or no studies have been carried out using coarse aggregates as a reinforcing material in the soil to enhance its properties.

4) Ref. [4] Singh, Virender, Kumar, Prakash studied the effects of surcharge and compaction on the CBR value of alluvial soil. They concluded that the surcharge load and the compacting effort both influence the CBR value of the soil, i.e., the CBR value of soil increases with the increase in surcharge load and the compacting effort.

5) Ref. [5] Duncan-Williams & Attoh-Okine Both show that the soil with low CBR values benefited more than soil with higher CBR values both in un-soaked and soaked conditions when reinforced with geo-synthetic. However, the improvement in strength and the CBR value depends upon the characteristics of the geo-synthetic used. They also concluded similar results. The strength and the CBR value increase when the layer is placed in the middle of the granular soils but decreases when used in the fine-grained soils.

A. Motivation

A review of literatures given in reference reveals that most of the work has been carried out using fly ash/ geotextile/ lime or rice husk ash as a reinforcement material to enhance the CBR value of the soil. Very few studies have been carried out using coarse aggregates as a reinforcing material in the soil to improve its properties. Hence, an investigation is needed to evaluate this aspect. In areas where coarse aggregates are available in abundance and procuring other reinforcing materials proves to be uneconomical, adding coarse aggregates will be a suitable option.

III. AIMS & OBJECTIVES

A. To study the effect of variation in the percentage of coarse aggregate on CBR value of soil.
B. To develop and implement the procedure to design subgrade according to such variation in CBR.
C. To check the possibility of improving the CBR value with the variation of aggregate percentage.
D. To develop the method of estimating the CBR of various layers of subgrade.
E. To determine the most suitable aggregate size range for the strength of subgrade.
F. To develop the chart to estimate the CBR with a variation of aggregate size.
G. To compare results with standards given in IS 37-2012 and other international standards.

IV. METHODOLOGY

A. General

1) *Sandy Soil:* The sandy soil used in the study is procured from river basins transported by stream etc. The different geotechnical properties of soil and the particle size distribution curve are shown in the analysis part.

2) *Coarse Aggregates:* The coarse aggregates obtained in this study are the same as used for making plain cement concrete. The different physical properties of the coarse aggregates used are given.

3) *Water:* The CBR tests in the study have been carried out in the laboratory. Therefore, water used for mixing during the preparation of the samples is taken as available in the laboratory, which is an ordinary tap water

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B. Flowchart

Table-I
Flow Chart of Methodlogy

Sample from Site

Soil **Aggregates**

Conducting basic relationship test

1) Sieve analysis
2) Moisture content
3) Density
4) Liquid limit
5) Plastic limit
6) Specific gravity

Only sieve analysis for grading

Finding OMC & MDD of test soil for heavy

Finding basic CBR for 2 test soil in both unsoaked condition

Addition of aggregates with different combinations for soaked and unsoaked conditions						No. of tests
Sr. No.	Combination (mm)	Increment of addition (%)				
1	4.75-6.7	2.5	5	7.5	10	4
2	6.7-10	2.5	5	7.5	10	4
3	10-12.5	2.5	5	7.5	10	4
4	12.5-19	2.5	5	7.5	10	4
5	4.75-10	2.5	5	7.5	10	4
6	4.75-12.5	2.5	5	7.5	10	4
7	4.75-19	2.5	5	7.5	10	4
Total no. of tests						28

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Table-II
Number of Test Required

No. of tests required to be performed in both condition			
Name of Test		Frequency	
Sr. no.	Basic tests	Soil A	Aggregate
1	Sieve analysis	1	1
2	Moisture content	1	-
3	Density	1	-
4	Specific gravity	1	-
5	Liquid limit	1	-
6	Plastic limit	1	-
7	OMC & MDD	1	-
8	Basic CBR on Test soil	2	-
9	CBR with trail combination	28	-
	Total Tests	37	1
	Grand Total	38	

V. TEST RESULTS & CALCULATIONS

Out of the total 30 C.B.R. test (2+28), sample test results and calculations of 2 tests has given below,

A. Basic CBR Test on soil sample 1-

1) *Observations:* Following Table gives information about basic value of C.B.R readings without addition of coarse aggregates in soil sample 1.

a) Proving ring constant: 3.782 kg/div
b) Least count of dial gauge: 0.01 mm

Table 3
Readings of Basic C.B.R. test of Soil Sample 1

Sr. No.	Dial Gauge Reading (D.G.R)	Proving Ring Reading (P.R.R)	Penetration D.G.R x L.C	P.R.C x P.R.R Axial Load(kg)
1	50	9.80	0.5	37.06
2	100	14.60	1	55.21
3	150	19.80	1.5	74.88
4	200	24.20	2	91.52
5	250	28.40	2.5	107.40
6	300	33.20	3	125.56
7	400	37.80	4	142.95
8	500	41.20	5	155.81
9	750	44.60	7.5	168.67
10	1000	49.20	10	186.07
11	1250	51.80	12.5	195.90
12	1500	53.90	15	203.84
13	2000	56.20	20	212.54

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2) *Calculations*

From the fig. 1, value of CBR for the soil sample 1 can be determined.

a) At 2.5mm, CBR value= actual load on soil / standard load on crushed aggregate = 107.40/ 1370 = 7.83%

b) At 5.0mm, CBR value = 155.81/2055 = 7.58%

Therefore CBR = **7.83%.**

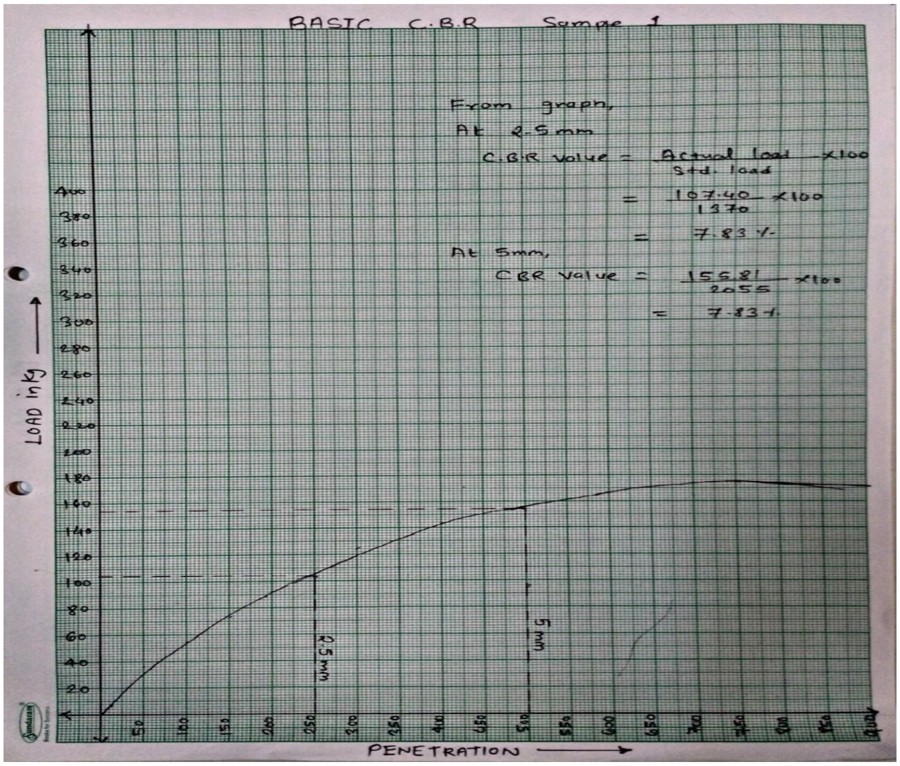

Fig.1 Graph of basic C.B.R. sample 1.

B. CBR test on range 4.75mm-19mm @2.5%

1) Observation: Following Table gives readings for 1 CBR test out of 28 tests for soil sample with the addition of coarse aggregate on range of 4.5mm-19mm @2.5%.

TABLE 4 - READINGS OF CBR TEST ON RANGE 4.755MM-19MM @2.5%

Sr. No.	Dial Gauge Reading (D.G.R)	Proving Ring Reading (P.R.R)	Penetration D.G.R x L.C	P.R.C x P.R.R Axial Load(kg)
1	50	10.80	0.5	40.84
2	100	16.20	1	61.26
3	150	28.40	1.5	107.40
4	200	32.60	2	123.29
5	250	36	2.5	136.15
6	300	41.80	3	158.08
7	400	46.20	4	174.72
8	500	53.20	5	201.20
9	750	60.20	7.5	227.67
10	1000	67.80	10	256.41
11	1250	71.40	12.5	270.00
12	1500	76.80	15	290.45
13	2000	79.20	20	299.53

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2) Calculations

Calculated CBR value =**10.01%**

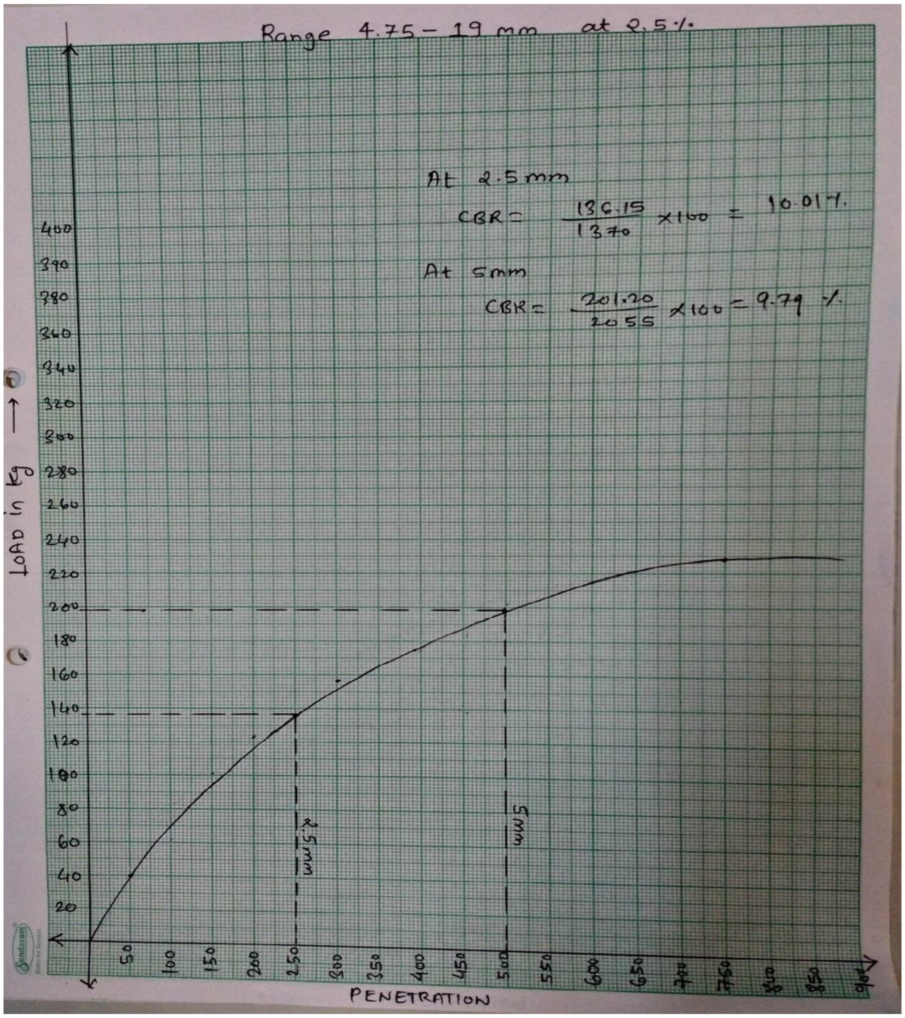

Fig. 2 Graph of CBR test on range 4.75mm-19mm @2.5%

C. Results of CBR tests

The following table will give resulted value of all 28 CBR tests with addition of coarse aggregate with varying percentage.

Table 5

CBR Values of 28 CBR tests with Addition of Coarse Aggregate

Range	Percentage of Coarse Aggregate (%)			
	2.5	5	7.5	10
4.75-6.7	10.35	12.47	11.46	10.76
6.7-10	10.27	11.12	12.05	11.03
10-12.5	10.37	11.13	11.97	10.95
12.5-19	9.8	9.79	11.04	11.48
4.75-10	9.82	10.19	11.31	11.831
4.75-12.5	9.92	11.09	11.532	12.03
4.75-19	10.01	11.81	12.51	13.88

VI. CONCLUSION & APPLICATIONS

A. Conclusion

1) From the analysis of table 5, it can be seen that for the range 4.75-6.7mm, optimum CBR is obtained at 5% addition of aggregates. Similarly, for 6.7-12.5mm, the optimum CBR is obtained at 7.5% addition of aggregates & for 4.75-19mm, the optimum CBR is at 10% adding of aggregates.
2) The above statement can conclude that aggregate surface area will be more when the aggregate size is less. Hence, the contact area of the aggregate with the soil particles will be more and will require thus less percentage of aggregate to improve CBR value.
3) As the size of aggregates increases, its surface will be less, i.e., the contact area with soil will also be less; hence more percentage of aggregates will be required to improve CBR value.
4) This improvement of CBR with the addition of aggregates will lead to a substantial decrease in the flexible pavement thickness (Approx. 150mm). The aggregates used are naturally available in abundance in most of the parts of India and are an economical reinforcement material.

B. Application

We found that for a basic CBR of 7.83%, the pavement thickness calculated is 600mm. After adding aggregates, the new CBR found is 13.88%, the pavement thickness calculated is 450mm. Thus, an adequate thickness reduction of 150mm is obtained. As per an approximate estimate, about 4 lakh rupees can be saved per kilometer road length.

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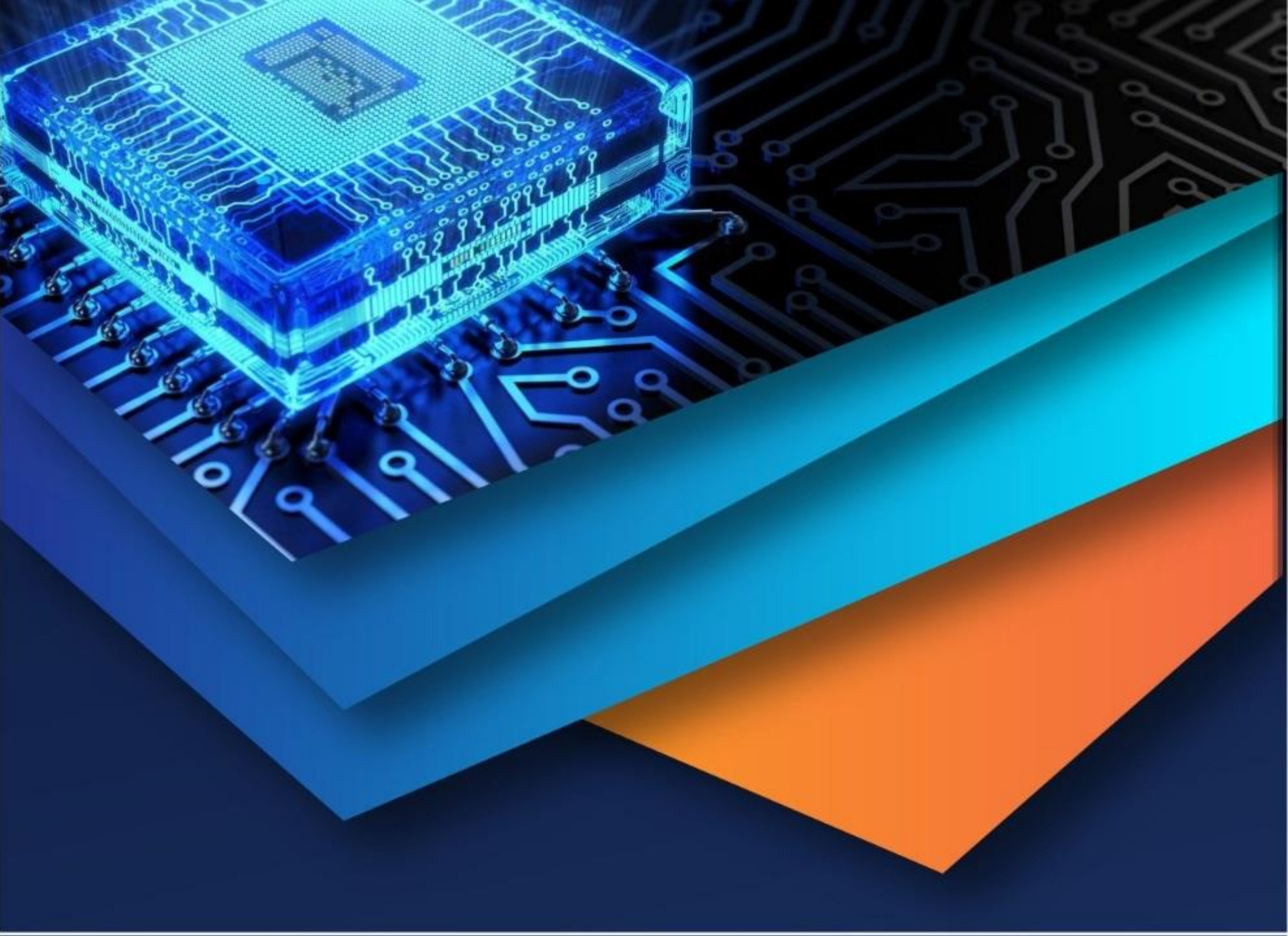

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