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Experimental Study on Conventional Recycled Aggregate Concrete Associate with Micro Silica

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Abstract: ***The ongoing need for infrastructure around the world as a result of continued population growth suggests that more aggregate and cement will be needed in the manufacture of concrete. This would eventually result in greater carbon emissions, increased resource extraction, and depletion. The increasing aggregate and cement requirements are a result of the constant global demand for concrete. More extraction occurs as a result, depleting natural gravel resources and increasing CO2 emissions from quarrying operations. Construction costs and carbon emissions could both be reduced by partially substituting recycled material for natural aggregate. Fine aggregate, coarse aggregate, potable water, and the cement-based binder make up the heterogeneous material known as concrete. The heterogeneity is increased more by the presence of coarse particles. An aggregate consumes about 60% to 75% of the overall volume of concrete. The aim of this research work was to develop high performance concrete using recycled coarse aggregate, microsilica, and synthetic macro fibre with the object to boost higher use of recycled coarse aggregate in the construction industry. Concrete is most important material used in the construction industry. Large amount of natural aggregates were used in concrete, this causes the nature. Now a day's many structures are demolished & rebuilt, demolishing of structures causes problem with dumping of waste material. An important aspect of sustainable construction is recycling or reuse of the construction material and demolition waste. It will maintain a friendly green environment. Recycled aggregates has micro cracks on its surface causes low strength, low workability of concrete. This draw back can be avoided by using micro silica. In this paper experimental results were shown for recycled aggregate incorporating with micro silica.***

Keywords: Micro silica; Recycled aggregate; Natural aggregate; Construction and demolition waste; Recycled concrete.

I. INTRODUCTION

Concrete is a heterogeneous substance made up of fine aggregate, coarse aggregate, drinkable water, and the cement-based binder. The heterogeneity is more pronounced if coarse particles are present. A typical aggregate uses between 60 and 75 percent of the total volume of concrete. Despite the fact that concrete has many highly advantageous qualities, including cost effectiveness, durability, outstanding compressive strength, and availability, the continued use of conventional concrete—that is, concrete made with virgin aggregates and regular Portland cement—has proven to be extremely unfriendly to the environment as a result of the depletion of natural resources. Nature has been impacted by growing waste management issues and massive energy usage in quarrying activities.Concrete usage has increased as a result of the rising need for infrastructure brought on by industrialisation and urbanisation. The second-most-consumed resource in the world after water is concrete, which has also become the most popular building material in recent years.

A. Background

Recycled aggregate developed microscopic cracks during the crushing process and as a result of the surface of the aggregate having loose mortar coating. The link between cement and aggregate is poor as a result. Low workability and low concrete strength are caused by this. Concrete's compressive strength is lower when recycled aggregate is used than when concrete made with natural aggregate. Researchers discovered that up to 30% of the aggregate can be replaced, however this replacement provides less strength than virgin aggregate. The physical and engineering qualities of recycled aggregate concrete could be improved by the addition of a mineral additive (micro silica, for example). Micro silica contributes both physically and chemically in concrete mix. The size of micro silica particles is smaller than that of cement. This will results in reduction of the average size of pores present in cement paste. While the chemical contribution takes place mainly by acting as an efficient pozzolanic material, which enables even distribution and higher volume of hydration products.

B. Aim

The major aim of this research is to develop conventional standard concrete using recycled coarse aggregates as substitute for natural coarse aggregate and mineral admixture (micro silica), in order to improve the properties of recycled aggregate concrete. With an additional goal to boost the potential of increasing its uses from the recommended 30% level from some past researchers. Adequate factual scientific information is thereby required to establish the mechanical and physical characteristics of concrete incorporating above-mentioned materials.

C. Objectives

The objectives are to;

1) Determination of the properties of freshly-poured and fully-cured concrete including varied amounts of recycled coarse aggregate;
2) Evaluate the effect of addition of mineral admixture (micro silica) on concrete produced in (1) above;
3) Identify the best way to employ the micro silica necessary to make the good strength concrete in (2) above;
4) Evaluate the flexural performance of nominal reinforced concrete incorporating micro silica which produced the optimal effect in above.

The outcome of this research will provide better understanding about the properties of recycled aggregate concrete produced from the aforementioned materials, and contribute greatly in ensuring that the construction sector increases the use of recycled coarse aggregate beyond the current recommendation. This research is also limited to the use of recycled coarse aggregate as a replacement for natural coarse aggregate, micro silica as an addition to cement respectively.

D. Significance of Research

The following listed are potential benefits from this research work to the construction industry and the environment. These are;

1) Reduction of pressure on landfills from construction and demolition debris;
2) Potential to increase the use of recycled coarse aggregate beyond the maximum recommended 30%;
3) Conservation of natural resources through reduction in the use of natural coarse aggregate for concrete work;
4) Mitigation of performance issue like low strength associated with recycled aggregate by incorporating micro silica (mineraladmixture) in the concrete mix;
5) Potential application of recycled coarse aggregate in structural concrete.

II. LITERATURE SURVEY

De-jianYANG ,Ya-han HAO and Tie-cheng W [1], has done experimental Research on Recycled Aggregate Concrete for Highway Pavement 2010**;** This research paper uses recycled aggregate replacements for 30%, 50%, 70% and 100% were investigated. They prepared M25 grade concrete. From obtained results they conclude that the replacement ratio of recycled aggregate gives less results for compressive strength of concrete.

RattaponSomna; Chai Jaturapitakkul, A.M.ASCE; WichianChalee; and PokpongRattanachu [2] did research on the effect of the Water to Binder Ratio and Ground Fly Ash on Properties of Recycled Aggregate Concrete. This research paper gives results for the mix proportions of normal concretes and recycled aggregate concretes, which had W/C (water to cement ratio) of 0.45, 0.55, and 0.65. For normal concrete, the mix proportion was designed by using ACI method. Recycled aggregate concrete was made with the same mix proportion of normal concrete, except that the recycled coarse aggregate was fully used to replace the crushed limestone. In addition, ground fly ash was also used to replace the OPC at 20, 35, and 50% by weight of cement in the recycled aggregate concretes. From this replacement & W/C ratio the maximum compressive result obtained was 42.7Mpa at 0.45 ratios with 20 % replacement of ground fly ash. Latter increasing W/C ratio and replacement of ground fly ash will decrease the compressive strength.

Verma Ajay, Chandak Rajeev and Yadav R.K. have explained the effect of microsilica on The strength of concrete with ordinary portland cement 2012)ISCA[3] *Vol. 1(3), 1-4, Sept. (2v 012);*[3] In this they prepared M30 concrete with different % of micro silica like 5%, 10%, 15% & 20%, they found following results. They conclude that silica fume increases the strength of concrete up to 25%. Silica fume is much cheaper then cement therefore it very important form economical point of view. Silica fume is a material which may be a reason of Air Pollution this is a byproduct of some Industries. Use of silica fume with concrete decrease the air pollution. Silica fume also decrease the voids in concrete. Addition of silica fume reduces capillary, Absorption and porosity because fine particles of silica fume reacts with lime present in cement. The results obtained are as below.

Viviana Letelier , Ester Tarela, Pedro Munozb, Giacomo Moriconi [4]done their research on combined effects of recycled hydrated cement and recycled aggregates on the mechanical properties of concrete. In these paper analyses of the mechanical properties of concrete manufactured replacing different amounts of cement and natural coarse aggregates with recycled hydrated cement and recycled aggregates respectively. The goal is to determine their optimal combination to maximize the reuse of recycled materials, and also maintaining the performance of the material and minimizing its environmental impact. The levels of the percentage of RA considered were 20%, 30% and 40%. The levels of the percentage of RHC replacing cement considered were 5%, 10% and 15%, chosen. The strength of control specimen was 32.1, as the replacement of aggregate & recycled hydrated cement the compressive strength of concrete was reduced. The maximum results obtained after replacement was 28.6 at the replacement of 20% aggregate & 5% recycled hydrated cement. After that strength was reduced rapidly. From this they conclude that the amount of cement replaced by the reused powder shows a low significance, but still perceptible. A loss of the strengths, both compressive and flexural, takes place when the amount of the RA increases, due to the low quality of the aggregates used.

ETXEBERRIA, M., VÁZQUEZ, E., MARÍ, A. & BARRA, M. et al., "Influence of amount of recycled coarse aggregates and production process on properties of recycled aggregate concrete."(2008)[5]

In this study recycled coarse aggregates obtained by crushed concrete were used for concrete production. Four different recycled aggregate concretes were produced; made with 0%, 25%, 50% and 100% of recycled coarse aggregates, respectively. The mix proportions of the four concretes were designed in order to achieve the same compressive strengths. Recycled aggregates were used in wet condition, but not saturated, to control their fresh concrete properties, effective w/c ratio and lower strength variability. The necessity to produce recycled aggregate concrete with low–medium compressive strength was verified due to the requirement of the volume of cement. The influence of the order of materials used in concrete production (made with recycled aggregates) with respect to improving its splitting tensile strength was analysed. The lower modulus of elasticity of recycled coarse aggregate concretes with respect to conventional concretes was measured verifying the numeral models proposed by several researchers

III. EXPERIMENTAL INVESTIGATION

To work with recycled aggregate concrete standard size moulds were used, total 34 specimens were casted, out of which 19 cubes of 150mm x 150mm x 150 mm size, 15 cylinder of 150mm x300 mm size.

A. *Materials*

1) *Cement:* The cement used in this research was Ordinary Portland pozzolona cement (OPC).These cement were stored within the laboratory, numbered with dates and used according to date of delivery.
2) *Fine Aggregate:* Crushed sand is used which is also called as artificial sand which is available in nearby area having specific gravity 2.63
3) *Coarse Aggregate*

a) *Natural Coarse Aggregate (Crushed Aggregate):* Crushed gravel with nominal maximum size of 20mm and 10mm and relative density of 2.79 and 2.72 was used as natural coarse aggregate in the research work. The impact value test and abrasion test for these aggregate were performed in the laboratory which gave result as 13.84% and 17.2% respectively. The materials were stored outside the laboratory at a designated area. Aggregate were obtained from the nearer dealer of construction material from college area.

b) *Natural Fine Aggregates (Crushed Sand):* Crushed sand with relative density of 2.65 was used as natural fine aggregate in the research. The materials were stored outside the laboratory at a designated area. Aggregate were obtained from the nearer dealer of construction material from college area.

c) *Recycled Coarse Aggregates:* Recycled aggregates are mainly crushed concrete obtained from materials that were previously used in construction activities and recovered from demolition debris. They may be grouped as either recycled concrete aggregate (RCA) when the components are largely from crushed concrete or generally referred to as recycled aggregates (RA) when they are made up of substantial amounts other than crushed concrete. The major difference between recycled coarse aggregate and natural coarse aggregate is that the former consists of two separate materials; natural aggregate and attached or adhered cement mortar. The recycled coarse aggregate used for the research has a nominal size of 20mm and 10mm and was obtained from Chatrapati college of Engineering and polytechnic, ahmednagar campus area. These aggregates have low specific gravity 1.89. The impact value and abrasion value were evaluated as 20.7% and 26.4% respectively. Fig. No. 3.3 shows the sample of recycled coarse aggregate used for concrete work in the laboratory.

Fig. No. 3.4: Recycled coarse aggregate

d) Impurities in Recycled Coarse Aggregate

The performance of recycled coarse aggregate can be reduced due to the presence of impurities, which emanated from demolition process including porous mortar and cement paste attached to the parent aggregate. The effect could also lead to general reduction in characteristics of recycled aggregate concrete. Some of the impurities identified through visual inspection from the recycled coarse aggregate.

The average percentage impurities present in the recycled coarse aggregate amounted to about 5% of the total mass of the sample. Although there is visual evidence to show the presence of adhered mortar on the parent material, it was practically impossible to estimate their percentage. However, the adhered mortar does not seem to be of significant quantity but its impact on the characteristics ofrecycled coarse aggregate concrete cannot be neglected.

4) Micro Silica

The micro silica used in the laboratory is complies with ASTM C1240 as shown in figure no.3.1

Fig. No. 3.2: Micro silica

A typical property of micro silica is given in Table 3.2 & 3.3.

Table No. 3.2: Typical properties of micro silica.

Form	Description
Colour	Grey
Odour	Odourless
Solubility (Water):	Insoluble/Slightly soluble
Specific Gravity (water=1)	2.11
Bulk density (gm/cc)	0.416

Table No.3.3: Chemical properties

Chemical property	Test Method	Result
Silicon Dioxide(SiO_2) % by mass	BS EN 196-2	92.0
Elemental Silicon % by mass	ISO 9286	0.12
Free Calcium Oxide %by mass	BS En 451-1	0.34
Sulphate (SO_2)	BS EN 196-2	0.14
Total Alkali (Na_2O_{eq}) %by mass		0.40
Chloride (Cl) %by mass		0.03
Loss on Ignition % by mass		2.10
Particle size, mean(μm)		25

5) Water

Water fit for drinking is generally considered fit for making concrete. Water should be free from acid, oils, alkalis, vegetables or other organic impurities. Soft water also produces weaker concrete. Water has two functions in concrete mixes. Firstly, it reacts chemically with the cement to form a cement paste in which the inert aggregates are held in suspension until the cement paste has hardened. Secondly, it serves as a vehicle or lubricant in the mixture of fine aggregate & cement.

B. Concrete Mix Design

M-30 Concrete mix was designed as per IS-10262. The 28 days characteristic strength is 30Mpa having water cement ratio 0.45.

RCA (%)	0%	25%	50%	75%
Cement (kg/m^3)	438	438	438	438
Sand (kg/m^3)	703.48	703.48	703.48	703.48
Gravel (kg/m^3)	1111.54	833.65	555.77	277.88
RCA. (kg/m^3)	0.00	277.88	555.77	833.65
Water (kg/m^3)	197	197	197	197
Micro silica (kg/m^3)				
5%	0	21.9	21.9	21.9
10%	0	43.8	43.8	43.8
15%	0	65.7	65.7	65.7

C. Concrete Mixing and Placing

Concrete is mixed by hand mixing on concrete base which is absorbent. Hence because of absorbent surface water is sprayed over it. Then coarse aggregate were placed after that fine aggregate was placed over coarse aggregate this is covered by cement & micro silica.firstly dry mixing was done.

After proper dry mixing required quantity of water was sprayed on the dry mix and then mix it thoroughly. After ascertaining consistency, the concrete was placed in various lubricated moulds (cubes, cylinders) in three layers with each layercompacted by 25 times using tamping rod & the vibrating table in order to expel any entrapped air.

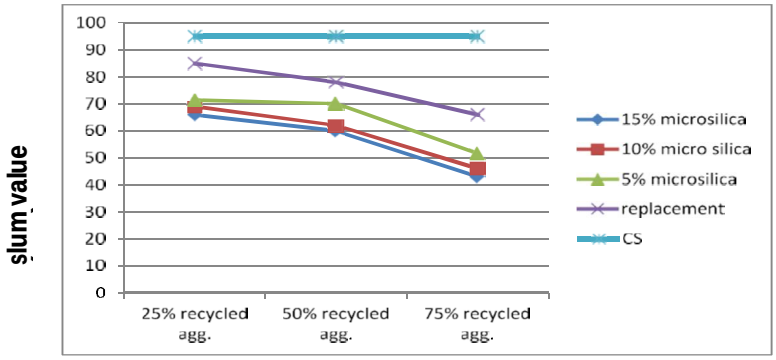
The surface was gradually levelled with steel hand trowel. The concrete samples were thereafter de-moulded and cured in the water tankat about 20°C.

IV. RESULTS AND DISCUSSION

Different tests were conducted on fresh and hardened concrete like on fresh concrete slum test and compaction factor test were carried out to know the workability of concrete, and compressive strength test, split tensile strength were carried out on hardened concrete to know the properties of hard concrete having recycled aggregates incorporating with micro silica the graph shows the variations with respect to percentage variation of recycled aggregate and micro silica.

A. Workability Test: Slump Test

The slump results indicate that the maximum value of 95 mm was measured at 0% recycled coarse aggregate content while the minimum value of 42 mm, which represents about 54.7% relative reduction from the maximum value in phase 5 was obtained at 75% recycled coarse aggregate content and 15% micro silica. A careful comparison of these results across the concrete mixes indicated that workability decreases as the percentage content of recycled coarse aggregate and micro silica increases due to higher rate of water absorption associated with recycled aggregate and increasing surface area due to micro silica.



Graph 1: slum value experimental results

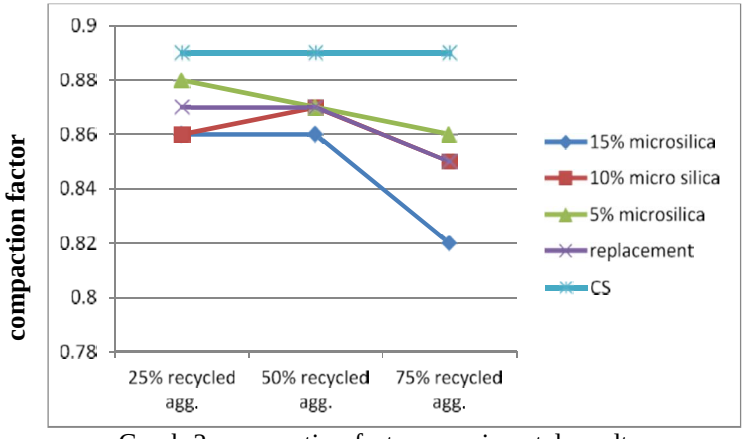
Table1: Result of slump test for concrete mix

RCA(%)	0% M Phase1	0%M Phase2	5%M Phase 3	10%M Phase 4	15%M Phase 5
0	95	- - -	- - -	- - -	- - -
25	- - -	84	72.5	70	67
50	- - -	80	73	61	60
75	- - -	69	50	48	42

RCA --- Recycled Coarse Aggregate, M --- Microsilica

B. Workability Test: Compaction Factor Test

Compaction factor test also gives low results; were shown by graph for compaction factor test,



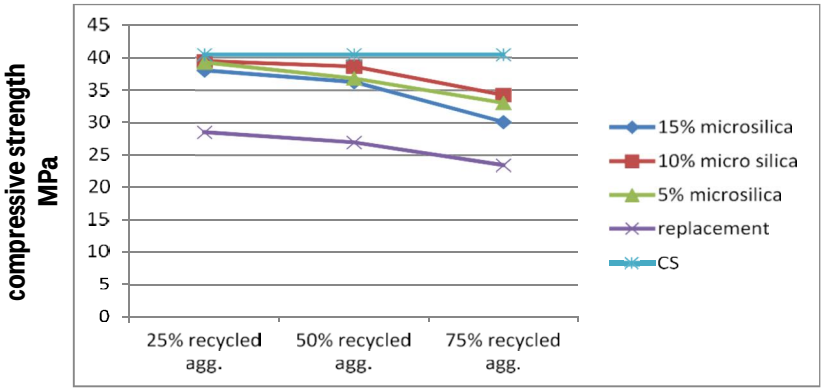
Graph 2: compaction factor experimental results

Table2: Result of compaction factor test for concrete mix

RCA (%)	0% M Phase 1	0%M Phase2	5%M Phase 3	10%M Phase 4	15%M Phase 5
0	0.89	- - -	- - -	- - -	- - -
25	- - -	0.88	0.87	0.86	0.86
50	- - -	0.87	0.87	0.87	0.86
75	- - -	0.85	0.85	0.85	0.82

C. Compressive Strength

The results of the compression tests carried out at age 28 days for the recycled concretes and for the conventional for the different replacement percentages.



Graph 3: compressive strength experimental results

Table 3: Result of compressive strength (Mpa) test for concrete mix

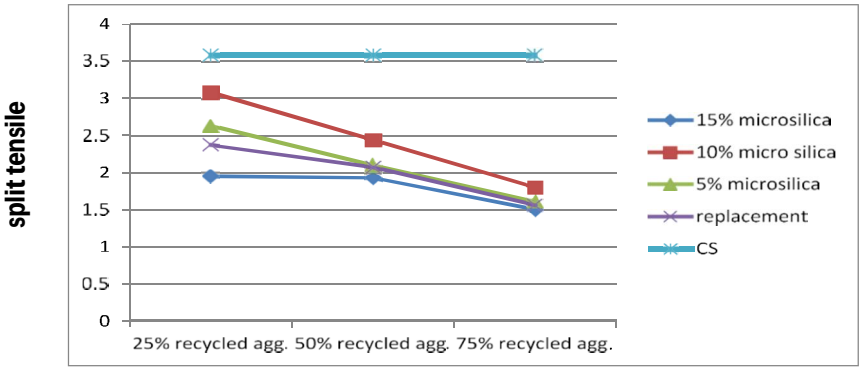
RCA (%)	phase1 (0%M)	phase2 (0%M)	phase3 (5%M)	phase 4 (10% M)	phase 5 (15% M)
0	41.38	-	-	-	-
25	-	28.32	39.32	40.05	37.93
50	-	27.85	36.62	38.52	36.16
75	-	24.38	32.87	34.27	30.09

RCA --- Recycled Coarse Aggregate, M --- Micro silica

Results from phase 1-5 illustrated in above graph 3 produced the highest compressive cube strengths of about 41.38 MPa, 28.32 MPa, 39.32 MPa, 40.05 MPa and 37.93 MPa in phase 1, 2, 3,4 and 5 at 28-day curing age respectively. The plot shows that only the concrete mix in phase 4 had 28-day compressive cube strength gave good results near to the expected target strength, as specified 28-day characteristic cube strength of 30MPa and target compressive cube strength of 38.52 MPa. The relative compressive cube strength gained by concrete mix in phase 4 with reference to the corresponding mixes in phase 2, and 3 and 5 were good.

D. Splitting Tensile Strength

The splitting tensile strengths of recycled concretes and of conventional concretes as the average of three tests in each case are presentedin Fig. 4. For RCA concretes,



Graph 4: split tensile experimental results

Table 4: Result of split tensile strength (Mpa) test for concrete mix

RCA (%)	phase1 (0%M)	phase2 (0%M)	phase3 (5%M)	phase 4 (10% M)	phase 5 (15% M)
0	3.60	-	-	-	-
25	-	2.39	2.59	3.05	1.98
50	-	2.08	2.15	2.46	1.97
75	-	1.36	1.66	1.85	1.5

RCA --- Recycled Coarse Aggregate, M --- Micro silica

Results of tensile splitting strength from graph 5.4 indicate that concrete mixes in phase 4 with 10% micro silica content produced better results than concrete mixes in Series 2, 3, and 5 respectively. The 28-days relative strength of phase 4 concrete mix were 15.01%, 26.05% and 15.76% higher that the corresponding mixes in Series 1, 2, 3 respectively. However, a comparison between Series 1 and 4 concrete mixes respectively, shows that at 0% and 25% recycled aggregate content; Series 4 had tensile splitting strengths that were 15.01% lower than the corresponding mixes in Series 1 at 28-day curing age.

V. CONCLUSION

The graph plotted using the results are shows results with addition of micro silica. Hence from the results we can conclude that Microsilica improves the strength as discussed before.

1) The water absorption of recycled aggregate is more as compare to the natural aggregate.
2) As the percentage of micro silica increases workability of concrete get decreases.
3) The incorporation of micro silica, significantly improves properties of recycled aggregate concrete up to 10% beyond which itget declines.
4) The outcome of research suggests potential to increase current recommended fraction of recycled aggregate in concrete.

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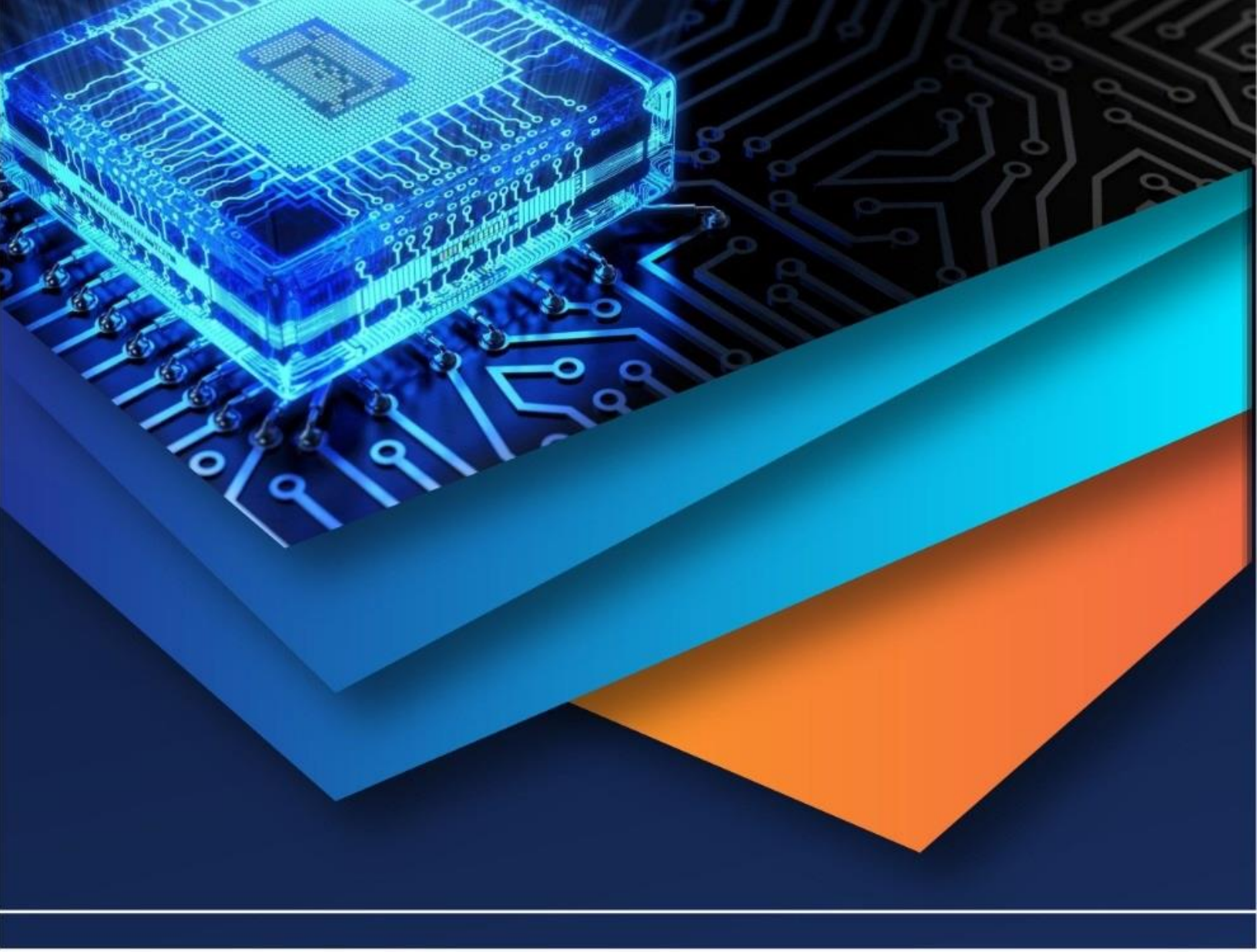

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