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Stabilization of Concrete using Rubber Tyre Waste

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Abstract: With increase in urbanisation and industrialisation disposal of rubber tyre waste has creates a lot of problems to the society. The International Rubber Study Group (IRSG) 2017 report revealed 12.9 million tonnes of global rubber production as increased from 12.4 million tonnes in 2016. The objective of this research is to investigate the use of used rubber tyre waste pieces of three different dimensions used as coarse aggregate in the concrete consecutively searching an alternate method for disposal of non-biodegradable solid tyre wastes. This research mainly focus on the performance of concrete strength parameters by incorporating relatively lower percentages i.e. 0.5%, 1% and 2% of discarded tyre rubber pieces of coarse aggregate as compared to percentages taken in previous studies compiled in literature and ultimately finding a replacement for cement results in reducing cost of construction. Compressive strength test, split tensile strength test and workability test are conducted on concrete specimens and results are compared and discussed along with advantages and disadvantages. The results showed that with up to 1% replacement, in each set, no major changes on concrete characteristics would occur, however with further increase in replacement ratios considerable changes were observed.
Keywords: Discarded Rubber Tyre waste, Concrete Stabilisation, Rubber disposal using lower percentages, Rubcrete strength test

I. INTRODUCTION

Concrete can be distinguished in its different types by changing proportions of the main ingredients or substituting the cement and aggregate phases. The finished product can be tailored to its application by taking strength, density, as well chemical and thermal resistances as variables. The use of recycled materials as concrete ingredients has been gaining popularity because of increasingly stringent environmental legislation, and the discovery that such materials often have complementary and valuable properties. Mineral admixtures such as fly ash, ground granulated blast furnace slag, silica fumes are becoming more popular for partial replacement in recent decades. With reduction in amount of industrial waste, displacement of expensive cement production is displaced ultimately results in attaining sustainable development.

The aim of investigation was to study the deformation properties of Portland cement concrete with rubber waste additives. A lot of rubber is produced worldwide. For example, 3.6 million tons rubber is produced annually only in US. It is not possible to discharge the rubbers in the environment because they decompose very slowly and cause lots of pollution. So, it is necessary to have a relevant use of these wastages.

These waste materials can be used to improve some mechanical properties of concrete. The present study provided the test results on the mechanical and physical properties of lightweight concrete obtained by replacing portions of the conventional fine aggregates with crumb rubber pieces from recycling waste tyres. Addition of rubber to concrete results in the, improvement of some mechanical and dynamical properties, such as more energy adsorption, better ductility, and better crack resistance. The mechanical properties like compressive, tensile strength and workability are determined as per Indian standards code provisions. The test program was carried out to develop information about the mechanical properties of rubberized concretes. A control Portland cement concrete mix (PCC) is designed usingmix design methods and crumb rubber contents were chosen by partially replacing the fine aggregate with used rubber pieces..In this paper, the 7-day and 28-day compressive strength as well as split tensile strength of concrete specimens containing 0%, 0.5%,1% and 2% by weight rubber tyre pieces of 3mm thickness and dimension 1cm x1cm, 1cm x 2cm & 1cm x 3cmare investigated. For this purpose, 228 concrete specimens (114 cubic & 114 cylindrical specimens) were prepared.

Future objectives of using discarded rubber tyre waste in concrete include quantification of energy absorption capacity of rubcrete material under vibrations during earthquake and fatigue.

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II. SPECIMEN TESTING AND OBSERVATIONS

A. Material Used

1) *Cement:* Ordinary Portland cement of Ultra Tech brand of 53 grade conforming to Indian Standard code IS 12269-1987(9) is used in the present study. The properties of cement used are shown below in Table I.

Table I
Properties of cement used in composite concrete specimen

S.No.	Property	Value
1	Initial setting time	35min.
2	Specific gravity	3.14
3	Fineness modulus	1.5%

2) *Fine Aggregate:* Natural sand as per Indian Standard codal provision IS: 383-1987 is used. The material specifically is local available river sand having bulk density 1860kg/m3. The properties of the fine aggregate are shown below in Table II.

Table II
Properties of aggregates used in composite concrete specimen

S.No.	Property	Result
1	Specific gravity	2.55
2	Fineness modulus	2.36%
3	Water absorption	0.50%

3) *Coarse Aggregate:* Crushed aggregate conforming to IS: 383-1987 is used. Tested aggregates of size 12mm are used with properties shown below in Table 3.

Table III
Property of coarse aggregates used in composite concrete specimen

S.No.	Property	Result
1	Specific gravity	2.63
2	Fineness modulus	6.75%
3	Water absorption	2.4%

4) *Crumb Rubber:* The properties of crumb rubber are shown in

Table IV
Property of crumb rubber used in composite concrete specimen.

S.No.	Property	Result
1	Specific gravity	1.72
2	Fineness modulus	4.48%
3	Water absorption	2%

Figure 1: Discarded Rubber tyre pieces of size 1cm x 2 cm used as aggregate in concrete specimens.

B. Specimen Size and Proportioning

The specimen of standard cube of (150mm x 150mm x 150mm) and standard cylinders of (200mm x 100mm) and prisms of (100mm x 100mm x 500mm) were used to determine the compressive strength and split tensile strength of concrete. Three specimens were tested for 7 & 28 days with proportion of crumb rubber replacement. Totally 30 cubes and 30 cylinders were cast the for strength parameters. The constituents were weighed and the materials were mixed by hand mixing. The water cement ratio was 0.50.Concrete mix design in this experiment was designed as per the guidelines in IS 10262-2009. All the samples were prepared using design mix. M20 grade of concrete was used for the present investigation. Mix design was done based on I.S 10262-2009. The table 5 shows mix proportion of concrete (Kg/m^3).

Table V
Proportioning in rubber tyre composite concrete specimen

Ingredient	Water	Cement	Fine aggregate	Coarse aggregate
Quantity	160lit.	380.95Kg/m^3	696.71Kg/m^3	1169.72 Kg/m^3
Proportion	0.42	1	1.82	3.07

Table VI
Cube Weight to ensure Compacted Concrete Density

Concrete density (Kg/cm^3)	Volume of 150mm size cubes (m^3)	Corresponding weight of cube (Kg)
2400	*0.003375*	*8.1*
2425	*0.003375*	*8.184*
2450	*0.003375*	*8.269*
2475	*0.003375*	*8.353*
2500	*0.003375*	*8.438*

C. Compressive Strength Test

Compressive strength or compression strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength, which withstands loads tending to elongate. Compressive strength is often measured on a universal testing machine; these range from very small table-top systems to ones with over 53 MN capacity. Measurements of compressive strength are affected by the specific test method and conditions of measurement. Compressive strengths are usually reported in relationship to a specific technical standard. The compressive strength of concrete is given in terms of the characteristic compressive strength of 150 mm size cubes tested at 28 days (fck). The characteristic strength is defined as the strength of the concrete below which not more than 5% of the test results are expected to fall. For design purposes, this compressive strength value is restricted by dividing with a factor of safety, whose value depends on the design philosophy used.

(a) (b) (c)

Figure 2: Compressive strength testing of concrete cubes specimens with different compositions.

D. Split Tensile Strength Test

It is the standard test to determine the tensile strength of concrete in an indirect way. A standard test cylinder of concrete specimen (300mm×150mm diameter) is placed horizontally between the loading surfaces of compression testing machine. The compression load is applied diametrically and uniformly along the length of cylinder until the failure of cylinder along the vertical diameter. To allow the uniform distribution of this applied load and to reduce the magnitude of high compressive stress near the points of applications of this load, strips of plywood are placed between the specimen and loading plates of the testing machine. Concrete cylinder split into two halves along this vertical plane due to indirect tensile stress generated by Poisson's effect. Assuming concrete specimen behave as an elastic body, a uniform lateral tensile stress of Ft acting along the vertical plane causes the failure of specimen, which can be calculated as-

$$F_t = 2P/\pi DL$$

where, P = compressive load at failure
D = diameter of cylinder
L = length of cylinder

(a) *(b)*
Figure 3: Split tensile strength test of cylindrical specimen with different composition.

III.RESULTS

A. Compressive Strength

The compressive strength values for a cube specimen plotted for different percentage composition of rubber tyre pieces of size 1cm x 1cm, 1cm x 2cm & 1cm x 3cm are shown in figure 3, figure 4 and figure 5 respectively. The 7th day and 28th day compressive strength values are observed and compared consecutively. For each tyre percentage content and dimension three cube specimen were cast and tested. The average of three is taken as compressive strength value.

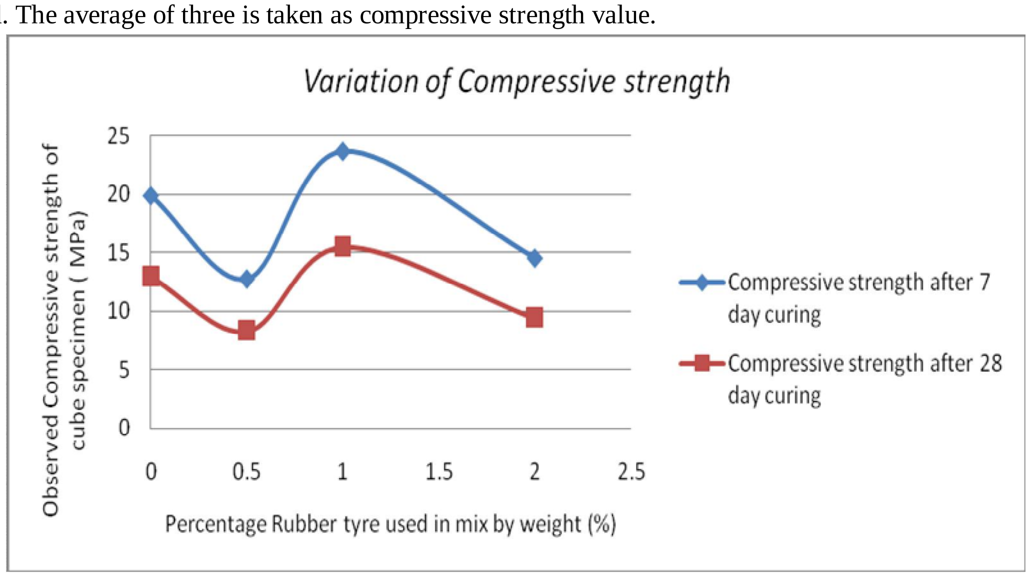

Figure 4: Compressive strength variation of cube after 7thand 28thday curing. (Rubber of tyre size 1×1 cm^2)

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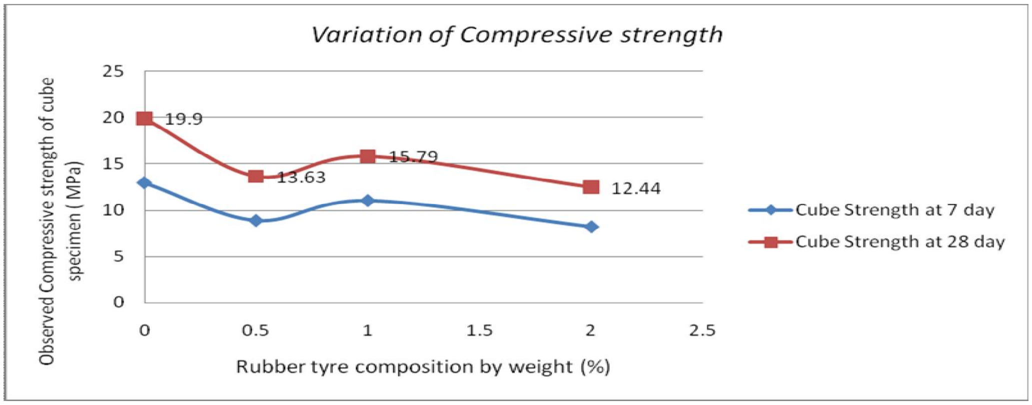

Figure 5: Compressive strength variation of cube on 7thand 28thday curing. (Rubber of tyre size 1×2 cm^2)

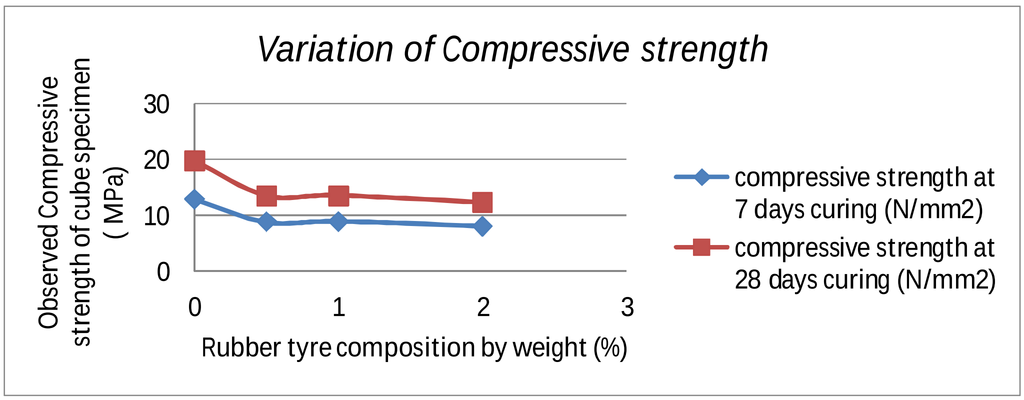

Figure 6: Compressive strength variation of cube on 7thand 28thday curing. (Rubber of tyre size 1×3 cm^2)

Both 7th and 28th day compressive strength values are generally observed on decreasing with increase in tyre percentage in the test specimens. However these values were seems to increase for 1% tyre content in all specimens. This increase is observed to be steeper for tyre aggregate size 1cm x 1cm when compared with normal concrete specimens without rubber aggregate content.

B. Split Tensile Strength

The splitting tensile strength of the crumb rubber concrete with the different percentage replacement of crumb rubber by fine aggregate in normal concrete at the 7thand 28thday results were observed and plot is derived as shown below in fig 6, fig 7 & fig 8.

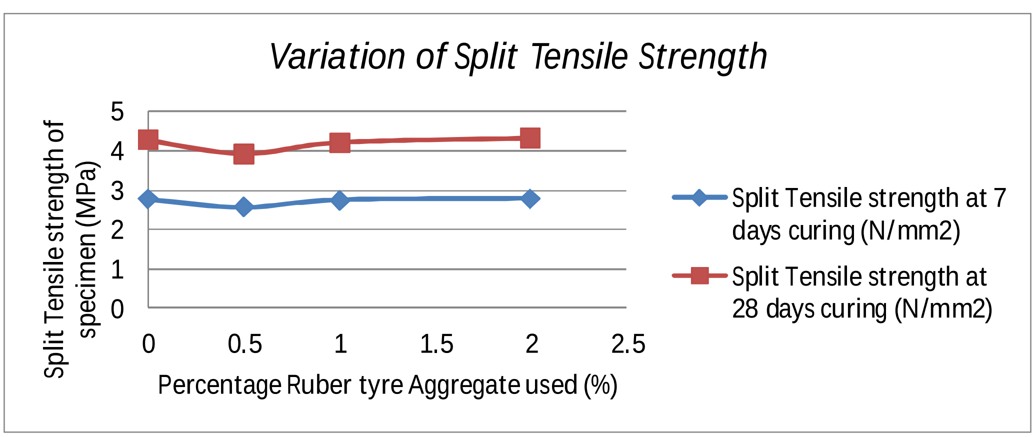

Figure7:Tensile strength variation on 7 and 28 days curing. (Rubber of tyre size 1×1 cm^2)

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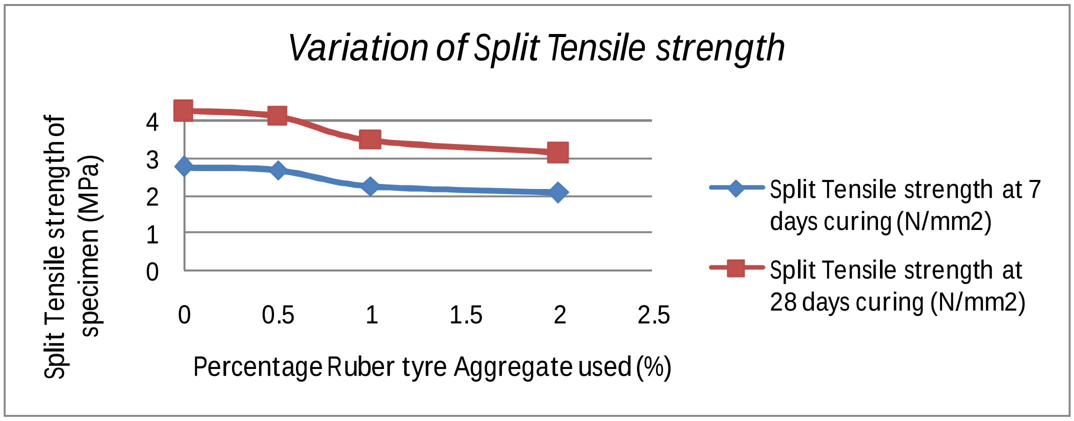

Figure8: Tensile strength variation on 7 and 28 days curing. (Rubber of tyre size 1×2 cm^2)

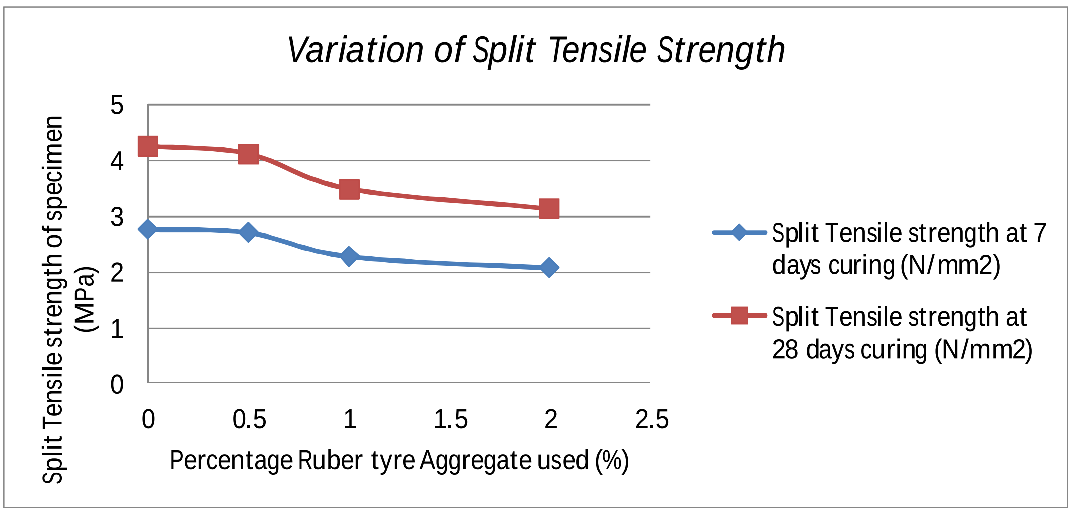

Figure 9: Tensile strength variation on 7 and 28 days curing. (Rubber of tyre size 1×3 cm^2)

The trend for both 7th day and 28th day tensile strength is seemed to decreasing with increasing rubber tyre content. However this decrement in tensile strength is slight less for tyre aggregate size 1cm x 1 cm [figure 7]. This is due to uniform dimension of tyre aggregate size in all direction and uniform distribution of stresses in tyre pieces.

IV. CONCLUSIONS

The results revealed that although there is a reduction in strength for crumb rubber mixture, but slump values increase as the crumb rubber content increase from 0% to 2%. It means that crumb rubber mixture is more workable compare to normal concrete. The results also indicated that inclusion of crumb rubber in concrete reduced the static modulus elasticity. Although there is a reduction in modulus of elasticity but the deformability crumb rubber concrete increasing compared to normal concrete. Results indicated that the unit-weight of crumb rubber concrete was lower than that of plain concrete. The decrease was found to be proportional with the crumb rubber content. In addition to the decrease in unit-weight, the crumb rubber concrete also exhibited better sound and thermal properties. However, due to the low strength and stiffness of rubber, the mechanical properties of crumb rubber concrete appeared to be lower than that of plain concrete. A plot of compressive strength and tensile strength of concrete specimens at 7th and 28th day is prepared with increasing rubber tyre content using different tyre pieces dimensions and results are observed thoroughly. The results showed that with up to 1% replacement, in each set, no major changes on concrete characteristics would occur, however with further increase in replacement ratios considerable changes were observed. Author has devised a better solution of decomposing non-bio-degradable rubber tyre waste and concluded that used rubber tyre waste pieces of size 1cm x 1cm served as better replacement in terms of compressive and tensile strength.

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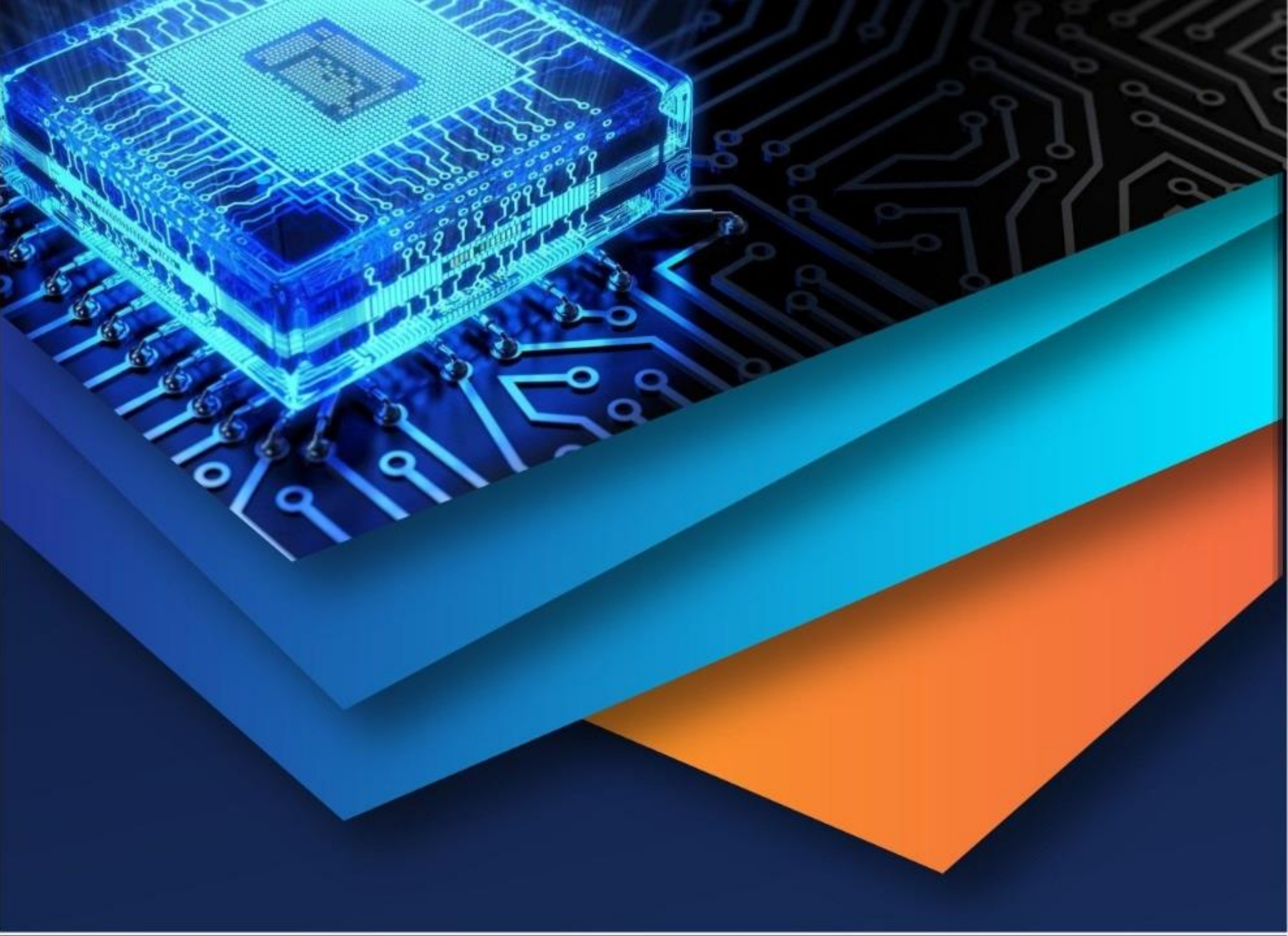

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