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To Investigate the Properties of Concrete Having Partial Replacement of Fine Aggregate with Copper Slag and Coarse Aggregate with Ceramic Tile Waste

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Abstract: The process of smelting copper produces copper slag as a by-product. The disposal of such a massive volume of copper slag raises environmental concerns. So, recycled copper slag can be utilised in place of fine aggregate or cement. This has several benefits, including lowering disposal costs and increasing recycling rates. In terms of coarse aggregates, their supply is a serious challenge in the construction industry. As a result, ceramic tile waste can be used as a coarse aggregate substitute. They are tough, long-lasting, and resistant to degrading forces. Ceramic tile wastes are simply leftover tiles from construction projects. Waste generated during building and demolition activities accounts for over 70% of all waste worldwide. Furthermore, approximately 60% of the waste generated during the creation of tile is discarded. As a result, discarding such a large amount of rubbish causes environmental issues. Concrete costs are lowered when they are used. The results of an experimental inquiry into the impact of partially substituting fine aggregate with copper slag and coarse aggregate with ceramic tiles waste on the strength properties of concrete are presented in this study. Utilizing 150x300mm cylindrical specimens for split tensile strength research and 150x150x150mm cubes for compressive strength testing. As the amount of ceramic waste in the mix rose, the concrete's workability, density, compressive strength, and flexural strength all decreased. The mix M5 had a compressive strength of 44.40 N/mm2 after 28 days of curing. Ceramic waste is porous and lighter than conventional coarse aggregate, resulting in lower density and strength. This study shows that ceramic waste may be utilised for both structural and non-structural purposes.
Keywords: Ceramic tiles waste, Copper slag, Compressive Strength, Flexural Strength, Split Tensile Strength.

I. INTRODUCTION

A. General

Concrete is the composite material of cement, water, and aggregates such as fine and coarse aggregates. Concrete is the second most utilised material in the world after water. By the increased use of aggregate materials for construction poses threat to the naturally available material and hence becoming scarce. due to the wide use of aggregates in the construction, it is estimated that about 5% of global CO_2 emissions is contributed by concrete industry. To give a clear understanding of the situation for everyone tons of cement produced 1 tons of CO_2 is produced and freed to the atmosphere favourable to global warming. Laterally with this demand for raw material such as river sand and gravel suffer to increase. It is projected that the global needs of aggregate were around 25.9 to 29.6 billion tones for the year 2012. As a non-renewable resource, it can be a huge drawback if not used wisely.

Efforts have been made to identify ‘green' alternatives to sand, cement and aggregates. The researchers replaced the cement by various binders like, fly ash, silica smoke, rice straw ash and observed dust. In addition, the excellent fine aggregate has been replaced by copper slag, rubber crumb waste and steel slag. Copper slag is a by-product derived from the smelting of copper. Eliminating this amount of copper slag causes environmental problems. As a result, copper slag waste can be used as a fine aggregate. In the case of coarse aggregates, their availability in the building sector is a major concern. Thus, one alternative material for coarse aggregate is ceramic tile waste. They are resistant, long-lasting and withstand the forces of degradation.

B. Copper Slag

Copper slag is an industrial product in terms of the content of products made from the process of making copper. It is a crystalline granular material with a high density and its particle size is the shape of the sand and can be used as finer aggregate in concrete. It has the same physical and chemical properties as sand.

Copper slag has pozzolanic properties such that it has cement properties and can be used as a partial or complete cement replacement. The use of copper slags in concrete provides the building industry with potential environmental and economic benefits. If copper slag is not disposed of properly, the main cause of CO_2 and other harmful gas vapours is global warming which destroys the ozone layer which is harmful to the planet Earth.

C. Ceramic Wastes

In the current construction environment, solid waste increases every day with the demolition of buildings. Ceramic tiles are widely used today Construction is underway and the construction field is growing day by day. Ceramic products are among the most often utilised building materials in most structures. Wall tiles, floor tiles, sanitary ware, household ceramics, and technical ceramics are some of the most regularly produced ceramics. They are mostly made from natural materials soil which contains large amounts of minerals. However, in spite of the decorative advantages of ceramics, its waste, among others, causes many problems for the environment. And this too on the other hand, waste tiles are also being produced from demolition waste. The production of Indian tiles in the ceramic industry is 100 million tons per year, approximately 15%-30% of waste material is generated from total production.

D. Objectives

1) To determine the compressive strength of concrete made by replacing sand with copper slag and coarse aggregate with ceramic tile waste and comparing it with standard concrete.
2) To determine the flexural strength of concrete made by replacing sand with copper slag and coarse aggregate with ceramic tile waste and comparing it with standard concrete.
3) To determine the split tensile strength of concrete made by replacing sand with copper slag and coarse aggregate with ceramic tile waste and comparing it with standard concrete.
4) To determine the workability of concrete made by replacing sand with copper slag and coarse aggregate with ceramic tile waste and comparing it with standard concrete.

II. MATERIALS

A. Cement

There was a use of OPC 43 Grade in accordance with IS: 8112. All relevant cement test results were completed at the relevant laboratory. The test results are shown in Table 1.

TABLE 1
TEST RESULTS OF CEMENT

S. No.	Properties	Exp Value	IS:8112-1989 limits
1.	Fineness (Sieving method)	5.73%	< 10%
2	Normal Consistency	29%	--
3	Initial Setting Time [minutes]	61	>30
4	Final Setting Time [minutes]	289	<600
5	Specific Gravity	3.13	3 to 3.25
6	Specific Surface Area (cm^2/g)	2781	>2250
7	Soundness Test (Le-Chatelier Apparatus)	0.7	10 mm (max.)
8	Compressive Strength (MPa) 1. 3 days 2. 7 days 3. 28 days	26.12 MPa 38.19 MPa 47.11 MPa	Minimum 16 MPa 22 MPa 43 MPa

B. Fine Aggregate

As fine aggregates, crushed sand was utilised. Table 2 shows laboratory measurements of the physical parameters of sands, such as their specific gravity and fineness modulus.

TABLE 2
TEST RESULTS OF FINE AGGREGATE

Test	Values obtained
Specific Gravity	2.64
Fineness modulus	2.81
Silt content	4.40%
Water absorption	1.1%
Bulk density (poured)	1378 kg/m^3
Bulk density (tamped)	1612 kg/m^3

C. Coarse Aggregate

In this study, angular crushed particles were used. In Table 3, the physical characteristics of coarse aggregate are listed. Coarse aggregates were graded in accordance with IS:383-1970. The nominal sizes of the aggregates, 20 mm and 10 mm, were blended. According to IS 2386-Part-III, the specific gravity and water absorption of coarse aggregate were calculated (1963).

TABLE 3
TEST RESULTS OF COARSE AGGREGATE

Test	Result
Aggregate Crushing Value (ACV)	17.14 %
Aggregate Impact Value (AIV)	11.31 %
Nominal Size	20 mm
Specific Gravity	2.67
Water absorption	0.75%
Grading ratio of 20mm to 10mm	2:1
Bulk Density (poured)	1701 kg/m^3
Bulk Density (tamped)	1938 kg/m^3

D. Water

In this project, potable water from a laboratory that met BIS:456-2000 criteria were utilised in the mixing and curing.

E. Copper Slag

Copper slag is an industrial product in terms of the content of products made from the process of making copper. It is a crystalline granular material with a high density and its particle size is the shape of the sand and can be used as finer aggregate in concrete. It has the same physical and chemical properties as sand. Copper slag has pozzolanic properties such that it has cement properties and can be used as a partial or complete cement replacement. It is regarded as a waste that can be used in the construction as a complete or partial alternative to cement or aggregate. The use of copper slags in concrete provides the building industry with potential environmental and economic benefits. If copper slag is not disposed of properly, the main cause of CO_2 and other detrimental gas vapours is global warming which destroys the ozone layer which is harmful to the planet Earth. The physical and chemical properties of copper slag are given as under in Table 4 and Table 5 respectively.

TABLE 4
PHYSICAL PROPERTIES OF COPPER SLAG

S. No	Property	Value
1	Shape	Irregular
2	Specific Gravity	3.54
3	Average Particle Size	0.5mm
4	Bulk Density	3.16 to 3.87 g/cm^3
5	Appearance	Black and Glassy

TABLE 5
CHEMICAL PROPERTIES OF COPPER SLAG

S. No	Property	Value
1	Iron Oxide (Fe_2O_3)	30–40%
2	Silicon Dioxide (SiO_2)	26–30%,
3	Calcium Oxide (CaO)	1%-2%
4	Aluminium Oxide (Al_2O_3)	1%-3%

F. Ceramic Tile Aggregate

The broken bricks were taken from the solid waste of the ceramic production unit and the demolished building. Bricks are crinkled into small pieces manually and using a crusher. The required size of crushed brick aggregate has been separated for partial replacement of natural coarse aggregate.

TABLE 6
PHYSICAL PROPERTIES OF CERAMIC TILE WASTE

S. No	Property	Value
1	Origin Rock	Feldspar
2	Impact value of ceramic tiles	12.5%
3	Specific gravity of ceramic tiles	2.6
4	Specific gravity of CTW powder (C.F.A)	2.5
5	Water absorption of crushed tiles	0.19%

III. METHODOLOGY

A. Casting

Before casting, the concrete's handling in terms of slump is measured. Test pieces of conventional size for compressive strength tests, i.e., 150 x 150 x 150 (all dimensions in mm) cast in eleven batches with different ratios of copper slag and ceramic waste. Similarly, for the split tensile test, a sample of size 300 x 150 is prepared with the same batch number. For the flexural strength test, mould of size 150 x 150 x 750 are prepared. After pouring concrete into the mould, proceed to compaction with a table compactor to achieve the desired compaction. The surface of the mould is then trowel-finished and the casting date with the designation number of the mixture marked on it.

B. Curing

The specimens were removed from the moulds after 24 hours and put in curing tanks where they underwent a 28-day curing process at ambient room temperature.

C. Tests on Concrete

1) *Slump Cone Test:* This test entails using a Slump Cone mould with standard dimensions. The mould is put on a firm, smooth surface, and concrete is poured into it in four equal-height stages. With a tamping rod, each layer is tamped 25 times. This test is used to assess the fluidity of a substance. It's important to keep in mind that the concrete should be free of bleeding and segregation
2) *Compressive Strength Test:* Concrete specimens of size 150 x 150 x 150 were tested for compressive strength at three different curing periods. Each layer is tamped 35 times, and if it is 100 mm in size, each layer is tamped 25 times. Specimens were placed in a CTM, and a progressive load of 14N/mm2 was applied up to failure. The load that caused failure was then recorded.
3) *Flexural Strength Test:* The Flexural Strength of Concrete is the ability of a span or beam to withstand failure when bent. In the current investigation, flexural test concrete beams with dimensions of 100x100x500 mm were cast and tested in accordance with IS:516-1959. Flexural *strength* of beam specimens was calculated as an average of three specimens for different % of copper slag & ceramic tiles waste. Each set consists of three cylinders that provide the Flexural Strength as the average Strength of the specimens. The test results are
4) *Split Tensile Strength Test:* Concrete's direct tensile strength cannot be determined since it is highly breakable under tension. Concrete's tensile strength is expressed as split tensile strength or flexural strength. Concrete's indirect tensile strength is determined by split tensile strength. A cylindrical specimen measuring 300 x 150 (all measurements in mm) was employed in our study. At 7, 14, and 28 days, tests were carried out. For each test, three specimens were cast, and the average of those three was used to determine the concrete's split tensile strength.
5) *Mix Design:* Concrete mix design was based on compressive cube strength of trial mixes arrived at as per IS 10262-2009.

TABLE 8
MIX DESIGN PARAMETERS

i.	Mix Grade :	M40
ii.	43 Grade Cement strength At 7 days At 28 days	 33 MPa 43 MPa
iii)	Maximum aggregate size (Coarse):	20 mm (angular size), graded.
iv)	Sp. Gravity of C.A (Saturated Surface Dry condition) :	2.64
v)	Sp. Gravity of F.A (Saturated Surface Dry condition) :	2.97
vi)	Bulk density of C.A. (loose) : (Rodded):	1.43 kg/L 1.64 kg/L
vii)	Bulk density of F.A. (loose) : (Rodded):	1.77 kg/L 1.82 kg/L
viii)	Workability :	120-140 slump
ix)	Fine Aggregate :	Zone II
x)	Quality Control at site :	Good
xi)	Exposure conditions :	Severe

The mix design ratio as calculated is as under: Cement: FA: CA = 1 : 2.24 : 3.24

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IV. RESULTS AND DISCUSSIONS

A. *Slump Cone Test*

TABLE 9
SLUMPVARIATION WITH CEMENT, CERAMIC TILES WASTE & COPPER SLAG

S. No	Mix Name	COPPER SLAG%	CTW%	Slump (mm)
1	M1	0	0	39
2	M2	11	7	46
3	M3	22	21	60
4	M4	33	28	71
5	M5	44	35	89
6	M6	55	35	83
7	M7	55	42	78
8	M8	66	42	76

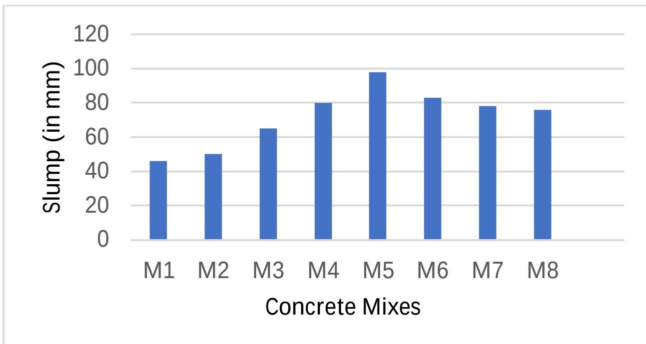

Fig. 1 Slump variation with cement, CERAMIC TILES WASTE & COPPER SLAG

B. *Compressive Strength Test*

In this test, we used the specimen size of 150 x 150 x 150 (All dimensions in mm). The specimens were casted and after 24 hours, they were placed in curing tank at required temperature and relative humidity. Compressive Strength was performed on specimens at three stages (7 days, 14 days and 28 days).

TABLE 10
COMPRESSIVE STRENGTH VARIATION

S. No	MIX	% CS+CTW	Compressive Strength (N/mm^2)		
			7 days	14 Days	28 Days
1	M1	0+0	26.65	34.81	39.98
2	M2	11+7	27.33	36.36	41.00
3	M3	22+21	28.54	38.45	42.81
4	M4	33+28	28.68	38.27	43.02
5	M5	44+35	29.60	39.84	44.40
6	M6	55+35	28.77	38.24	43.15
7	M7	55+42	27.87	36.91	41.81
8	M8	66+42	25.50	33.32	38.21

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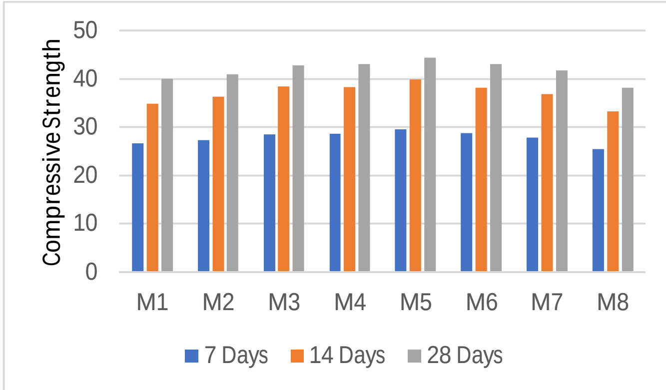

Fig. 2 28 Day Compressive Strength Variation

C. *Flexural Strength Test*

Flexural strength is a unit of measurement used to describe a concrete structure's capacity to resist bending failure. Testing was done after 7, 14, and 28 days of cure.

TABLE 11
FLEXURAL STRENGTH VARIATION

S. No	MIX	% COPPER SLAG+CTW	Flexural Strength (N/mm^2)		
			7 days	14 Days	28 Days
1	M1	0+0	3.29	4.25	5.00
2	M2	11+7	3.42	4.35	5.13
3	M3	22+21	3.56	4.60	5.35
4	M4	33+28	3.58	4.62	5.38
5	M5	44+35	3.62	4.78	5.55
6	M6	55+35	3.53	4.67	5.39
7	M7	55+42	3.45	4.46	5.23
8	M8	66+42	3.13	4.07	4.78

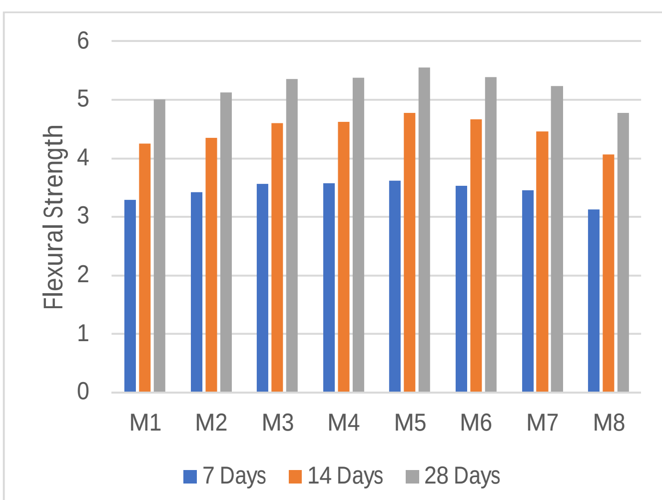

Fig. 3 28 Day Flexural Strength Variation

D. *Split Tensile Strength Test*

Direct tensile strength of concrete cannot be measured as it is very weak in tension. Tests were conduct at 7 days, 14 days and 28 days as shown in Table 12.

TABLE 12
SPLIT TENSILE STRENGTH VARIATION

S. No	MIX	% CS+CTW	Split Tensile Strength (N/mm^2)		
			7 days	14 Days	28 Days
1	M1	0+0	2.39	3.20	3.68
2	M2	11+7	2.43	3.24	3.74
3	M3	22+21	2.59	3.37	3.84
4	M4	33+28	2.52	3.39	3.85
5	M5	44+35	2.54	3.42	3.92
6	M6	55+35	2.52	3.37	3.86
7	M7	55+42	2.45	3.28	3.78
8	M8	66+42	2.32	3.14	3.58

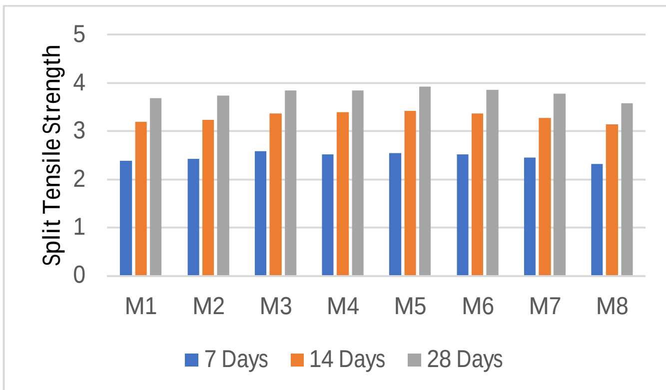

Fig. 4 28 Day Split Tensile Strength Variation

V. CONCLUSION

COPPER SLAG and CERAMIC TILES WASTE content both contributed to an increase in the compressive strength of partially replaced concrete. The values of compressive strength were higher than conventional concrete in most of mixes. Mix M5 showed maximum 7-day, 14-day, 28-day compressive strength having values 29.60 MPa, 39.84 MPa, 44.40 MPa respectively as shown Fig 5.2 to Fig 5.7. Maximum increase in compressive strength with respect to conventional concrete is given in Table 13.

TABLE 13
COMPARISON OF MAX COMPRESSIVE STRENGTH

S. No	Curing Age	Increase in Compressive Strength (MPa)	Percentage Increase (%)
1	7 days	2.95	11.06
2	14 days	5.03	14.44
3	28 days	4.42	11.05

Flexural strength was higher for most of the mixes than conventional mixes. Mix M3 had the highest 7-day, 14-day and 28-day flexural strength as 3.62 MPa, 4.78 MPa and 5.55 MPa respectively. Maximum increase in flexural strength with respect to conventional concrete is given in Table 14 as under

TABLE 14
COMPARISON OF MAX. FLEXURAL STRENGTH

S. No	Curing Age	Increase in Flexural Strength (MPa)	Percentage Increase (%)
1	7 days	0.33	10.03
2	14 days	0.53	12.47
3	28 days	0.55	11.00

7-Day Split Tensile Strength came out to be maximum for Mix M5 (2.54 MPa) whereas for 14-Days and 28-Days, the split tensile strength came out to be maximum for the mix X3 (3.4 and 3.92 MPa respectively). Maximum increase in split tensile with respect to conventional concrete is given in Table 15.

TABLE 15
COMPARISON OF SPLIT TENSILE FLEXURAL STRENGTH

S. No	Curing Age	Increase in Tensile Strength (MPa)	Percentage Increase (%)
1	7 days	0.15	6.27 %
2	14 days	0.22	6.87%
3	28 days	0.24	6.52%

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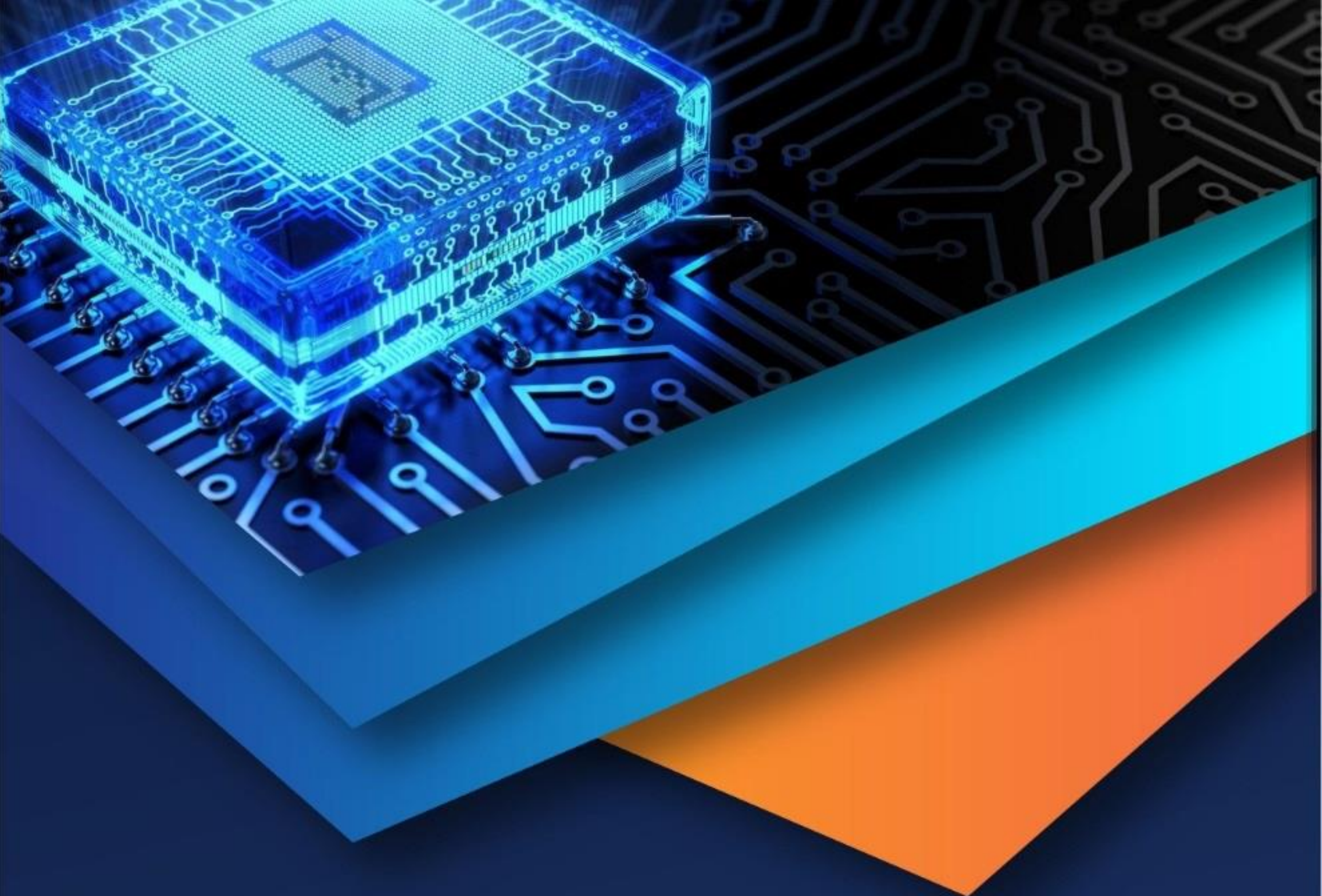

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