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Investigation on Partial Replacement of Various Waste Materials as Coarse Aggregate in Concrete

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Abstract: The reuse of ceramic waste and iron slag waste as a substitute for coarse aggregate in concrete has been investigated. The current option for disposal of ceramic waste is landfill and this waste is of three types, namely ceramic tiles, clay bricks, flower potspots. Ceramic tiles were obtained from construction and demolition sites, which caused environmental pollution utilizationation of crushed tile as a coarse aggregate in concrete would also have a positive effect on the economy. And slag is considered a third-class hazardous waste that requires a large place for dumping. To transform the slag into an environmentally friendly resource and save the environment from pollution, the possibility of using slag as coarse aggregate cannot be overlooked. In the present study, ceramic tile waste and iron slag were used in concrete as a replacement for natural coarse aggregate with 0%, 10%, 50%, and 100% of the substitution, and M25 grade concrete was used. The concrete modulus was cast and tested for compressive strength after a curing period of 15 and 21 days.
Keywords: coarse aggregate, fine aggregate, ceramic waste, Iron slag, water cement ratio.

I. INTRODUCTION

The reutilization of waste materials as new construction materials is the main objective for sustainable construction activities in the future. The concerns related to sustainability and limited natural resources along with the use of recycled and secondary aggregates are of utmost importance nowadays. Materials such as construction and demolition wastes (C&D wastes) and organic wastes (e.g., rice husk) have been introduced in the production of concrete for both reasons of environmental sustainability and improvement of concrete properties. However, ceramic waste and iron slag waste are not commonly used in the making of concrete. Ceramic wastes have the possibility to be incorporated into concrete due to their pozzolanic properties. They are also known for their resistance to abrasion and lower-density properties, which can be expected to improve the quality of concrete. The necessity of utilizing recycled aggregates and industrial wastes in civil works is due to the great volume of waste materials generated. Applications for fills and embankments, road base and sub-base layers, and as aggregate for concrete are some possible destinations for recycled aggregates and industrial wastes. Because of the large volume of materials required for construction and pavements being favorable structures recycling g of a wide range of waste materials, the possibility of replacing coarse aggregate with other waste materials has been investigated. Gravel, crushed stone, granite, and limestone are conventionally used as coarse aggregate in concrete production. (N. Sivachandiran A. Magesh; 2018) On the other hand, the production and utilization of concrete are rapidly increasing, which results in increased consumption of natural aggregate and construction waste as the largest concrete component. For example, two billion tonnes of aggregate are produced each year in the United States; production is expected to increase to more than 3.5 billion tonnes per year by the year 2030. (Priyanka Kusum, Sayed Tabish Quadri 2021, Dr. Varinder Singh 2019). Demolition of old and deteriorated buildings and traffic infrastructure and replacement with new ones is a common occurrence in many parts of the world today. The main reasons for this situation are change of purpose, structural deterioration, management of a city, expansion of traffic directions and increasing traffic loads, natural disasters (earthquakes, fires, and floods), etc. For example, about 850 million tonnes of construction and demolition waste are generated each year. In the USA, the waste produced from building demolition alone is estimated to be 123 million tonnes per year. The most common method of managing this material has been through its disposal in landfills. In this way, huge deposits of construction waste are created, consequently becoming a special problem of human environmental pollution, (Bikash Subedi, Dhurba Kumar 2020) henceforth laws have been put in practice time to restrict this waste in the form of prohibitions or special taxes for creating waste areas in developed countries. The present study aims to investigate the partial replacement of coarse aggregate by waste material in concrete.

II. MATERIALS AND METHODS

The experiments were performed to analyze the strength of the concrete obtained from the replacement of coarse aggregate by various waste materials at various mixed proportions.

A. *Ceramic title waste and its Properties*

A ceramic material is an inorganic, non-metallic, often crystalline oxide, nitride, or carbide material. Elements, such as carbon or silicon, may be considered ceramics. (MD Daniyal et al 2015) They are brittle, hard, strong in compression, and weak in shear and tension. Other than their normal use as filling material, ceramic wastes are classified as non-recyclable waste and have the potential to be used in the production of concrete and to improve its strength and durability, according to research on recyclable construction and demolition (C&D) wastes (S. Sharmiladevi, Dr. K. Ramadevi 2017). However, there are no guidelines or standards for the usage of these wastes in concrete. In addition, the local construction industry does not have the knowledge and experience to utilize the material.

Some of the highly desirable properties of, ceramic is:

- High Strength.
- High Fracture Toughness.
- High Hardness.
- Excellent Wear Resistance.
- Good Frictional Behavior.
- Anti-Static

Fig 1.1: ceramic waste

B. *Iron slag waste and its properties:*

Slag is a by-product obtained as a leftover in steel production after a desired metal has been separated (i.e., smelted) from its raw ore, and it is usually a mixture of metal oxides and silicon dioxide. (Khalid Raza et al 2012) Iron slag is considered third-class hazardous waste, which may require a large place for dumping. (R. Kamala et al 2012) Traditional coarse aggregates are very costly and withdrawn every day resulting in exhausting eserves, which will pose a great threat in near future. As per the survey conducted by Safe, Inc. (2002), a single ferroalloys industry produces 220,000 tonnes of low-carbon slag per year.

Mixed Slag Aggregate (SM) | Heavy Slag Aggregate (SH) | Light Slag Aggregate (SL)

Fig 1.2: Iron slag waste

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C. Cement

Cement is used as a binding material in concrete, where strength and durability are important considerations. The concrete is made with ordinary Portland cement 53 grade conforming to IS:12269-1987. Consistency test, setting time test, and Specific gravity test were performed.

D. Aggregates

The size of aggregates used is 20 mm, and the grain size of sand is used.

1) *Fine Aggregate:* It consists of small, angular, or grounded grains of silica (SiO2) and is formed by the decomposition of sandstone under the influence of weathering agents. A size that is less than 4.75 mm is called fine aggregate. River sand is used as fine aggregate, conforming to the requirements of IS 383. Before using that, it can be properly cleaned by sieving and washing to eliminate the impurities.
2) *Coarse Aggregate:* coarse aggregate may be in the form of irregularly broken stones or naturally occurring rounded gravel. Coarse aggregate refers to materials that are too large to be retained on a 4.75mm sieve. It acts as the main filler and forms the bulk of some of the adhesive, some of which adheres in the form of film. Aggregates are used to balance the shrinkage and home changes of cotton that conforms to IS: 383.

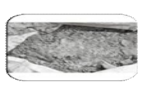
E. Water:

Water plays an important role in the mixing, laying, compaction, setting, and handing of concrete. Water influences the strength development and durability of concrete. On tiny drinking water can be used for preparing concrete; guidance on examining the stability of the available water for construction can be obtained from the following specified data in **IS 456- 2000**: The pH value of water should generally not be less than 6.

F. Ceramic tile aggregate waste (CTA)

Waste ceramic tiles are crushed uniformly to about 20 mm size manually using a hammer and sieved through a 20 mm sieve. Various tests were performed on the ceramic tile waste, such as specific gravity, water absorption, and an impact test.

Composition of materials for ceramic waste:


cement


fine aggregate


coarse aggrgate


creamic tile waste

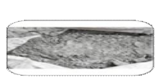
Table:1.1 Mix proportion used during replacement of ceramic waste.

% Replacement of CTA	w/c ratio	cement content in Kg	Water in ml	Fine Aggregate	Coarse aggregate	Ceramic waste
0	0.5	3.0	250	3.0	6.0	0.0
10	0.5	3.0	250	3.0	4.0	2.0
50	0.5	3.0	250	3.0	3.0	3.0
100	0.5	3.0	250	3.0	0.0	6.0

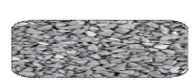
G. Iron slag waste

Iron slag is a by-product of steel that is produced during the separation of molten steel from impurities in the steel-making furnace (Keerthi Kumar et al. 2017, P. Vignesh Kumar, and R. Ranjith Kumar, 2016). The slag occurs as a molten liquid and is a complex solution of silicates and oxides that solidifies upon cooling.

Composition of materials for ceramic waste


cement


fine aggregate


coarse aggregate


Iron slag waste

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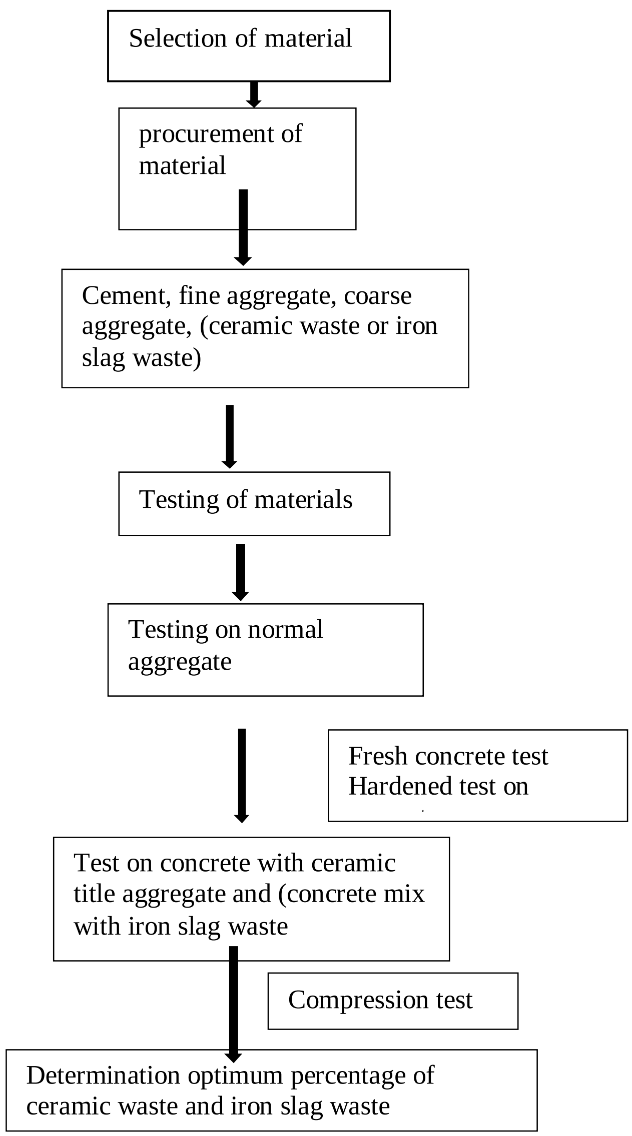
Table:1.2 Mix proportion used during replacement of Iron slag waste.

% Replacement of CTA	w/c ratio	cement content in Kg	Water in ml	Fine Aggregate	Coarse aggregate	Iron slag waste
0	0.5	3.0	250	3.0	6.0	0.0
10	0.5	3.0	250	3.0	4.0	2.0
50	0.5	3.0	250	3.0	3.0	3.0
100	0.5	3.0	250	3.0	0.0	6.0

III. METHODOLOGY

The flow table indicates the whole process which consists of a selection of materials such as cement, fine aggregate coarse aggregate, and waste. Concrete is prepared for M25 grade mix design for plain concrete. Ceramic tile waste was used as partial replacement with coarse aggregate and these were used as floor finishing and wall (S.O. Ajamu, et al 2018) Materials are mixed by considering the proportions as per the mix design. The mold of ddimensions 150 x150 x150 mm in 03 layers with each layer of height approximately 50mm (Priyanka Kusum, Sayed Tabish Quadri 2021). in each layer, compaction is done by using a tamping rod/shake table. the molds were prepared for different proportions as per the design IS:10262-2009. The cubes were cured for 7&28 days of curing period and the concrete were

Table:1.3 Flow chart of the methodology



IV. RESULT AND DISCUSSION

Table: 3.1 Physical Properties of Cement

SI No	PARTICULARS	VALUES
01	Specific Gravity	3.15
02	Setting Time Of Cement Initial Setting Time Final Setting Time	 30 min 285min

Table: 3.2 Physical Properties of Fine Aggregate

Si No	PARTICULARS	VALUES
01	Fineness Modulus	2.55
02	Maximum Size	2.36 mm
03	Specific Gravity	2.65
04	Water Absorption	1%

Table: 3.3 Physical Properties of Coarse Aggregate

Si No	PARTICULARS	VALUES
01	Fineness Modulus	2.26
02	Maximum Size	20 mm
03	Specific Gravity	2.68
04	Water Absorption	0.6%

Table: 3.4 Physical Properties of Ceramic Tile Waste

Si No	PARTICULARS	VALUES
01	Specific Gravity	2.22
02	Impact Value	24%
03	Water Absorption	14.4%

Table: 3.5 Physical Properties of Iron Slag Waste

Si	PARTICULARS	VALUES
01	Specific Gravity	3.20
02	Impact Value	45%
03	Water Absorption	0.61%

Table: 3.6 Comparison of Properties of Normal Aggregate With Ceramic Waste And Iron Slag Waste.

Si No	Particulars	Normal Aggregate	Ceramic Aggregate	Iron Slag Aggregate
01	Shape	Angular	Flaky	Rough and angular
02	Texture	Rough	All sides rough except top face	Rough
03	Specific gravity	2.68	2.22	3.20
04	Impact value	15%	24%	45%
05	Water absorption	0.6%	14.4%	0.61%

A. Compressive Strength Test

The compressive strength of aerated replacement concrete was determined on 7 & 28 days for each sample. Three samples for each test and the mean of the results were obtained. Fewer variables had been set for different mixture this variable would be changed accordingly while the others were fixed to forecast their effect on the mixture. It is one of the most important properties of concrete and influences many other describable properties of the hardened concrete. Compressive strength of the concrete is usually found by testing cube specimen. Cube of size 150mm x 150mm x150mm were casted using M25 grade concrete. Specimen with control concrete and ceramic waste concrete and Iron slag waste (waste were replaced with crushed stone) were casted. After 24 hours the specimen was removed from the mould and subjected to curing for 7 & 28 days. The specimen was tested for compressive strength as per IS 516-1959 using a calibrated compression testing machine.

Fig 3.1: Mold Used for Casting

Fig: 3.2 Concrete cast at various proportion

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Fig3.4: Showing the behavior of cubes

B. Behavior And Mode of Failures

The cubes were subjected to compressive force to expose their behavior. The failure pattern of various concrete cubes is shown in the figure. As the load increased, the diagonal crack width also increased and extended toward the top of the cube. The concrete was crushed and spalling down. Various mixes including one control mix were used to examine the influence of adding ceramic waste and Iron slag waste. The concrete M25 grade was prepared in the laboratory in various mix proportions, the coarse aggregate was replaced with 0%,10%,50%, &100% (by weight) of ceramic waste and Iron slag waste (Keerthi Kumar et al., 2017; Priyanka Kusum, Sayed Tabish Quadri, 2021) respectively. The concrete was poured into the mold in 3 layers with 25 strokes with a tapping rod. The cast specimen was removed after 24 hours and these are immersed in a water tank. After curing for 7 &28 days the specimens were removed and tested for their compressive load and found to be for concrete which was replaced with ceramic waste and Iron slag waste.

Fig 3.5: cubes casted for investigation

C. Compressive Strength for Different Percentage of Ceramic Tile Waste Used for M25 Grade

Table 3.7 Test results of M25 grade concrete with 0%,10%, 50% and 100% replacement of CTA with coarse aggregate for 7&28 Days

SI no	% Replacement of coarse aggregate	7 days	28 days
01	0%	20	25
02	10%	15	19
03	50%	19	23
04	100%	17	20

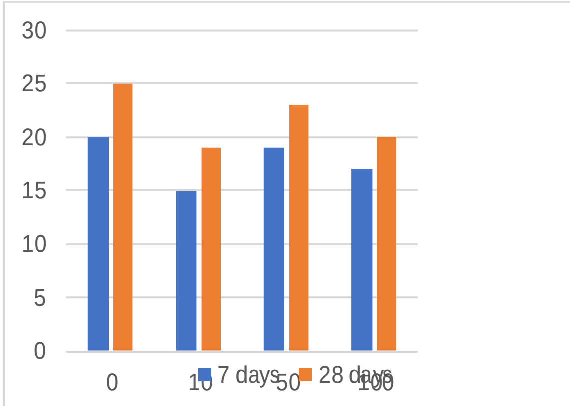

Fig:3.6 Compressive strength of concrete at various % replacement of ceramic waste on 7 Days and 28 Days.

D. Compressive Strength for Different Percentage of Iron Slag Waste Used For M25 Grade

TABLE 3.8 Test results of M25 grade concrete with 0%,10%, 50% and 100% replacement of Iron slag waste with coarse aggregate for 7& 28 Days

SI no	% Replacement of coarse aggregate	7 days	28 days
01	0%	20	25
02	10%	15	20
03	50%	18	23
04	100%	16	22

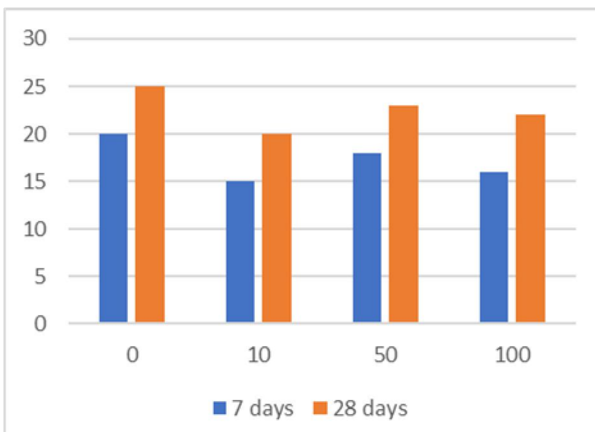

Fig 3.7 Compressive strength of concrete at various replacement of Iron slag waste on 7 &28 days

V. CONCLUSIONS

This paper is on the use of recycling waste material into useful construction material to reduce the cost of waste disposal. The use of ceramic tile aggregate and iron slag waste as partial replacements for coarse aggregate in concrete has a positive effect on the environment and lowers the cost since the tile aggregate is easily available. Based on the findings, the following conclusions were drawn: The maximum compression strength was obtained when 50% of ceramic tile waste and iron slag waste were replaced with normal aggregate. The compressive strength for 100% replacement was low for both the ceramic waste and iron slag waste due to the properties of the waste. By adding ceramic tile aggregate and iron slag to coarse aggregate, proper utilization of ceramic waste and iron slag waste can be achieved.

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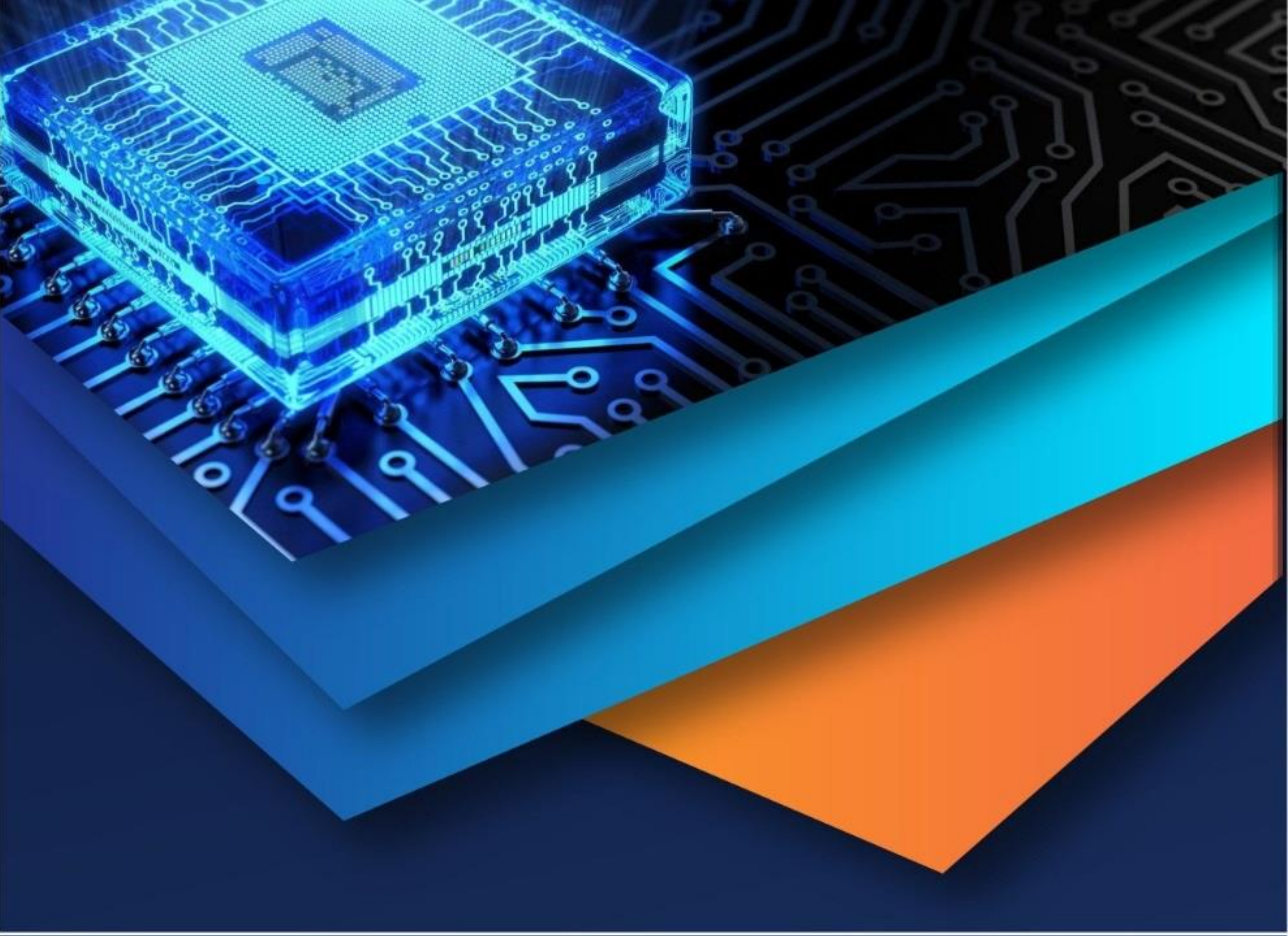

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