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Analysis of High Strength Concrete processed from Recycled Concrete Aggregates

Shanu Sharma[1], Siddharth Pastariya[2]
[1]Assistant Professor, Department of Civil Engineering, Indore Institute of Science & Technology Indore M.P
[2]Assistant Professor, Department of Civil Engineering, Sri Aurobindo Institute of Technology Indore M.P

Abstract: As everyone is aware of the fact that Natural Coarse Aggregate (NCA) is the main constituent of traditional concrete mixes. Whenever an existing concrete structure is demolished, it produces smashed concrete waste in the large amount. Concrete waste give rise to negative effects on the environment. To evade the environmental pollution and mark effective reuse of the concrete waste as Recycled Aggregates in the place of NCA. This operative initiative provides an opportunity to reduce air pollution and soil exploitation to some extent.

Such concrete is sustainable in nature and also eco-friendly to the environment. Also, such waste material will lower the usage of naturally occurring stone to produce NCA and thus various natural energy resources will be safeguarded. This study covers the suitability norms for a material to be used for Recycled Aggregate. In this study the natural aggregate is replaced with recycled aggregate in the different percentages (0%, 25%, 50%). When percentage of recycled aggregate mixed in the fixed proportion as percentage replacement to natural aggregates, it imparts improvement in the property of fresh as well as hardened concrete like, compressive strength & split tensile strength. Laboratory results of this research indicates that the value of compressive strength, tensile strength stress-strain curve & NDT of these mixes drives on decreasing, but at the 25% replacement level, it achieves target mean strength. Hence, for the fundamental concrete mix Natural Coarse Aggregate can be efficiently replaced by the Recycled Aggregate to the range of 25%.

Keywords: Concrete, Recycled aggregate, Natural Coarse Aggregate (NCA), Compressive Strength, Tensile strength, , NDT, Stress-Strain Curve

I. INTRODUCTION

To introduce the concept of sustainability in the construction area, researchers are using demolished waste concrete pieces as a fresh concrete constituent. It is known as recycled aggregate (RA) which can be produced easily in the concrete crusher. Using RA in place of natural coarse aggregates in the concrete mix is the immense opportunity to maintain healthy atmosphere, the properties and characteristics of RA has not been fully investigated far. While it is hard to standardize the characteristic of RA it is required to understand that recycled aggregate must be studied for their source/ parent concrete, which will be used as RA, to increase the characteristics of processed concrete specimens.

The quality of RA could be different by its parent or source concrete because the parent concrete was planned for its purpose such as permeable, durable and high strength concrete. For example water/cement ratio of concrete will give an impact on water absorption capacity of RA which is correlated to uniqueness of concrete issue such as durability, permeability, compressive strength, tensile strength, split tensile strength, stress-strain curve and elastic modulus. There is a remarkable turn dejected in the high-quality aggregate accessible for the construction utility.

Globally aggregate use is estimated to be around 10-11 billion tones every year, out of which about 8 billion tones of aggregate (sand, gravel, and crushed rock) are being used in Plain Cement Concrete every year. The environmental impact assessment of the demolished concrete is significant. There is environmental impact of transportation of waste demolished concrete from the construction location but also, the waste concrete fill-up valuable landfills and causes soil exploitation. Construction and demolition concrete waste sum up a large portion of total generated solid waste. Concrete construction and demolition waste can be easily recycled as it is less expensive than disposing it into landfills and RCA can be effectively used as it is less costly than natural coarse aggregate of equivalent quality. This research will definitely provide an innovative perspective towards sustainable development in construction field with real futuristic approach.

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II. MATERIAL USED

1) *Cement:* In this study, Ordinary Portland Cement is used conforming to IS: 8112-1989. The fundamental properties of cement used are presented in the Table 1 below:

Table 1: Properties of Cement

Physical Property	Result
Fineness of Cement	8%
Normal Consistency	27%
Initial Setting Time (minutes)	35
Final Setting Time (minutes)	370
Specific Gravity	3.15

2) *Natural Fine Aggregate:* Fine Aggregate in the form of locally available sand with 4.75 mm maximum dimension is used in the research, having specific gravity, fineness modulus and unit weight as presented in the Table 2 below:

Table 2: Properties of Natural Fine Aggregates

Physical Property	Result
Fineness Modulus	3.21
Specific Gravity	2.7
Surface Texture	Even
Particle Shape	Curved

3) *Natural Coarse Aggregate:* Crushed stones are used as natural coarse aggregate with 20 mm maximum sieve size having specific gravity, fineness modulus, angular shape and unit weight is presented in the Table 3 below:

Table 3: Properties of Natural Coarse Aggregates

Physical Property	Result
Fineness modulus	7.58
Specific Gravity	2.71
Particle shape	Angular

4) *Recycled Aggregate:* The Recycled Concrete Aggregates passing through maximum 20mm sieve size and retained on 4.75mm size sieve is used as partial replacement to natural coarse aggregates at varying percentages.

III. EXPERIMENTAL WORK & RESULT

A. *Mix Design for M-30 Grade*

Mix design is done as per Indian Standard Codes IS 10262-2009 & IS 456-2000. The ratio of M-30 grade of concrete are tabulated here for the discussion in the Table 4 below:

Table 4: Mix Proportions

Cement	Water	FA	CA	W/C Ratio
380kg/m3	160	711 kg/m3	1283 kg/m3	0.42
1	0.42	1.87	3.37	0.42

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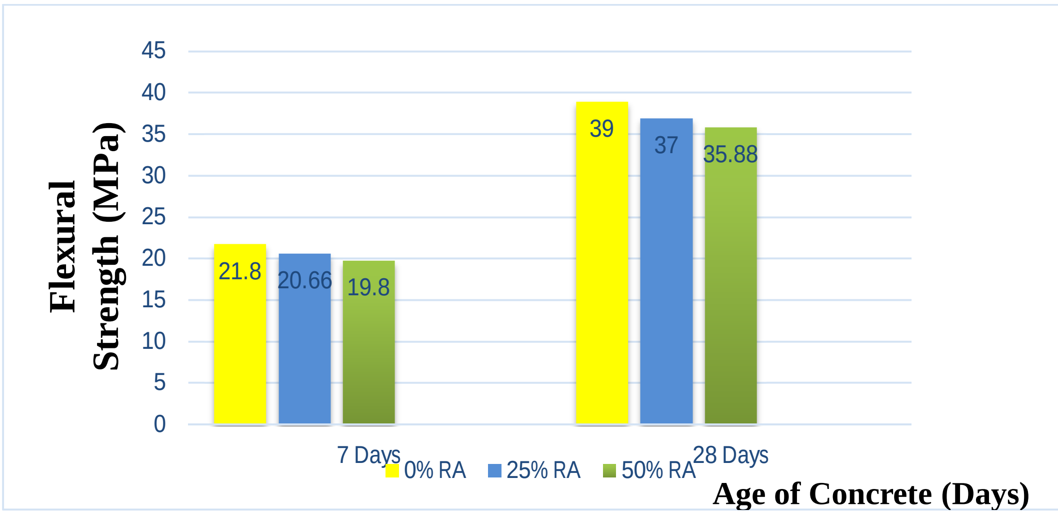
B. Testing of Concrete

1) *Compressive Strength:* Compressive strength test is completed on three cubes of every batch mix at 7 days & 28 days of curing. There are 5 batch mixes and each one having 9 cubes. Out of 9 cubes, 3 cubes are tested at 7 days & 28 days each. An average of 3 values is presented in the Table 3.1 below and corresponding Graph 1.

Table 3.1: Variation of Compressive Strength with age

% of RA	0%	25%	50%
7 Days	21.80 MPa	20.66 MPa	19.80 MPa
28 Days	39.0 MPa	37.0 MPa	35.88 MPa

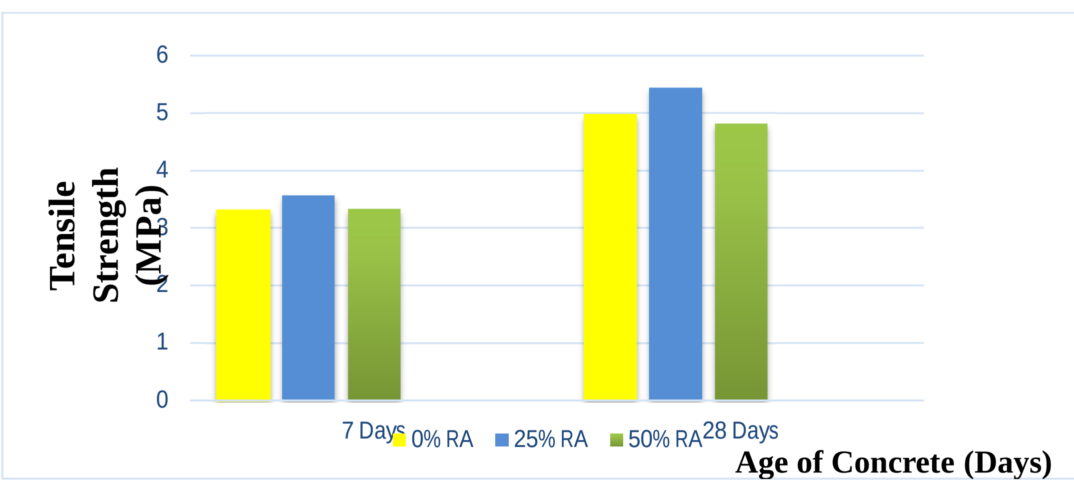


Graph 1: Flexural Strength Analysis at increasing % of Recycled Aggregate

2) *Split Tensile Strength:* Split Tensile Strength is performed on 3 cylinders foe every batch mix at 7 days & 28 days of curing. There are total 7 batch mixes and each of 9 cylinders. Out of these 9 cylinders, 3 cylinders are tested for 7 days & 28 days each. An average of 3 values as presented in the Table 3.2 below for discussions and corresponding Graph 2.

Table 3.2: Split Tensile Strength Analysis at 7days & 28 days of Curing

% of RA	0%	25%	50%
7 Days	2.62 MPa	3.33MPa	3.28MPa
28 Days	5.26MPa	5.64MPa	5.10MPa



Graph 2: Tensile Strength Analysis at increasing % of Recycled Aggregate

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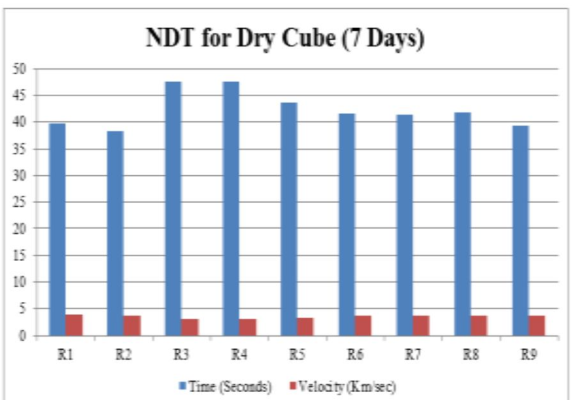
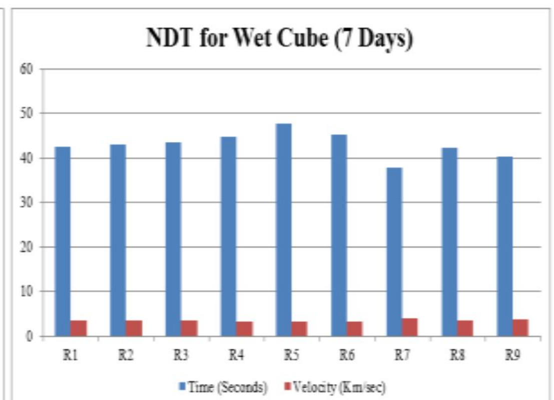
3) *Result Analysis of Ultrasonic Pulse Velocity(UPV):* Since after doing the partition of M30 cube, has been cured for 7 days and 28 days, following results has been drawn shown in Table 3.3 & Table 3.4 below along with its graphical representation in Graph 3, Graph 4, Graph 5 and Graph 6:-

Table 3.3: NDT of Cube for 7 days

Reading No.	Type of Specimen	Type of Transmission	Path Length (mm)	Dry (8.7 KG)		Wet (8.75 KG)	
				Time	Velocity	Time	Velocity
R1	CUBE (150mm x 150 mm x 150 mm) Grade M 30	Direct	150	39.8	3.88	42.5	3.54
R2		Direct	150	38.3	3.82	43	3.45
R3		Direct	150	47.6	3.15	43.4	3.46
R4		Direct	150	47.5	3.18	44.6	3.31
R5		Direct	150	43.7	3.4	47.7	3.12
R6		Direct	150	41.6	3.68	45.3	3.28
R7		Direct	150	41.3	3.63	37.8	3.94
R8		Direct	150	41.9	3.7	42.2	3.47
R9		Direct	150	39.4	3.72	40.3	3.71
		Average Velocity			3.96		3.47



Graph 3: NDT of Dry Cube (7 days)



Graph 4: NDT of Wet Cube (7 days)

Table 3.4: NDT of Cube for 28 days

Reading No.	Type of Specimen	Type of Transmission	Path Length (mm)	Dry (8.7 KG)		Wet (8.75 KG)	
				Time	Velocity	Time	Velocity
R1	CUBE (150mm x 150 mm x 150 mm) Grade M 30	Direct	150	41.5	3.72	39	3.72
R2		Direct	150	43.8	3.42	42.1	3.58
R3		Direct	150	41.5	3.52	44.7	3.43
R4		Direct	150	39.5	3.69	42.5	3.55
R5		Direct	150	42.2	3.64	42.8	3.51
R6		Direct	150	40.9	3.75	40.3	3.63
R7		Direct	150	40.5	3.75	51.4	3.88
R8		Direct	150	41.8	3.52	46.2	3.32
R9		Direct	150	38.4	3.8	40.6	3.77
		Average Velocity			4.06		3.48

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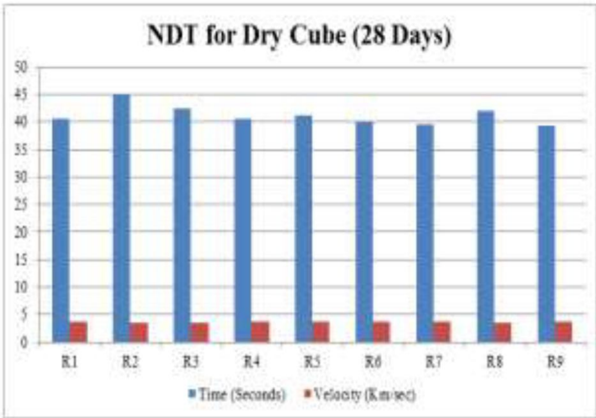
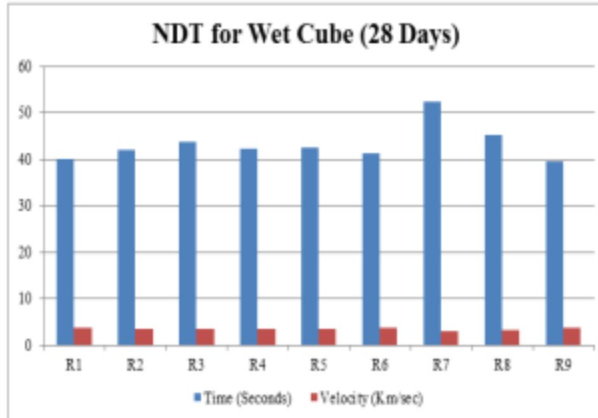
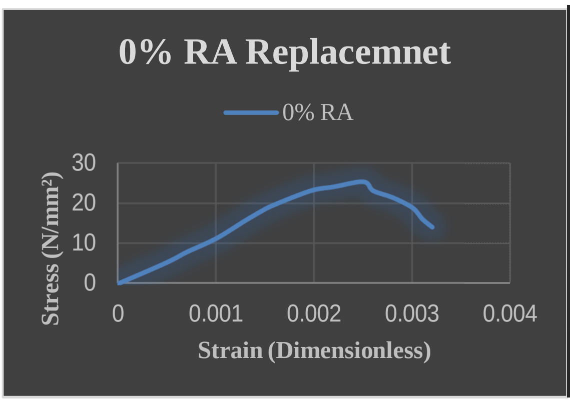


Graph 5: NDT of Dry Cube (28 days)

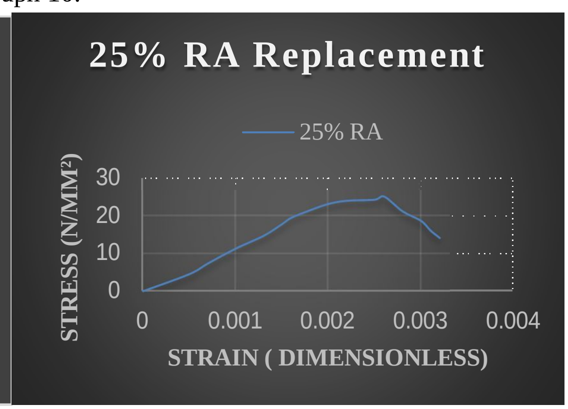


Graph 6: NDT of Wet Cube (28 days)

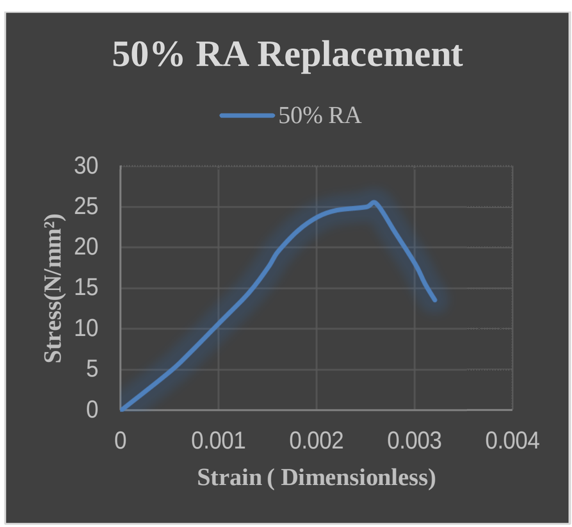
4) *Result Analysis of Stress-Strain Curve for Concrete:* For determining the stress-strain behavior of cylindrical specimens of concrete3 cylinders of each batch mix were casted and cured for 7 days & 28 days. An average of 3 values as calculated and graphically represented are considered for discussions in Graph 7, Graph 8, Graph 9, and common stress-strain curve for all percentage replacements is systematically presented in the Graph 10.



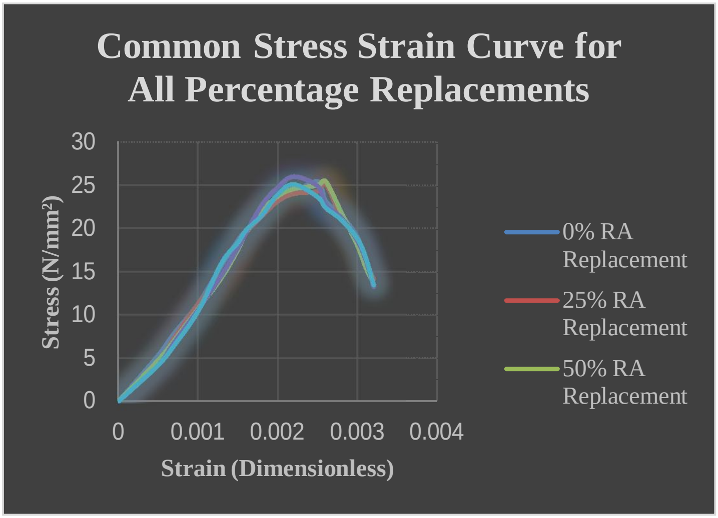
Graph 7: Stress-Strain Curve for 0% Recycled Aggregate



Graph 8: Stress-Strain Curve for 25% Recycled Aggregate



Graph 9: Stress-Strain Curve for 50% Recycled Aggregate



Graph 10: Common Stress Strain Curve for All Percentage Replacements

IV. CONCLUSION

As per experimental observations of this research, following conclusions can be drawn:

1) The influence of the use of recycled aggregate on the strength of high strength concrete depends on the percentage replacement of recycled aggregate with natural coarse aggregates in the concrete.
2) Maximum compressive strength was observed when recycled aggregate replacement is about 25%.
3) For low percentages of aggregate replacement (less than 25%), any influence on the strength of the concrete is negligible in all experimental terms.
4) Maximum split tensile strength was observed when recycled aggregate replacement is about 25%. It is observed before testing that there is increase in the weight of concrete specimen when it has been cured under water for 7 and 28 days.
5) A different test result value has seen when the specimen is parted to detect the exact position location of probe used.
6) The wet NDT results have been drawn after taking away the specimen from curing tank, wiping surface water properly by a clean cloth and then NDT test has been performed and then, it has been placed in the oven to maintain and remove the moisture, than after dry test has performed.
7) Variation in result obtained when thickness of specimen changes along with distance of probe in our case, thickness is 15 cm.
8) The best value of stress-strain curve is observed at 50% natural coarse aggregate replacement with recycled aggregate.
9) Recycling waste demolition aggregates in the high strength concrete production may contribute in resolving serious environmental issues.

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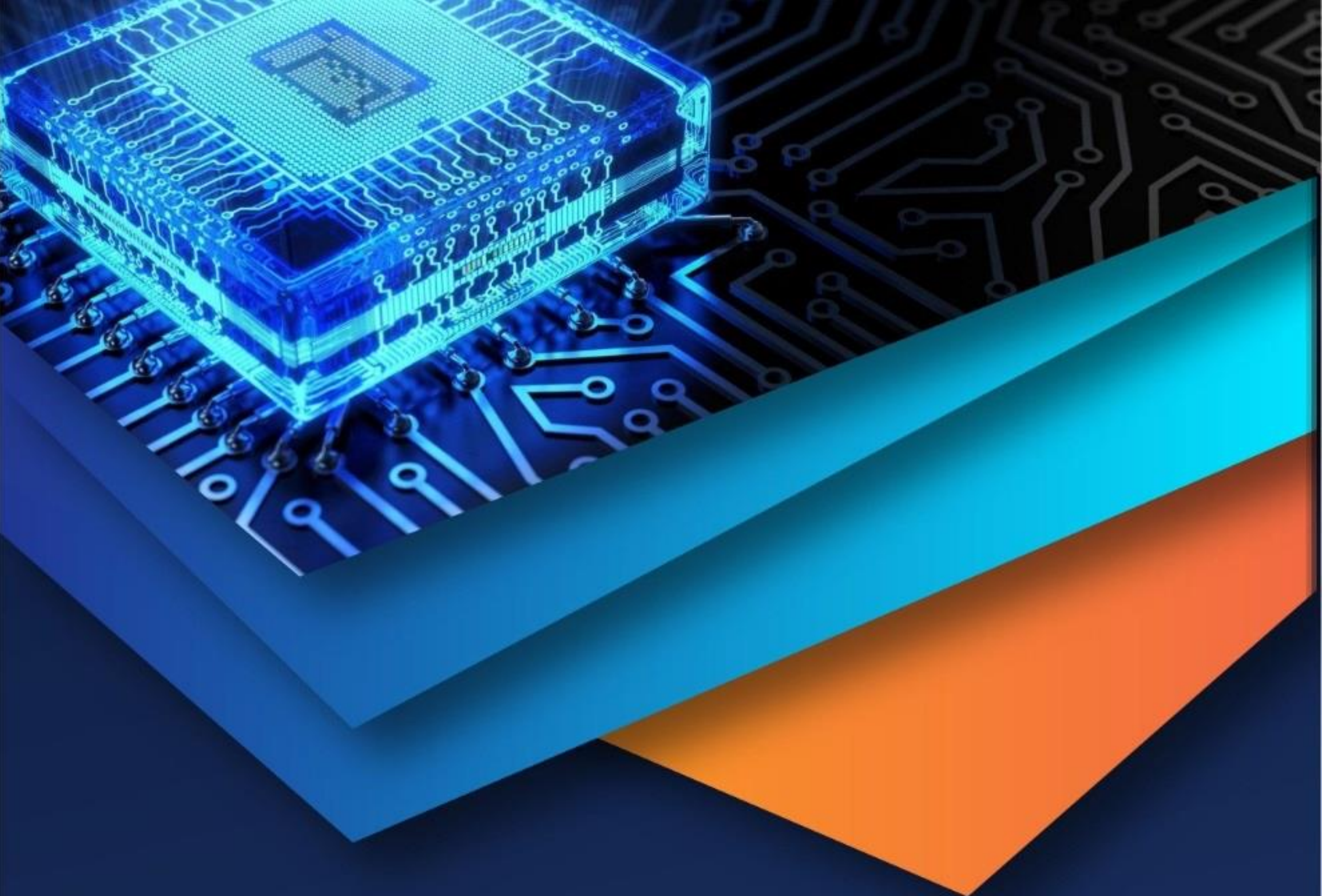

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