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Recycling of Concrete by Partial Replacement of Heat Processed Waste Aggregate

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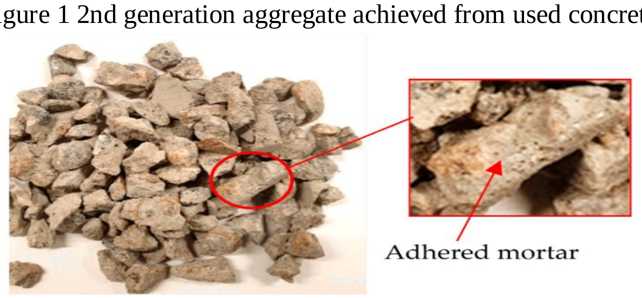
Abstract: Concrete is the second highest abandon material on the earth surface after water, it is inorganic in nature therefore it can be a big cause of the construction inorganic unsustainability by accumulating solid waste on the earth surface, in concrete coarse aggregate is the major component of the concrete hence in this research work recycled concrete made with the heat processed used coarse aggregate in first generation concrete, it is qualitative work so it is concentrated on the strength and durability of the concrete made of the partial replacement of the heat processed coarse aggregate, first generation concrete can be further utilize as the second generation by heat and mechanical treatment, mortar starts loosing the bonding between cement and aggregate temperature above 300^{0}C, in this research work recycling of aggregate from waste concrete chunks are heat treated and mechanical rubbing optimum utilization of this recycled aggregate is achieved 15% possible replacement of conventional aggregate with the heat processed aggregate.
Keywords: Concrete, heat, aggregate, mortar, recycling.

I. INTRODUCTION

Demand of the concrete is rising with respect to the urbanization and development day by day, the conventional concrete is made of the four basic elements cement as binding material, fine aggregate, coarse aggregate, and water. Coarse aggregate is major component in the concrete and conventional coarse aggregate abstracted from the stone mining that leads fast natural resource depletion and other side solid waste produced by demolished concrete is a big problem as the face of solid waste. Reuse of the used concrete as coarse aggregate having very high deviation in strength due to a thick layer of mortar present over the surface of used coarse aggregate.

Concrete chunks of used concrete consist stone (generally granite or basalt) covered with the adhere mortar over it.

Figure 1 2nd generation aggregate achieved from used concrete.



The recycling of the concrete may become very difficult that raise the cost of the project, In this case study political and technical difficulties are discussed with respect to the concrete recycling resistances, in this research analysis of a survey is done 27234 companies of recycling of construction material found major resistance of the cost, scientific development and sources.

With the help of questionnaire, they ask about resistance over the utilization of the construction waste and recycled aggregate. (Katerusha 2021) treat RCA with 10% HCl solution for 24hours for reduce the layer of impurities(mortar) from recycled coarse aggregate up to 70% by this research shows significant results in water absorption, specific gravity, Bulk density, Abrasion resistance, impact vale and crushing value. They process RCA with Hydrochloric acid which remove mortar up to 10-35% and shows the relation between mortar attach and water absorption, specific gravity, abrasion resistance, bulk density, impact value , crushing value that shows result as (i) Water absorption - Decreasing with decreasing of mortar attached ,(ii) Specific gravity - Increasing with decreasing mortar attached , (iii) Bulk density- Slightly increasing with decreasing mortar attached , (iv) Abrasion resistance - Slightly decreasing with decreasing mortar attached ,(vi) Impact value - Increasing with decreasing mortar attached , (vii) Crushing value - Decreasing with decreasing mortar attached. R.S. Selvi et al. (2019)

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Perform experiment to examination concrete strength with respect to high temperature range on different concrete samples made by using Barite, Diatomite, Silica fume and fly ash. In this experiment was 105 degrees centigrade to 800 degrees centigrade, for measurement of strength Ultrasonic pulse velocity device is used. They find in Barite reinforced sample rate of decrement of compressive strength is very mild up to 400 degrees centigrade but the rate of decreasing of strength was rapid after 400 degrees centigrade, In the case of other three samples strength is little increased up to 400 degrees centigrade but after 400 degrees centigrade strength was decreasing rapidly, shows the curves between mortar percentage and mechanical properties variation. Alperkurt et al. (2017)

Confirmed the reactivity of metakaolin for compressive strength, splitting tensile and flexural strength of concrete at the age of 7, 28, 56 and 90 days using locally produced metakaolin as cement replacing material. It was found that locally produced metakaolin enhanced the compressive strength by about 5% higher than silica fume concrete at the age of 28 days. This study divulges that calcination at 800^0 C for 3 h is the most suitable condition to convert kaolin into highly reactive metakaolin. With 5–20 % CK, high early compressive strength, splitting tensile strength, and flexural strength were observed. For strong early compressive strength, 15% CK substitution is ideal. Shafiq N. et al. (2015)

Replace the recycle coarse aggregate from natural coarse aggregate by 0%, 30%, 40% and 50% gives significant results in 28 days compressive strength as $33N/mm^2$, $28N/mm^2$, $26N/mm^2$ and $27\ N/mm^2$ respectively. Dwivedi et al. (2014)

Study and find impurities imposed on the recycle aggregate are depend upon the source of material, generally these are mortar, bitumen, soil, organic deposition etc there are mortar impurity is most common material which covered the surface of aggregate is mortar found from demolition and construction waste produced, it is more porous material so it increase water absorption, decrease specific gravity, decrease bulk density, increase impact value , increase crushing value. In other word it reduces durability and strength of concrete [7]. Presented a review of the properties of fresh concrete including workability, heat of hydration, setting time, bleeding, and reactivity by using mineral admixtures fly ash (FA), silica fume (SF), ground granulated blast furnace slag (GGBS), metakaolin (MK), and rice husk ash (RHA). Comparison of normal and high-strength concrete in which cement has been partially supplemented by mineral admixture has been considered. It has been concluded that mineral admixtures may be categorized into two groups: chemically active mineral admixtures and microfiller mineral admixtures. Chemically active mineral admixtures decrease workability and setting time of concrete but increase the heat of hydration and reactivity. On the other hand, microfiller mineral admixtures increase workability and setting time of concrete but decrease the heat of hydration and reactivity. In general, small particle size and higher specific surface area of mineral admixture are favourable to produce highly dense and impermeable concrete; however, they reduce workability and demand more water which may be offset by adding effective superplasticizer.

II. METHODOLOGY

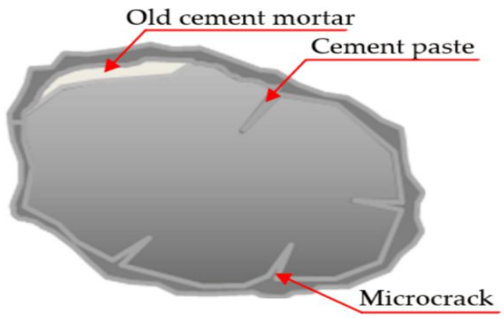
A Primary aim of this research work is to reduce the mortar thickness from the used coarse aggregate by heat processing and mechanical rubbing, secondary aim is comparison of the mortar removal from other methods, and the ternary aim is to calculate strength, mechanical properties and workability of the concrete made by the heat processed coarse aggregate

Collection: effort of mortar removal can be varied with different source of the concrete due to the following factors:

Different grade of the concrete used at different places.

Mortar is not only covered the outer surface of the aggregate even it penetrates in the micro cracks, therefore different sources with different micro cracks are possible.

Figure 2 Micro cracks of the 2nd generation concrete.



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Therefore, random collection is there.
Recycling of aggregate: Coarse aggregate obtain from the used concrete debris can be a good alternative for the conventional coarse aggregate, but used concrete have a big thick layer of the mortar over it, mortar has less strength and specific gravity with respect to the actual coarse aggregate.
Conventional coarse aggregates show higher strength with compare to the recycled coarse aggregate found from used concrete chunks due to thick layer of the mortar which reduce.
In this research work heat processing is used to remove the mortar layer from the concrete chunks.

The following steps are follows in the work:
1) Obtain concrete chunks of size (mean size 25mm) by impact action or crushing.
2) Heating of the chunks in control temperature 300 to 500 degree Celsius.
3) Removal of the weak mortar (first layer of mortar) from the surface of the coarse aggregate by abrasion action from los angles machine (200 rotation without steel balls).

Sampling of the aggregate: Coarse Aggregates are classified in three aggregate types in this research according to shape in texture, those are represented in following table:

Table 1 Sampling of the aggregate

Type	Shape	Surface texture
RCA-1 (concrete chunks produce by demolition)	Irregular (Angular) shape by attrition and crushing.	Rough surface
RCA-2 (recycled aggregate; recycled by mechanical process)	Irregular (Rounded) shaped by rough attrition.	Smooth surface
AT-RCA (Acid treated)	Irregular shape depend on crusher	Rough(Granular)
Natural aggregate	Irregular shape depends on crusher.	Rough(Granular)

AT-RCA is acid treated recycled coarse aggregate, the treatment of acid is done with concentrated HNO3 use and tooth brush is used for complete mortar removal, AT-RCA used as datum for calculation of mortar percentage in RCA-1, RCA-2 and HT-RCA.
Sampling of concrete: Name of the concrete samples are on the basis of the replacement of the conventional coarse aggregate with HT-RAC, such as

Table 2 Sampling of concrete

Name of sample	Percentage replacement
CR-0 (Control)	0% replacement of the conventional aggregate with HT- RAC
CR 5	5% replacement of the conventional aggregate with HT- RAC
CR10	10% replacement of the convectional aggregate with HT-RAC
CR15	15% replacement of the convectional aggregate with HT-RAC
CR 20	20% replacement of the conventional aggregate with HT-RAC

Fresh test: calculation of the workability done by the slump cone test because IS code recommend slump cone test is gives most reliable results for medium workable concrete.
Hard test: Calculation of strength is done on the basis of the compressive strength test as well as flexural strength test only.

III.RESULTS

Material and concrete are tested to determine its quality so the following results are associated with the work:

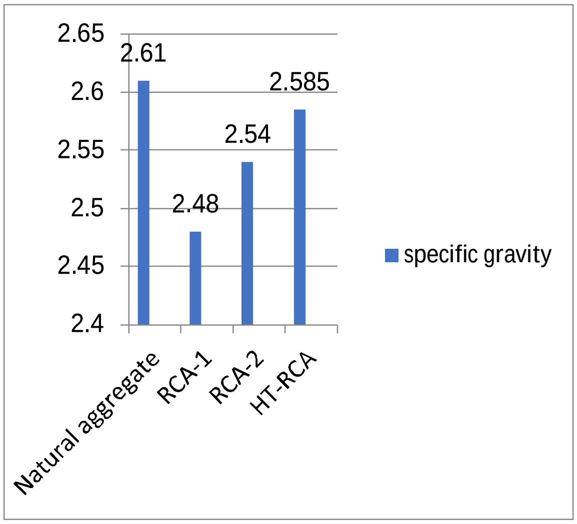
Cement is tested for consistency, IST (Initial setting time) and FST (Final setting time) which found as 30%, 93 minute, and 212 minutes respectively.

Fine aggregate is tested for Specific gravity, fineness modulus and waster absorption percentage which found 2.6, 2.71, and 1.2% respectively.

Coarse aggregate is tested for Specific gravity, Side of aggregate, fineness modulus, and water absorption which are found 2.61, 20mm,6.20 and 0.60% respectively.

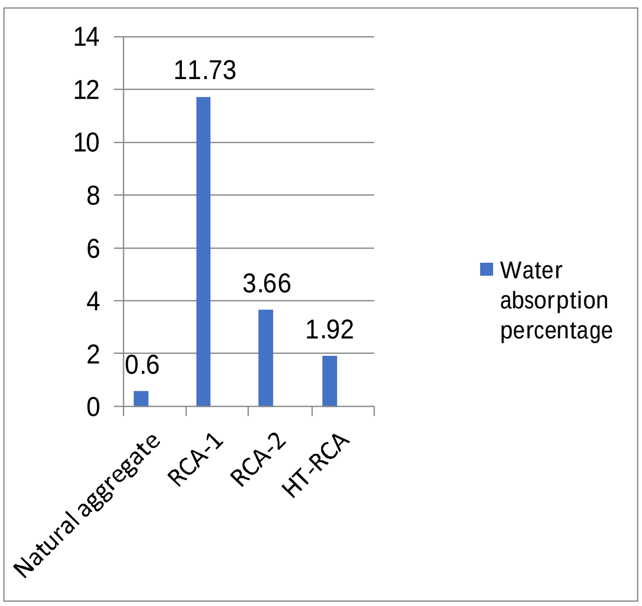
Recycled coarse aggregate is tested for specific gravity, comparison of the specific gravity as given in the figure.

Figure 3 comparison of the specific gravity



The recycled aggregate tested for water absorption; comparison of the water absorption is given below.

Figure 4 , comparison of the water absorption



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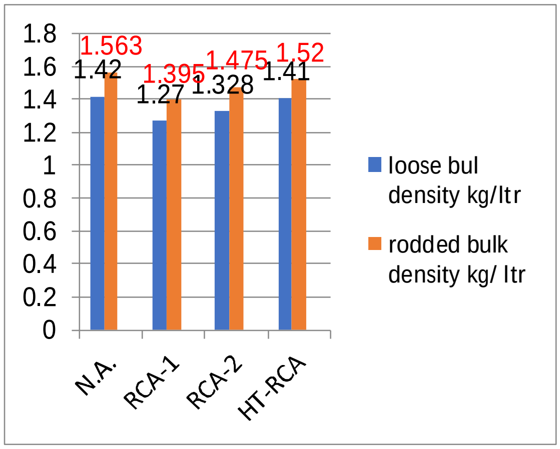
The recycled aggregate tested for bulk density; comparison of the bulk density is given below

Figure 5 comparison of the bulk density



The recycled aggregate tested for Void percentage; comparison of the Void percentage is given below.

Table 3 comparison of the Void percentage

Coarse aggregate	Specific gravity	Bulk density	Void content (%)
Loose N.A.	2.61	1.42	45.59
Compacted N.A.	2.61	1.563	40.11
Loose RCA-1	2.48	1.27	48.79
Compacted RCA-1	2.48	1.395	43.75
Loose RCA-2	2.54	1.328	47.7
Compacted RCA-2	2.54	1.475	41.92
Loose HT-RCA	2.585	1.41	45.45
Compacted HT-RCA	2.585	1.52	41.19

The recycled aggregate tested for Impact value, comparison of the impact values are as given below.

Table 4 comparison of the impact values

Aggregate	W_2 in gram	W_1 in gram	Impact value %
N. A	25.3	357.7	7.07
RCA-1	102.5	276	37.13
RCA-2	86	295.3	29.12
HT-RCA	74.3	315.4	23.55

Mortar removal of the different method of treatments are as given below:

Table 5 Mortar removal of the different method

Coarse aggregate	Numerical approach	Mortar percentage
RCA-1	$(w_4-w_1)x100/w_1$	50.88%
RCA-2	$(w_3-w_1)x100/w_1$	30.41%
HT-RCA	$(w_2-w_1)x100/w_1$	18.3%
N.A. or AT-RCA	-	0.00

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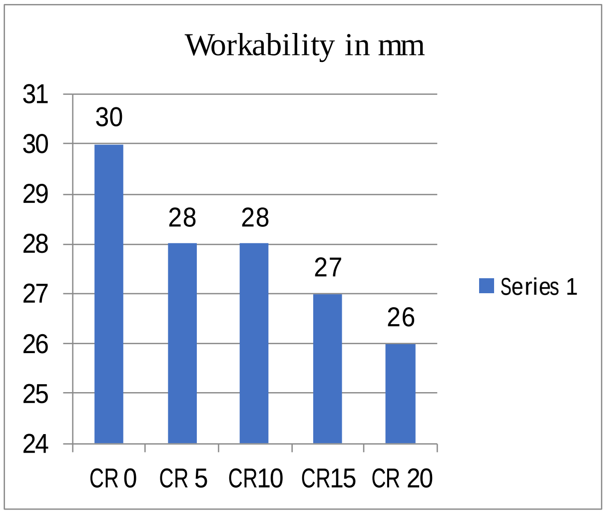
Fresh Concrete test: In the research fresh workability is tested by slump cone apparatus, every sample is tested thrice to observe the variability and opting the accurate result.

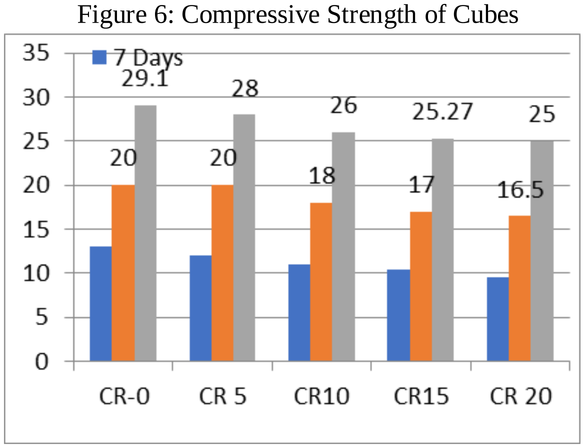
The graph of workability is in decreasing trend as shown in the following figure-

Figure 5: Slump Value of concrete mix



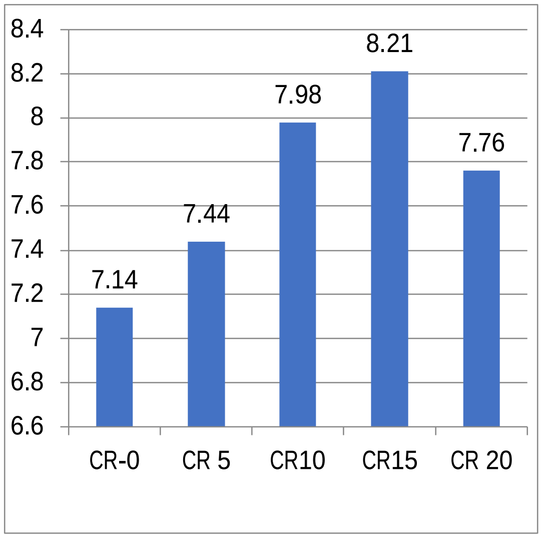
-The workability falls beyond the permissible limit with respect to adulteration due to fine particle size of the RHA, and SBCA.
- Low workable concrete can be form with the conventional fine aggregate replacement with ashes therefore it cannot be preferred for self compacting concrete.
- Thyrotrophic nature is observed in concrete at the time of blending and fresh concrete testing.
Hard Concrete Test-Hard concrete is tested for after setting and hardening of concrete, these tests are use to justify the strength criteria of the concrete.
In hard concrete test is observed with compressive as well as flexural test as follow:
Compressive Strength Test:
Concrete is good in compression; hence concrete is designed for compression the concrete sample is designed as M-25 concrete the test results are as following:

Figure 6: Compressive Strength of Cubes



Flexural Strength: Concrete is weak in tension, tensile strength of the concrete is about 10% of the compressive strength, tensile strength can be justified with the help of direct tension test, split cyclinder test or flexural strength test, flexural strength test results are as given below:

Figure7: Flexural strength of sample beams



Weight loss of cubes is calculated in 14 day and 28 days to observe the cement water relationship analysis.

Table 6: Weight loss in concrete samples

Initial weight of concrete in Kg	Weight after 14 days in Kg	Weight after 28 days in Kg	% of weight loss in cube measured 14days	% of weight loss in cube measured 28days
8.2	8.1	7.9	1.21	2.46
8.10	7.89	7.80	1.483	2.46

IV. CONCLUSIONS

Used concrete having thick cover of the mortar, thickness of the cover can be reduced by heat treatment and mechanical rubbing.
Complete mortar removal is not possible either by heat treatment or acid treatment because some mortar take place in micro cracks.
Mechanical properties of aggregate recovered by heat treatment is possible.
Maximum utilization of HT-RCA in concrete 15% by weight of the total coarse aggregate.
Increasing the percentage of HT-RCA leads decrease in workability continuously, Strength is under the permissible limit up to 15% of replacement.
Adhere mortar strength can be varying sample to sample due to its age and grade of the concrete hence HT-RCA having high deviation in effort of recycling.

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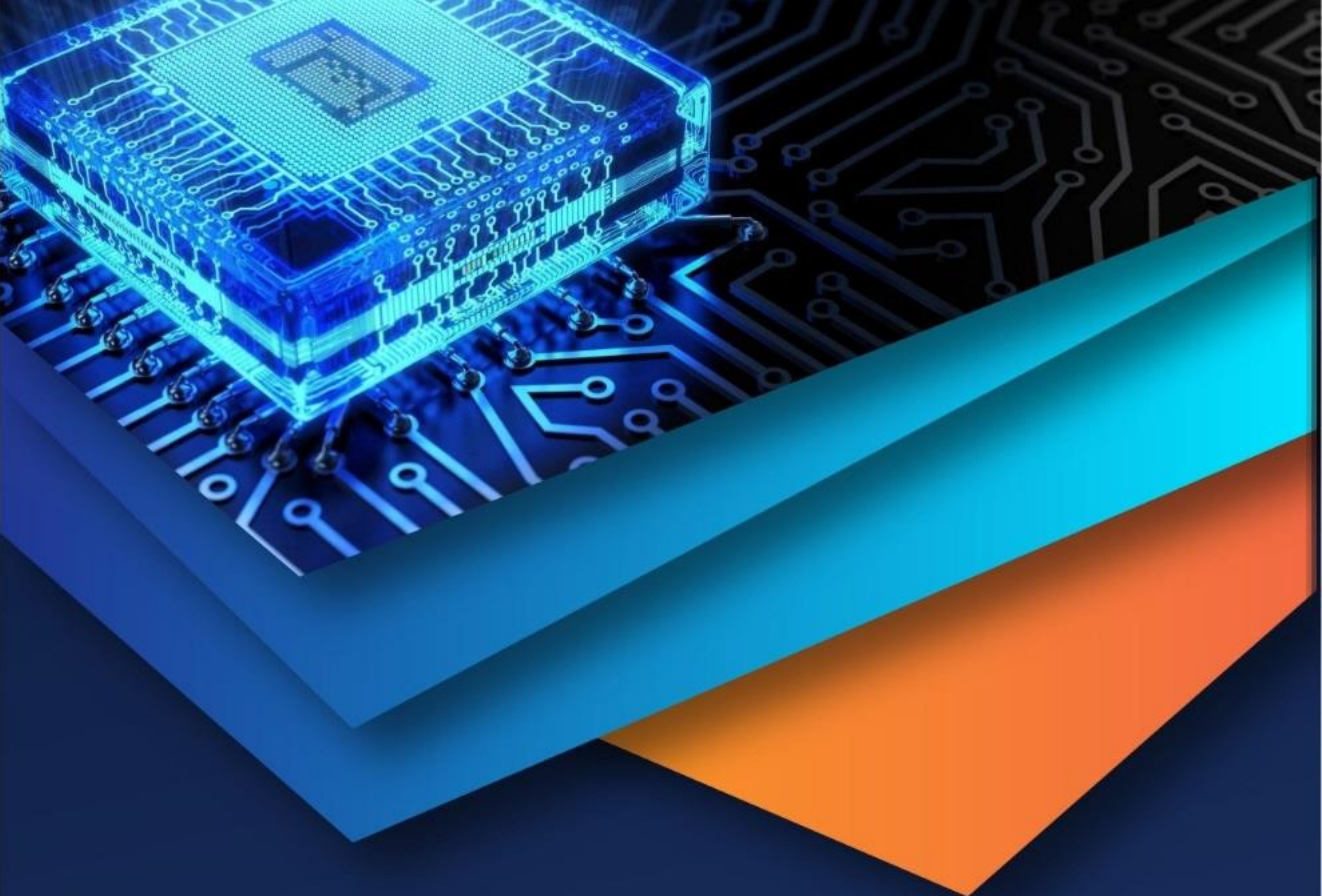

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