iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 Issue: VI Month of publication: June 2023

DOI: https://doi.org/10.22214/ijraset.2023.53608

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue VI Jun 2023- Available at www.ijraset.com

An Experimental Study on Partial Replacement of GGBS with Cement and Utilizing Demolished Coarse Aggregate in Concrete

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Abstract: The majority of municipal solid wastes are made up of debris from construction and demolition projects, including recycled construction aggregate (RCA). This paper presents the findings of an experimental and analytical examination of the creation of environmentally friendly concrete. It is a good idea to replace natural material with aggregate from old, demolished structures to reduce debris and preserve the environment. To reduce consumption, recycled aggregate can be utilized in place of natural aggregate. To address these issues, an attempt is undertaken in the current experimental work to substitute GGBS in varied proportions for cement. The purpose of this research is to demonstrate the findings of an investigation into the applicability of GGBS in the manufacturing of concrete by using construction and demolition debris as a recycled resource. Ground granulated blast furnace slag (GGBS) and recycled concrete aggregates are the recycled materials employed in this study. A concrete mix of grade M25 was created through the mix design process. GGBS was partially replaced with waste-destroyed aggregate in the amounts of 0, 10, 20, 30, and 40% to create the mixes. Cubes of 150x150x150mm3 were poured. The compressive strength of the concrete cube specimens was measured by smashing the cube after 7, 14, 28, 60, and 90 days of curing for various curing intervals. The compression test results on the cubes show that strength increases with the amount of slag added up to the maximum value. Compressive strength was seen to grow when GGBS content increased up to 30%, but after the replacement level was above 30%, strength began to deteriorate. The outcomes of GGBS with conventional concrete and concrete made entirely of demolished aggregate without GGBS are compared to the outcomes of GGBS with concrete containing demolished aggregate.

Keywords: GGBS, Demolished Coarse Aggregate, PPC, Compressive strength, Cement, Environment

I. INTRODUCTION

Concrete is the most world extensively habituated construction material and it is an admixture of cement, natural sand, coarse aggregate, and water. It is desirable as compared to steel structure and has low cost of maintenance. In the recent studies it is said that India Produces about 170- 185 million tons of debris annually. Hence, this demolished structure debris in India generally goes to waste in landfill. Therefore, by using aggregates from old demolished structure as a substitution to natural aggregate is a good practice to conserve terrain as well as to reduce debris. In order to reduce the operation of natural aggregate, recycled aggregate can be used as the replacement. In this present experimental study, an attempt is made to replace cement by GGBS in varying proportion to overcome these problems. Numerous explorations have been studied on substitution of GGBS with cement in concrete and set up the inspiring results. The operation of GGBS to replace the cement is because the production of the cement emits carbon dioxide gas into atmosphere. About 7% of the yearly CO_2 gas product comes from the cement production process. The release of carbon dioxide gas will laterally increase the effect of global warming due to the emission of greenhouse gases. To overcome similar issues GGBS, silica fume, copper slag/sediment, fly ash, etc. artificial waste is being introduced in exchange of cement. When added as a mineral to concrete, it acts as a stabilizing agent and improves the quality of concrete.

II. LITERATURE SURVEY

A.H. Buller, B.A. Memon, I.N. Sodhar, M. Oad & A.S. Buller, (2020)-The work shows diversified attempts for improving concrete performance, finding alternate of one or other ingredients of concrete, use of recycled aggregates in new concrete. As the literature reveals that the use of demolished construction waste in concrete as a coarse aggregate with the different percentage (0% to 100%), but the use of 50% Recycled aggregates in concrete replaced with natural aggregates has a satisfactory result in green concrete.

Gagan and Sumit Arora, (2015)- The study shows that the natural resources are limited in nature and will be depleted with time. In order to conserve the natural resources, unnecessary wasting of natural resources should be restricted and regulated. Formulation and implementation of proper waste management plan throughout the life cycle of the projects can minimize C&D waste.

D. Suresh and K. Nagarajun, (2015)- - The study shows that the movement of moisture of GGBS mixes, probably due to the dense and strong microstructure of the interfacial aggregate/binder transition zone are probably responsible for the high resistance of GGBS mixes to attack in aggressive environments such as silage pits. As we have seen GGBS is a good replacement to cement in some cases and serves effectively but it can't replace cement completely.

Pankaj Munjal, Kong Kian Hau, Cheng Chuen Hon Arthur (2021)- This study examined the influence of GGBS replacement on class G cement slurry. The compressive strength and microstructures of blended cement paste are studied. The blended sample with 40 % GGBS (G40A) has reduced 26 % cumulative heat in initial 24 h of hydration. Further, the cumulative heat flows decrease with increases of percentage of GGBS replacement in cement.

M.Rajaram, A.Ravichandran, A.Muthadhi ,(2017)- From the studies it is observed that the strength level increases at 20% replacement of GGBS and falls at 35% replacement for compressive strength and split tensile strength. The concrete has reached its maximum compressive strength at 20% replacement of GGBS which is 11.1% greater strength than the nominal concrete strength.

III. RESEARCH METHODOLOGY

1) The cement concrete mix is prepared as per the procedure given in the BIS 10262:2009. For optimal intake selection of GGBS in concrete blend, specimens (proportion ranging from 10% to 40%) are set and compared it with plain cement concrete cube specimen with mixture of proportion 1: 1: 2 are prepared. The replacements of OPC with GGBS are made on an equal weight basis. The w/c ratio is taken 0.45 for all the mixes.
2) The Cubes with the dimension of 150 x 150 x 150 mm are prepared for each batch of mixes to measure compressive strength of concrete respectively at the age of 7 days, 14 days, 28 days, and 90 days of curing. In this Project total 72 cubes were made and tested periodically.
3) All the specimens are kept in water tank for curing and thereafter tested as per BIS norms and standards. All the cube specimens are tested for compressive strength in compression testing machine (CTM) in our respective Institute.
4) In the present work the effect of ground granulated blast furnace slag on the strength of concrete samples cured for period of 7, 14, 28 and 90 days was studied. Concrete mixes containing 0%, 10%, 20%, 30%, 40%, by GGBS as a replacement of cement are cast at water cement ratio of 0.45 for M25 and are compared to the conventional concrete mix.

A. *Abbreviation and Acronym*

C&D - Construction and Demolition.
GGBS - Ground Granulated Blast Furnace Slag
OPC - Ordinary Portland Cement
C.A. - Coarse Aggregate
C.T.M - Compression Testing Machine
D.A -Demolished Aggregate

B. *Problem Statement*

The aim of this project is to investigate the effect of ground granulated blast furnace slag (GGBS) and cement on the strength and durability properties of concrete containing DA. Purposefully, our strategy is to dig the answer for the following experimental questions:

What is the optimal replacement ratio of DA with GGBS and cement to achieve the desired mechanical and durability properties of concrete?

How does the addition of GGBS and cement affect the mechanical and durability properties of concrete containing DA?

Can the use of GGBS and cement mitigate the negative effects of DA on the properties of concrete?

The project will involve laboratory testing of concrete specimens containing various combinations of DA, GGBS, and cement. The results of the project will provide valuable information on the feasibility of using DA with GGBS and cement in concrete construction, and may contribute to the development of sustainable and environmentally friendly construction practices.

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C. *Materials.*

1) *Cement* -The cement used has been tested for different properties as per IS: 1489 :2015 (Part 1). Fly ash-based Portland Pozzolana Cement (PPC) has been used in the present work. The physical properties of cement used in the study are given in following table.

Table 3.1 Tests on cement

Sr. no	Name of Test	Result
1.	Fineness	3.5%
2.	Initial Setting Time	35min
3.	Final Setting Time	200min
4.	Standard Consistency	26%
5.	Specific Gravity	3.16

2) *Fine Aggregate* – The fine aggregates used for this work were locally available natural river sand. Sand Confirms to grading zone II as per IS: 383 (2016).

Table 3.2 Test on Fine aggregate

Sr. No	Name of Test	Result
1.	Fineness Modulus	2.55
2.	Gradation Test	Zone 2
3.	Water Absorption	0.8 %
4.	Specific Gravity	2.51

3) *Coarse Aggregate* – A maximum size of 10mm is usually selected as coarse aggregates up to 20mm. In the present work 20mm size of C.A. is used and the size of 20mm is used for Demolished C.A.

Table 3.3 Test on Coarse aggregate

Sr. No	Name of Test	Result
1.	Aggregate impact value (Natural)	4.16 %
2.	Aggregate impact value (Demolished)	7.07 %
3.	Specific Gravity (Natural)	2.88
4.	Specific Gravity (Demolished)	2.79
5.	Water Absorption (Natural)	0.36 %

4) *GGBS (Ground Granulated Blast Furnace Slag)* – Ground Granulated Blast Furnace Slag which is a by-product of iron manufacturing industry is an accepted mineral admixture for use in concrete.

Table 3.4 Test on GGBS

Sr No	Name of Test	Result
1	Specific Gravity	2.92
2	Fineness (m^2 / kg)	366

D. *Mix Proportions*

1.Cement = 370 kg/m³ 2.Water = 166 kg/m³ 3.FA = 774 kg/m³ 4.CA = 1127 kg/m³
5.Admixture = 4.07 kg 6.W/c Ratio = 0.45

Cement	FA	CA	Water
370	774	1127	166
1	2.09	3.04	0.47

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E. *Testing of Specimen*

The cube specimen is of the size 150 mm x 150 mm x 150 mm, which were used to conducting the compressive testing. The sample cubes, after curing period of 7, 14, 28 and 90 days were tested for compressive strength on a compressive strength testing machine. The compression test is carried out on all samples i.e., GGBS concrete, Demolished concrete as well as conventional concrete. Typical proportions of concrete constituents were mixed completely by hand mixing to form samples of GGBS concrete and conventional concrete for test. The samples were made in 150 mm^3 standard cube specimen. The concrete was placed in three layers by manually and each subcaste was tamped 25 times by tamping rod and steel bar of 16 mm periphery. Cube specimens were also safely stored in the dry place for 24 hours also, concrete cubes were removed from specimen and kept immersed in water for 7, 14, 28 and 90 days. After 7, 14, 28 and 90- days cubes were taken out from curing tank on respective days for testing. The cubes were tested on compression testing machine. The aspects such as length, width, height of cubes was first measured and then tested in compression testing machine.

The cubes were placed in CTM as shown in figure 4.1. and the loading being applied from the upper sides of the specimen. For the average strength, set of three samples of each 7, 14, 28 days and 90 days is taken as the cube strength. This test performed on roughly 72 compressive cube specimen samples. At last, the test managed to determine the maximum compressive force permitted by the specimen.

For the computation of compressive strength, following Equation was used-

$\sigma_c = P/A$.

where, σ_c = compressive strength,

P = the maximum compressive force tolerated by the specimen and

A = cross-sectional area of the specimen (150 * 150 mm).

Fig 4.1. Testing of specimen

Fig 4.2. Tested specimen

F. *Result and Discussion*

1) Average compressive strength of 3 cubes at 7,14,28 and 90 days is taken and represented it in the graphical form. As for M25 grade concrete, it seems that after 28 days, concrete gains strength of 32 N/mm^2 which is acceptable for conventional concrete. Whereas as per studies after 7 days concrete should achieve 65% of its total strength. So, after testing we attained 18.34 N/mm^2 of strength which is acceptable for conventional concrete.

Table F.1 Compressive strength of cube specimen @ 7, 14, 28, 90 Days (Conventional):

Sr. No	Days	No. of Specimen	Ultimate load in KN	Ultimate compressive strength in N/mm^2
1.	7	3	412.66	18.34
2.	14	3	522.54	23.22
3.	28	3	738.28	32.87
4.	90	3	995.53	44.24

2) Average compressive strength of 3 cubes made with demolished aggregate without GGBS at 7,14,28 and 90 days is taken and represented it in the graphical form. As for M25 grade concrete, it seems that after 28 days, concrete gains strength of 23.67 N/mm^2 which is much lower as compared to conventional concrete. Whereas as per studies after 7 days concrete should achieve 65% of its total strength. So, after testing we attained 16.70 N/mm^2 of strength which is unsatisfactory and risky for construction purpose.

Table F.2 Compressive strength of cube specimen @ 7, 14, 28, 90 Days (Demolished)

Sr. No	Days	No. of Specimen	Ultimate load in KN	Ultimate compressive strength in N/mm²
1.	7	3	375.67	16.70
2.	14	3	426.88	18.97
3.	28	3	532.33	23.67
4.	90	3	841.23	37.38

3) As per our study replacing more than 30 % of GGBS with cement at 7 days will result in decrease in strength of concrete which is unsatisfactory. Strength is gradually increasing when GGBS is introduced in concrete up to 30% by weight of cement.

Table F.3 Compressive strength of Demolished + GGBS cube @7 days

Sr. No	Partial Replacement	No. of Specimen	Ultimate load in KN	Ultimate compressive strength in N/mm²
1.	0%	3	412.66	18.34
2.	10%	3	207.67	9.22
3.	20%	3	249.67	11.09
4.	30%	3	281.33	12.5
5.	40%	3	197.33	8.76

4) As per our study replacing up to 30 % of GGBS with cement at 14 days will result in increase in strength of concrete which is somewhat acceptable. Strength is gradually increasing as the days passes when GGBS is introduced in concrete up to 30% by weight of cement.

Table F.4 Compressive strength of cube specimen at 14 days (Demolished + GGBS)

Sr. No	Partial Replacement	No. of Specimen	Ultimate load in KN	Ultimate compressive strength in N/mm²
1.	0%	3	522.67	23.22
2.	10%	3	322.86	14.34
3.	20%	3	350.28	15.56
4.	30%	3	498.52	22.14
5.	40%	3	382.32	16.9

5) As per our study replacing up to 30 % of GGBS with cement at 28 days will result in increase in strength of concrete which is somewhat acceptable. Strength is gradually increasing as the days passes when GGBS is introduced in concrete up to 30% by weight of cement.

Table F.5 Compressive strength of cube specimen at 28 days (Demolished + GGBS)

Sr. No	Partial Replacement	No. of Specimen	Ultimate load in KN	Ultimate compressive strength in N/mm²
1.	0%	3	738.67	32.82
2.	10%	3	542.53	24.11
3.	20%	3	602.28	26.76
4.	30%	3	648.42	28.81
5.	40%	3	513.92	22.84

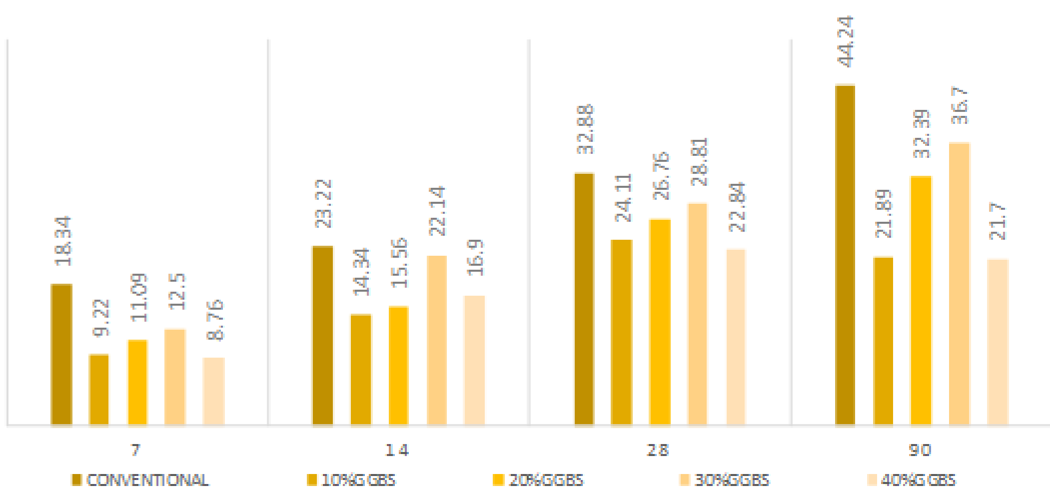
6) After testing the specimen having GGBS in various proportion, we studied that maximum strength at 90 days after replacing 30% of GGBS is 36.70 N/mm^2 which is higher than acceptable limit for M25 grade of concrete. As per our study replacing up to 30 % of GGBS with cement at 90 days will result in increase in strength of concrete which is somewhat acceptable as the compressive strength is greater than demolished material only. Strength seems to be gradually increasing as the days passes when GGBS is introduced in concrete up to 30% by weight of cement.

Table F.6 Compressive strength of cube specimen at 90 days (Demolished + GGBS)

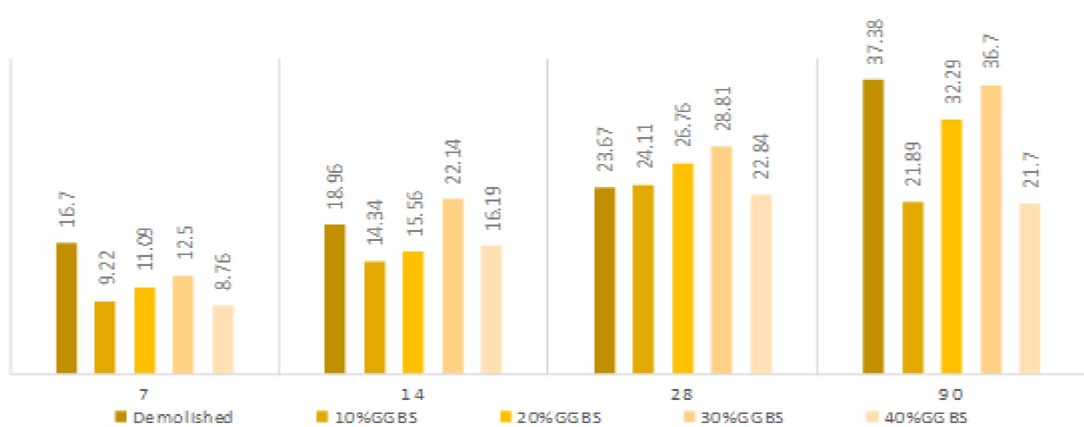
Sr. No	Partial Replacement	No. of Specimen	Ultimate load in KN	Ultimate compressive strength in N/mm²
1.	0%	3	993.53	44.24
2.	10%	3	492.65	21.89
3.	20%	3	728.92	32.39
4.	30%	3	825.88	36.70
5.	40%	3	488.28	21.70

G. Discussion

There are many worldwide examples of using the GGBS concrete in the construction like World Trade Centre which is substituted by 40% of GGBS, also Airfield Pavement of Minneapolis Airport with about 35 % replacement of GGBS. This experimental study is done to get the best optimum percentage of partial replacement of GGBS with cement and therefore several proportions are made from 0%,10%,20%,30% and 40% and then their compressive strength is calculated after 7,14,28 and 90 days each. The study shows maximum of 30% of partial replacement of cement by GGBS has greater impact on compressive strength while compared to 100% PPC (0%GGBS). Therefore, the optimum substitution as per our research is found out to be 30%. To reduce the cost of construction and consumption of cement, GGBS can be used as a substitution material for cement.



Comparison of compressive strength between Conventional concrete (natural aggregate) and Demolished aggregate with GGBS.



Comparison of compressive strength between concrete made of Demolished aggregate and Demolished aggregate with GGBS.

IV. CONCLUSIONS

1) The increase in proportion of GGBS results in drop in strength of concrete.
2) The partial replacement of PPC in concrete by GGBS, not only provides the frugality in the construction but it also facilitates environmentally friendly disposal of the waste sediment which is generated in huge amounts from the steel industries.
3) Use of industrial waste products saves the environment and conserves natural resources.
4) It is better to replace up to 30% ground granulated blast furnace slag in demolished aggregate concrete.
5) The compressive strength of Demolished with addition of GGBS concrete seems to be slightly dwindling after comparing it with conventional concrete.
6) Still, there's need of further work with respect to the use of demolished aggregates in new concrete.

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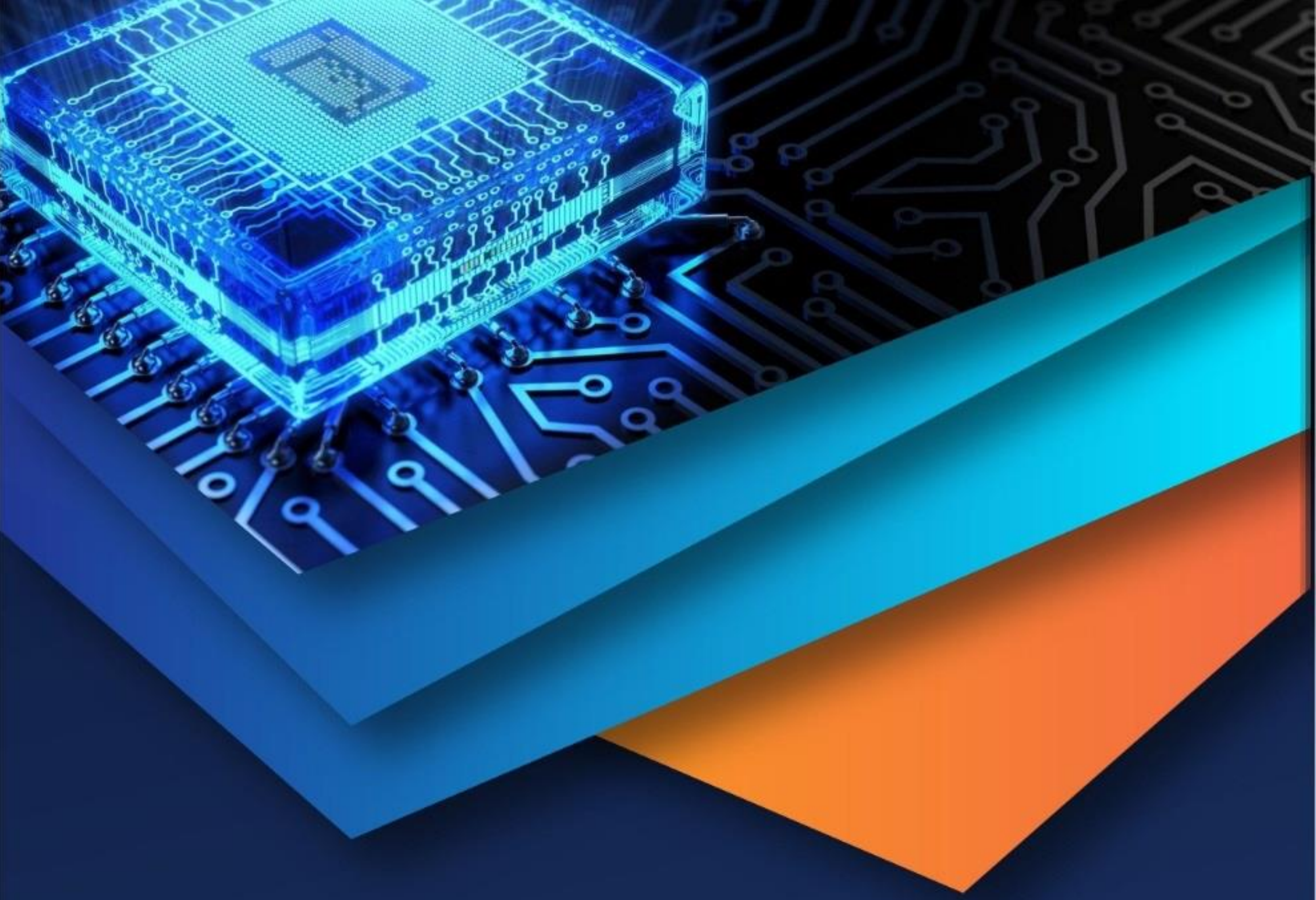

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