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.2023.54459

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

Experimental Studies on Hybrid Fiber Reinforced Concrete Utilizing Polypropylene Fiber and Natural Fiber

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Abstract: The construction industry is responsible for the depletion of large amounts of non-renewable resources. This activity generates not only millions of tons of mineral wastes but also carbon dioxide gas emissions. More building materials based on renewable resources such as natural fibers are needed. This chapter discusses the utilization of natural fibers for concrete reinforcement. It covers the compatibility between the fibers and the cement matrix and also how the fibers influence cement properties. It also includes the properties and durability performance of concrete reinforced with natural fibers. This paper presents an overview of the effect of polypropylene (PP) fibers on various properties of concrete in fresh and hardened state such as compressive strength, tensile strength, flexural strength, workability, bond strength, fracture properties, creep strain, impact and chloride penetration. The role of fibers in crack prevention has also been discussed.

I. INTRODUCTION

One of the popular materials utilized in the construction is concrete. Concrete is generally considered to be the material which resists the compressive stress and it becomes weak under tensile stress. The concrete tends to crack even at minimal loads when the concrete member gets loaded due to the low tensile strength. The occurrence of failure gets triggered due to the widening of cracks under further dynamic loading. The property of ductility gets affected due to the widening of cracks in the concrete structural member. By the incorporation of single type of fiber in the concrete, the characteristic of being ductile and weak due to the tensile stress and impact loads can be avoided. Thus, the concrete made of fiber is called Fiber Reinforced Concrete. By providing fiber as the secondary reinforcement adds less value to the concrete and does not fulfil the purpose completely. The fibers in the concrete not only enhances the desired engineering properties but also enables the concrete to be used as the most suitable material for wide varieties of application.

II. MATERIALS AND METHODOLOGY

A. Materials

The materials used in the preparation of HFRC are cement, sand, aggregate, water, polypropylene fiber, sisal fiber, banana fiber and superplasticizer (naphthalene sulphonate). The superplasticizer dosage used was 0.5% weight of cement throughout the experimental study.

B. Mix Proportions And Casting Procedure

Mix proportion for CC of M30 grade was 1:0.75:1.5 (cement: sand: aggregate). For making HFRC different fiber contents were added in 0.5, 1, 1.5 and 2% by weight of concrete. A constant water cement ratio of 0.43 is used. For preparing specimen ingredients are mixed in various proportions and Specimen are designated as follows:

CC - Conventional Concrete
HFRC 1 - Concrete with 1% Polypropylene fiber and 1% Sisal fiber
HFRC 2 - Concrete with 0.5% Polypropylene fiber and 1.5% Sisal fiber
HFRC 3 - Concrete with 1.5% Polypropylene fiber and 0.5% Sisal fiber
HFRC 4 - Concrete with 2% Sisal fiber only
HFRC 5 - Concrete with 2% Polypropylene fiber only
HFRC 6 - Concrete with 0.5% Polypropylene fiber and 1.5% Banana fiber
HFRC 7 - Concrete with 1.5% Polypropylene fiber and 0.5% Banana fiber

HFRC 8 - Concrete with 1% Polypropylene fiber and 1% Banana fiber
HFRC 9 - Concrete with 2% Banana fiber

Table 2.1 Mix Proportion

S.No.	Sample	Water (Lit/m3)	Cement (Kg/m3)	Sand (Kg/m3)	Coarse Aggregate (Kg/m3)	Polypropylene Fiber (Kg/m3)	Sisal Fiber (Kg/m3)	Banana Fiber (Kg/m3)
1.	CC	170	395	296.25	592.5	-	-	-
2.	HFRC1	170	395	296.25	592.5	3.95	3.95	-
3.	HFRC2	170	395	296.25	592.5	1.975	5.925	-
4.	HFRC3	170	395	296.25	592.5	5.925	1.975	-
5.	HFRC4	170	395	296.25	592.5	-	7.9	-
6.	HFRC5	170	395	296.25	592.5	7.9	-	-
7.	HFRC6	170	395	296.25	592.5	1.975	-	5.925
8.	HFRC7	170	395	296.25	592.5	5.925	-	1.975
9.	HFRC8	170	395	296.25	592.5	3.95	-	3.95
10.	HFRC9	170	395	296.25	592.5	-	-	7.9

Before mixing all ingredients should be weighed in required proportions. Firstly, dry mixing is done by mixing cement, sand, aggregate and fibers. Now adding Super Plasticizer to dry mix prepared and mixed thoroughly until the colour of concrete mixture becomes uniform. To this mixture water should be added in proportion and mixed to get uniform colour. The cube of size 150*150*150 mm, cylinder of size 150*300 and beam of size 100*100*500 mm were casted for M30 grade HFRC. Before casting, mould should be cleaned and oiled properly. The fresh concrete is being placed in mould in 3 layers having equal depth. Make sure that tempering should be done at least 25 times for each layer. Casting of the cube is achieved by smoothing the to surface with trowel gauge. The specimens were kept in the mould for 24 hours at suitable condition.

III. TESTING METHODS OF HYBRID FIBER REINFORCED CONCRETE

The main focus of this research is to utilize the fibers such as banana fiber, sisal fiber and polypropylene fibers for making of high strength performance concrete. The fresh concrete is prepared and its workability is found out using the slump cone test and the compaction factor. The standard test specimens are casted and various modulus tests have been carried out with respect to Indian Standards.

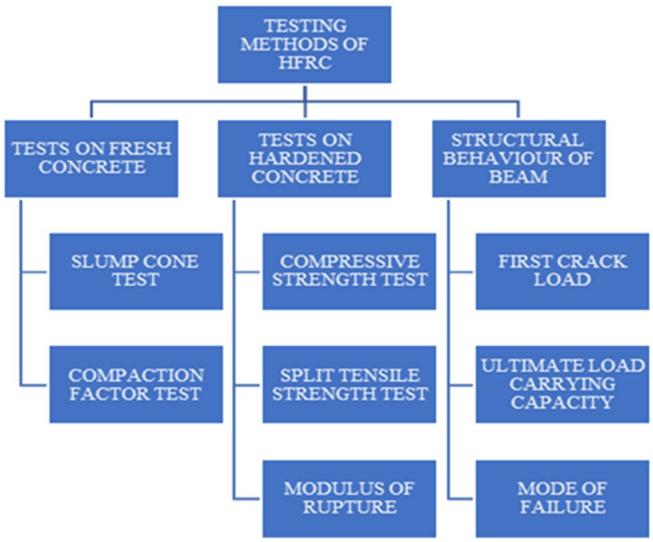

Figure 3.1 Flow chart of testing methods of HFRC

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IV. RESULT AND DISCUSSION

The results of the tests conducted on the different proportions of specimens are discussed. The test results of fresh concrete, hardened concrete of various proportions and the beams are discussed in detail.

A. Test On Fresh Concrete

1) Slump Test Results for Fresh Concrete

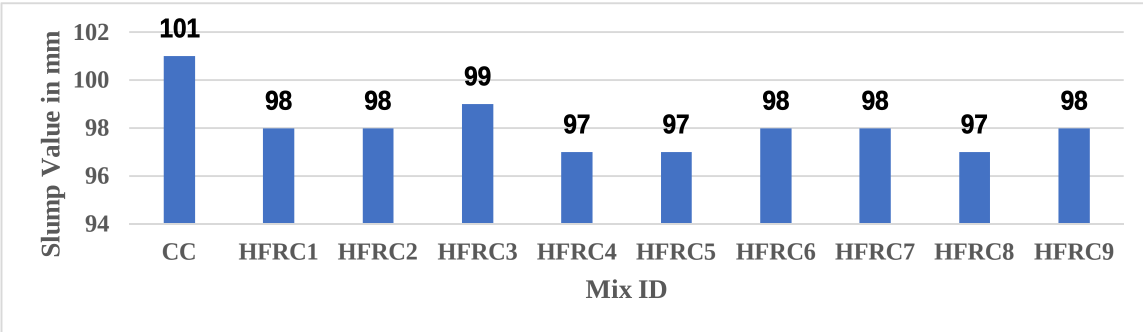

Figure 4.1 Bar Graph of Slump Value with Respect to Different Mix IDs

From the graph it is clear that the value conventional concrete is greater above all concrete mix but HFRC3 gives good result comparative to other mixes.

2) Compaction Factor Test Results of Fresh Concrete

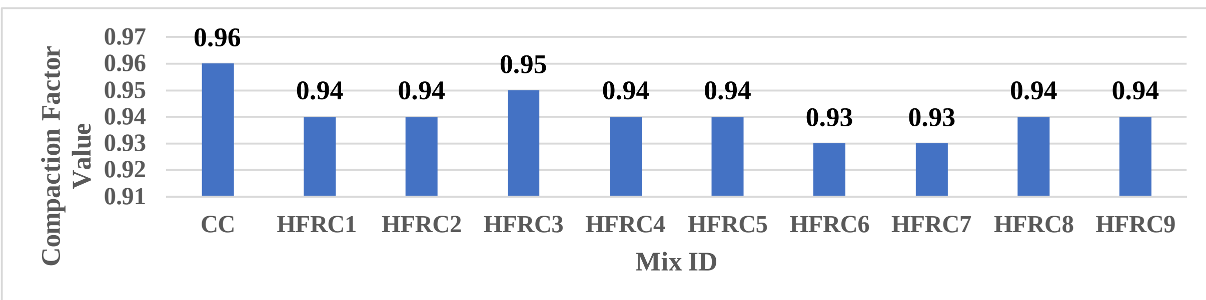

Figure 4.2 Bar Graph of Compaction Factor Value with Respect to Different Mix IDs

Compaction factor values shows the workability of conventional concrete mix is higher than other concrete mix but the HFRC3 gives good result comparative to other mixes which is 0.96 but less than the conventional concrete which is 0.96.

B. Test On Hardened HFRC

1) Compressive Strength test Results of HFRC

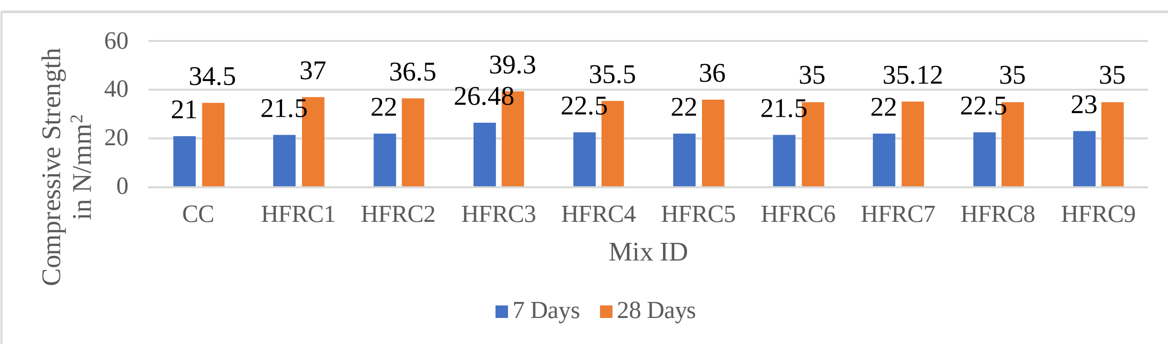

Figure 4.3 Bar Graph of Compressive Strength Test of Concrete

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Graph shows the compressive strength of HFRC3 with 1.5% polypropylene fibers and 0.5% of sisal fibers gives greater strength in 7 days ae well as in 28 days comparative to all other concrete mix and even greater than conventional concrete also.

2) Split Tensile Strength Test Results of HFRC

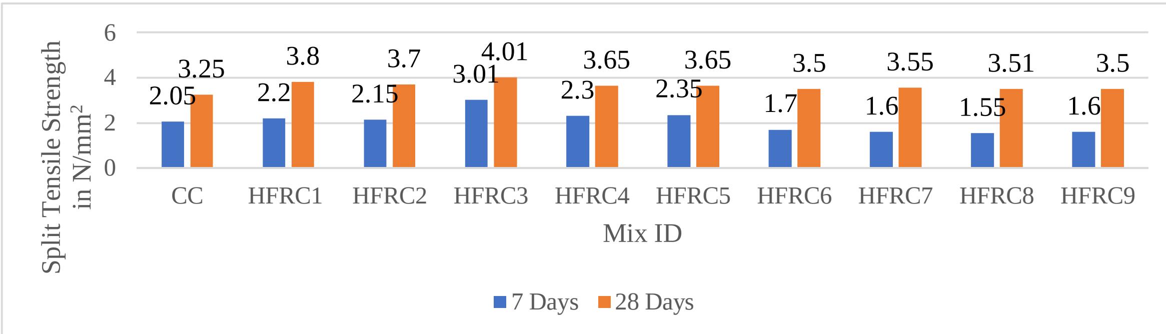

Figure 4.4 Bar Graph of Split Tensile Strength of Concrete with Respect to Different Mix IDs

Graph shows the split tensile strength of HFRC3 gives greater strength in 7 days as well as in 28 days comparative to all other concrete mix and even greater than conventional concrete also.

3) Modulus of Rupture Test Result of HFRC

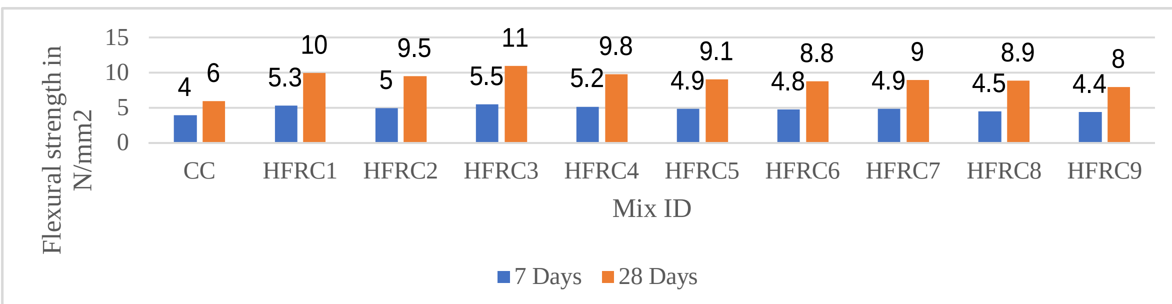

Figure 4.5 Bar Graph of Flexural Strength of Concrete with Respect to Different Mix IDs

Graph shows the flexural strength of HFRC3 gives greater strength in 7 days ae well as in 28 days comparative to all other concrete mix and even greater than conventional concrete also.

C. Structural Behaviour Of HFRC Beams

Under static loading it was observed that the crushing and spalling of concrete was not found till the ultimate load was reached due to the crack-bridging mechanismsof hybrid fibers in the concrete. The first crack load, ultimate load carrying capacity and mode of failure were carried out and the results obtained are discussed in the following sections.

1) First Crack Load Results

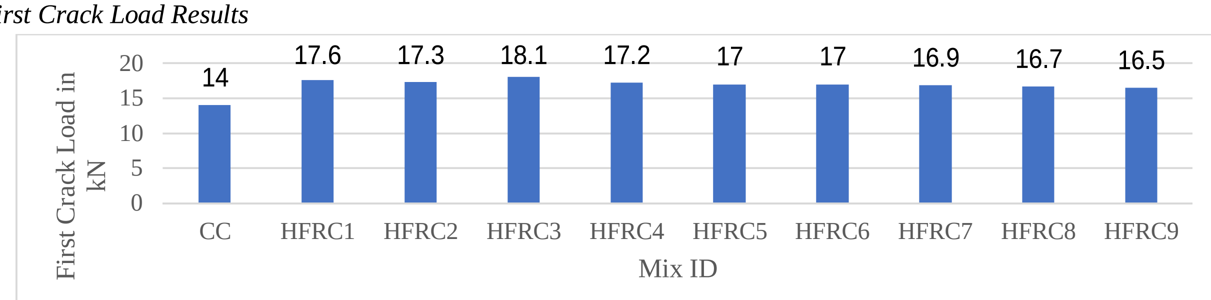

Figure 4.6 Bar Graph of First Crack Load of CC and HFRC Beams

Graph shows the HFRC3 with 1.5% polypropylene fibers and 0.5% of sisal fibers resists greater before cracking comparative to the conventional concrete and all other concrete mix.

2) Ultimate Load Carrying Capacity Results

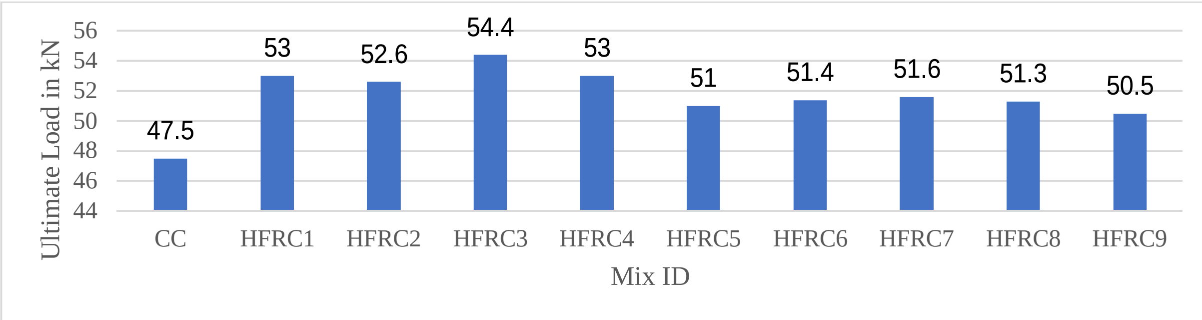

Figure 4.7 Bar Graph of Ultimate Load Carrying Capacity of CC and HFRC Beams

Graphs shows that HFRC3 has greater capacity with ultimate load comparative to other HFRCs is mainly due to the fact that the PP fibers when added in lower percentages improves the ultimate load carrying capacity by the phenomenon of crack arresting and the load is taken by the fibers in order to withstand crack and helps in avoiding the failure of the concrete specimen. But when the addition of PP fibers crosses beyond the threshold limit, the excess PP fibers present in the HFRC starts to interfere with the cohesion of the concrete matrix thereby reducing the ultimate load carrying capacity of beams. Comparative graphical representation of first crack load and ultimate load carrying capacity shown in figure 4.8 below.

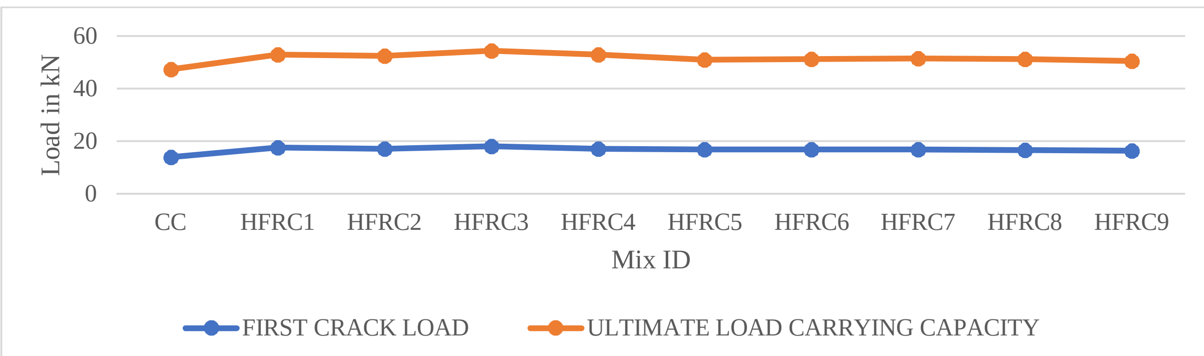

Figure 4.8 Comparison of First Crack Load and Ultimate Load Carrying Capacity of CC Beam and HFRC Beams

It was observed from the figures 4.8 that both the series of plots was found to have the same trend. As compared to conventional concrete beam specimen, the ultimate load carrying capacity of HFRC1 to HFRC9 increased gradually. The Ultimate load carrying capacity of HFRC1 having 53 kN was found to be considerably less than that of HFRC3 beam specimen having 54.4 kN load. However, among the HFRC beam specimens casted, HFRC3 was found to have the highest load carrying capacity value of 54.4 kN. This is 1.15 times greater than that of Conventional Concrete beam.

3) Mode of Failure

The Ultimate load carrying capacity was found to be 47.5 kN for the conventional concrete beam and 54.4 kN for the HFRC 3 The maximum deflection at the center of the beam was noted to be 20 mm and 17.6 mm respectively.

It is found that the cracking of the conventional concrete beam is wider compared to the concrete mixed with the hybrid fibers, in particular, HFRC 3 (1.5% PP fiber and 0.5% sisal fiber). The cracks formed in the HFRC 3 beam are found to be much smaller than the conventional concrete beam. Thus, the addition of optimum fiber dosage of 1.5% PP fiber and 0.5% sisal fiber, the cracks in the concrete can be controlled to a greater extent.

V. CONCLUSION

Result shows using of natural fibers and polypropylene fiber in hybrid fiber reinforced concrete can fulfil the almost every aspect of concrete properties. Result analysis of this experimental study are:

1) Compressive strength of HFRC3 with 1.5% polypropylene fibers and 0.5% of sisal fibers is greater than conventional concrete in 7 days and also in 28 days.
2) Split tensile strength of HFRC3 with 1.5% polypropylene fibers and 0.5% of sisal fibers is greater than conventional concrete in 7 days and also in 28 days.
3) Flexural strength of HFRC3 with 1.5% polypropylene fibers and 0.5% of sisal fibers is greater than conventional concrete in 7 days and 28 days
4) Structural behavior like first crack load and ultimate load carrying capacity of all the HFRC (1-9) shows better result than conventional concrete. In mode of failure test of HFRC3 and CC, it is found that the cracking of conventional beam is wider compared to the HFRC3.

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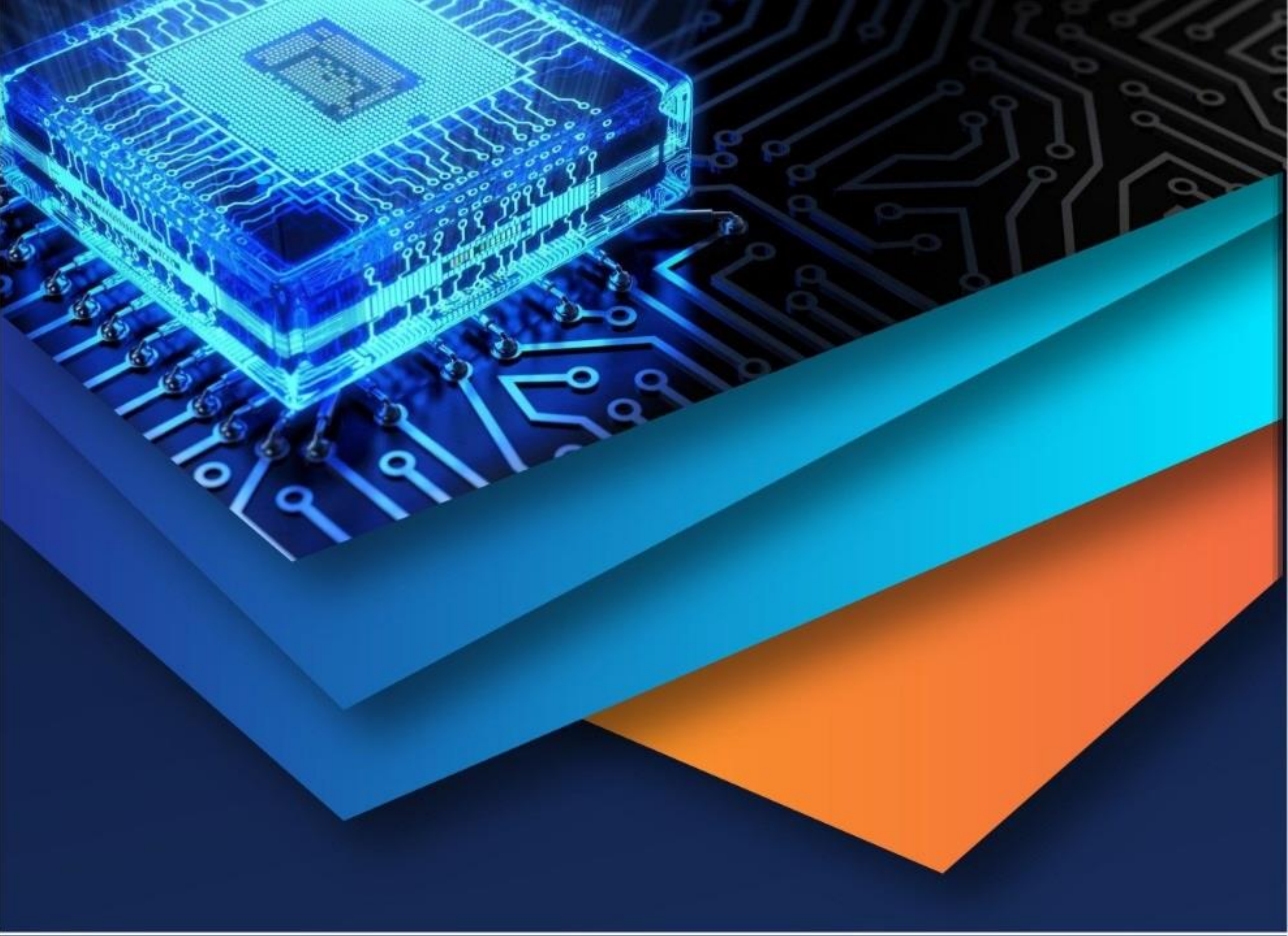

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