iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 **Issue:** XI **Month of publication:** November 2019

DOI: http://doi.org/10.22214/ijraset.2019.11027

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 7 Issue XI, Nov 2019- Available at www.ijraset.com

Development of Fiber Reinforced Concrete (FRC) with Coir and Glass Fibers

Dr. E. Devaki[1], T. R. Indumathi[2]
[1] MSc, MPhil, MBA, Ph.D., Assistant Professor, Department of Costume design and Fashion, PSG College of arts and Science, Coimbatore, Tamilnadu.
[2]MSc, M.Phil., (Ph. D), Assistant Professor, Department of Costume design and Fashion, Dr.N.G.P. Arts and Science College, Coimbatore, Tamilnadu..

Abstract: Investigations to overcome the brittle response of concrete led to the development of fiber reinforced concrete using discrete fibers within the concrete mass. The design of a durable and low cost fiber reinforced cement concrete for building construction is a technological challenge in developing countries.Since,with the materialsof locally available rural fibers, a concrete mix has been designed to achieve the minimum grade of M20 as required by IS 456 – 2000. The investigation to identify the effects on workability and mechanical strength properties due to the addition of these rural fibers, workability tests such slump and the mechanical strength tests on standard specimens such as compressive strength , split tensile strength were conducted on the different fibrous concrete specimens to obtain the optimum volume fraction and length of fibers. To ascertain the durability of natural fibers and synthetic fibers in concrete, an accelerated test was conducted on concrete under alternate wetting and drying conditions. From elaborative experimental and analytical investigations, it is concluded that the contribution of glass fiber and coir waste fibers are significant.
Keywords: Concrete, Slump, Fibers, Mould, Reinforced, Cementation composites.

I. INTRODUCTION

The earthquake damages in rural areas get multiplied mainly due to the widely adopted non –engineered constructions. Cement concrete composite is the most important building material and its consumption is increasing in all countries[1]. Concrete is a composite material composed of course of coarse aggregate bonded together with fluid cement which hardens over time[3]. Most concretes used are lime-based concretes such as Portland cement concrete or concretes made with other hydraulic cements, such as cement fondue[2,4].

The only disadvantage of cement concrete is its brittleness, with relatively low tensile strength and poor resistance to crack opening and propagation and negligible elongation at break. To overcome the dispersion of short fibers, the mechanical properties as well as the durability of the concrete can be improved. A wide variety of fibers have been proposed by the researchers such as steel, glass, polypropylene, carbon, polyester, acrylic and aramid etc.,[4,6] Economic considerations have restricted the use of carbon fibers in cementitious composites on a commercial level for their non-ecological performance.[8,9] Natural (cellulosic) fibers might offer the opportunity as a convenient reinforcing agent in concrete composite due to its low density and high tensile property.[10] The durability of such fibers in a highly alkaline cement matrix must be taken into consideration by effective modifications. A specific chemical composition has to be chosen that can modify the fiber surface as well as strengthen the cement composite.

Coir fibers and glass fiber has been decided to be used as reinforcing element in cement concrete in which fibers will chemically bridge in one side and cement on the other side. Coir fiber is expected to act as a flexible reinforcing agent in cement concrete enabling it to transmit both static and dynamic stresses to its surrounding bulk as well as absorb a portion of the stress by virtue of its flexible nature. An optimized weight fraction of fiber in cement concrete may lead to excellent mechanical properties.

II. MATERIALS AND METHODS

A. Materials

1) OPC cement as per IS 1489-1991 with specific gravity of 3.14 was used in this research
2) Locally available river sand confirmed to zone II (as per SI 383-1970) of fineness modulus of 2.7 was used as fine aggregate
3) Crushed blue granite as per SI 383-1970 passing through 20mm sieve and retained on 12.5mm sieve was used as coarse aggregate
4) Coir fiber and glass fiber has been used as reinforcing material

B. Tests For Cement

1) *Standard Consistency Test:* For finding out initial setting time of cement, a parameter known as standard consistency is used. The apparatus used for the test is vicat apparatus.

a) *Procedure:* About 500gms of cement is taken and prepared a paste with weighed quantity of water for first trial (24%by weight of cement).the paste prepared in standard manner and filled in to the mould within 3 to 5 minutes. After completely filling the mould, the mould is shaking well to expel air. A standard plunger, 10mm diameter and 50nmm long is attached and brought down to touch the surface of the paste in test block and quickly released allowing it to sink into the paste by its own weight. Take the reading by nothing down the depth of penetration of the plunger. Similarly, conduct trials with higher and higher W/C ratios till such time the plunger penetrates for a depth 33 to 35 mm from the top. That particular percentage of water which allows the plunger to penetrate only to a depth of 33 to 35 mm from the top is known as the percentage of water required to produce a cement paste of standard consistency.

2) *Initial Setting Time Test:* The cement paste with a contest of 31%(obtained from standard consistency test) is prepared and filled in to the mould as like that in standard consistency test. The plunger is replaced by a needle. Then needle is lowered gently and bring it in contact with the surface of the test block and quickly release. Allow it to penetrate into the test block. The elapsing between the time when water is added to the cement and the time at which the needle penetrates the block to a depth equal to 33 to 35 mmfrom the top is taken as initialtime.Opc43grades in one lot was produced and stored in tight container. The cement used was fresh, used within three months of manufacture. it should satisfy the requirements of IS 10262. The property of cement is determined as per IS4031P:1968& results are tabulated.

Table 1: Properties of cement

s.no	Properties	values
1	Fineness modulus	10%
2	Initial setting time	30mm
3	Final setting time	10hours
4	Standard consistency	34%
5	Specific gravity	3.15

C. Tests For Aggregate

1) *Specific Gravity Test:* Specific gravity of aggregate is made use of in design calculation of concrete mixes. With the specific gravity of each constituent know, its weight (w) can be converted into solid volume and hence a theoretical yield of concrete per unit volume can be calculated.The clean dry pycnometer with its cap is weighted (w1) one third of the pycnometer is filled with the aggregate and weighted (w2). Add the water in to the pycnometer and make it full and weighted(d3).then take the full of water in the pycnometer and weigh. All of these weights are noted as w1, w2, w3 and w4 respectively. Specific gravity is found out as fallows,

2) *Fine Aggregate:* Fine aggregate used in this investigation was medium sand properties of the fine aggregate used in the experimental work are tabulated.

Table 2: Silver analyses for fine aggregate

S.no	Characteristics	Value
1	Type	natured
2	Specific gravity	2.87
3	Total water absorption	0.9%
4	Fineness modulus	2.61

3) *Course Aggregate:* Locally available in coarse aggregates having the maximum size of 10mm and 20mm were used in the present work. They were washed to remove dust and dirt and were dried to surface dry condition. The results of various tests conducted on coarse aggregate are given in table.

Table 3: Sieve analysis for coarse aggregate

S.no	Properties	Values
1	Type	Manufactured
2	Specific gravity	2.60
3	Total water absorption	0.85%
4	Fineness modulus	10%
5	Impact value	32.2%
6	Crushing value	19.58%
7	Flakiness index	14.75%
8	Elongation	18.81%
9	Abrasion	3.67%

D. Water Absorption Test

The potable water available in college campus was used for mixing and curing of concrete. Water helps in dispersing the cement event, so that every particle of the aggregate is coated with it and brought into ultimate contact with the ingredients.

1) *Coir Fiber:* Coir is a seed-hair fiber obtained from the outer shell or husk of the coconut, the fruit of cocosnucifera, a tropical plant of the Arecaceae(palmae) family. The course, stiff, reddish brown fiber is made up of smaller threads, each about 0.01 to 0.04 inch (0.03 to 0.1 centimeter)long and 12 to 4 microns (a micron is about 0.00004 inch) in diameter, composed a lignin, a woody plant substance, and cellulose.
2) *Water Absorption Test (Coir Fiber):* A weight quantity of coir fiber is taken and immersed in water for 24 hours, and then weighed. Water absorption is calculated as follows

Water absorbed = final weight-initial weight

286-100=186

3) *Glass Fiber*
a) *Water absorption test (Glass fiber):* A weight quantity of coir fiber is taken and immersed in water for 24 hours, and then weighed. Water absorption is calculated as follows

Water absorbed = final weight-initial weight

184-100=84

E. Moulds

Cubical mould of size 150 mm*150 mm and mould of size 500mm*100mm*100mm were used to prepare the concrete specimens for the determination of compressive strength and split tensile strength of foundry sand concrete at various replacement levels. Care was taken during casting. Cylindrical mould of size 150mm*150mm and prism mould of size 500mm*100mm*100mm were used toprepare the concrete specimens for the determinations of split tensile strength.

F. Mix Designation

Concrete mix has been designed based on Indian standard recommended guidelines IS 10262-2009. The proportions for the concrete, as determined were 1:1.46:3.26 the mix design for a concrete of m 20 grade is given below:

1) *Determination Of Cement Contest*

Water cement ratio =0.50

Water =186

Cement=186/0.5

Total =372kglm^3

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2) Determination of Coarse and Fine Aggregate Contest

The specified maximum size of aggregate of 20mm, the amount of entrapped air in the wet concrete is 2 percent.

$V=(W+C/S_C+1/P.f_{a/sfa})*1/1000$

$0.98=(186+372/3.15+1/0.315*f_a/2.60)*1/1000=544kg/m^3$

$V=(W+C/S_a+1/p\text{-}1.c_{a/}s_{ca})*1/1000$

$0.98=(186+372/3.15+1/0.085*c_a/2.60)*1/1000$

$C_a=1216kg/m^3$

3) Determination of Fiber Content

Fiber content should be taken from 0.5 to 2.5 percent by its volume of mix. Coir and glass fiber has been taken in three different propositions

a) Coir fiber : glass fiber , 0.5:0.5
b) Coir fiber :glass fiber , 0.5:1
c) Coir fiber :glass fiber ,0.5:1.5

Table 4: Mix proportions

Water	Cement	Fine aggregate	Coarse aggregate
$186L/m^3$	$372kg/m^3$	$544kg/m^3$	$1216\ kg/m^3$
Or 0.50	1	1.46	3.26

Water =$60L/m^3$
Cement = 60 kg/m^3
Fine aggregate = 88 kg/m^3
Coarse aggregate = 170 kg/m^3
Glass fiber = 0.2937 kg/m^3
Coir fiber = 0.180 kg/m^3

G. Mixing Concrete

Thorough mixing is essential for the production of uniform,high quality concrete. Separate paste mixing has shown that the mixing of cement and water into a paste before combining these materials with aggregates can increase the compressive strength of the resulting concrete. The paste is generally mixed in a high speed, shear-type mixer at a w/cm (water to cement ratio) of 0.30 to 0.45 by mass. The premixed paste is then blended with aggregates and any remaining batch water and final mixing is completed in conventional concrete mixing equipment. The fiber has been added in different proportions.

1) Workability: Workability is the ability of a fresh (plastic) concrete mix to fill the form/mold properly with the desired work (vibration) and without reducing the concrete's quality. Workability depends on water content, aggregate (shape and size distribution), cementitious content and age (level of hydration). Raising the water content or adding chemical admixtures increases concrete workability. Excessive water leads to increased bleeding and /or segregationof aggregates. The use of an aggregate with an undesirable gradation can resultin a very harsh mix design with a very slump, low slump, which cannot readily be made more workable by addition of reasonable amounts of water.One of these methods includes placing the cone on the narrow end and observing how the mix flows through the cone while it is gradually lifted. After mixing, concrete is a fluid and can be pumped ta the location where needed.

H. Casting and Curing of Specimens

A common misconception is that concrete dries as it sets, but the opposite is true- damp concrete sets better than dry concrete. Curing allows concrete to achieve optimal strength and hardness. Curing is the hydration process that occurs after the concrete has been placed.

Hydration and hardening of concrete during the first three days is critical. Properly curing concrete leads to increased strength and lower permeability and avoids cracking where the surface dries out prematurely. Care must also be taken to avoid freezing or overheating due to the exothermic setting of cement. Improper curing can cause scaling, reduced strength, poor abrasion resistance and cracking.

1) *Curing Techniques:* During the curing period, concrete is ideally maintained at controlled temperature and humidity. To ensure full hydration during curing, concrete slabs are often sprayed with "curing compounds" that create a water-retaining film over the concrete. Traditional conditions for curing involve by ponding the concrete surface with water. 12 clean and oiled moulds for each category were then placed for the cubical samples for compression strength testing and four prism moulds for split tensile strength. Tamping was stopped as soon as the cement slurry appeared on the top surface of the mould.The specimens were allowed to remain in the steel mould for the first 24 hours at ambient conditions. After that these were demoulded with care so that no edges were broken and were placed in the curing tank at the ambient temperature for curing.

I. Testing and Analysis of Specimen

Testing of concrete plays an important role in controlling and confirming the quality of cement concrete. Clue and cylinder are tested for its strength characteristics.

1) *Fresh Concrete Test*
   a) *Slump Cone Test:* Workability of fresh concrete mixturemould is filled with freshly preparedconcerned in three layers of concrete and each layer is given with 25 blows using tamping rod. Mould is removed from the concrete immediately by raising it slowly and carefully in a vertical direction. Slump is the fall of height in vertical height of freshly prepared concrete with respect to its standard height.
   b) *Compaction Factor Test:* Compaction factor test works on a principle of determining the degree of compaction achieved by a standard height. The degree of compaction called compaction factor is measures by the density ratio. It is achieved in the test to the density of concrete fully compacted. Hence this method is particularly useful for concrete of very low workability requiring vibration.

2) *Hardened Concrete Test*
   a) *Compressive Strength Test:* The specimen of standard cube of (150 mm *150mm*150mm) was used to determine the compressive strength. The specimens were tested for 7,14 and 28 days with each proportion of egg shell and sea shell replacement in cement and coarse aggregate. Totally 44 cubes were casted. The specimen was placed in compression testing machine and load was applied to the opposite sides of the cube. The load at the time of first crack and the time of failure is noted. Same procedure is repeated for two more cube and the average value is taken.
   b) *Split Tensile Strength Test:* The cylindrical specimen of 15cm diameter and 30cm length is used for the test. Specimens were tested for 7, 14, and 28days.Totally 44 cylinders were casted. Specimen is kept horizontally and compressed in compression testing machine. In this test the cylindrical specimen is subjected to a uniform line load acting along the length of the specimen brakes down.

III. RESULT AND DISCUSSION

A total of 12 cubes, 12 prism were casted and tested and there compressive strength, split tensile strength. Results have been compared with the conventional specimens of m20 grade design mix.

A. Fresh Concrete

1) *Slump Cone Test:* Slump test is used for measuring the workability of concrete, conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch, which can be employed either in laboratory or at site of work.The difference in level between the height of the mould and that of the highest point of the subsided concrete is measured. This difference in height is 10mm which is taken as slump of concrete.

B. Hardened Concrete Test

1) *Compressive Strength Test:* The cubes of sizes 150 *150 *150 mm are placed in the machine such that load is applied on the opposite side of the cubes are casted. align carefully and load is applied, till the specimen breaks.the formula use for calculation.

Compressive Strength = Total failure load/ Area of the cube

Table 5(a): compressive strength result plain concrete and FRC coir/glass (0.5:1.5)

Concrete	Plain	Coir/glass (0.5:1.5)
SAMPLE 1	15.77	13.84
SAMPLE 2	15.73	13.17
SAMPLE 3	15.95	14.42
T-TEST VALUE		0.0108

Table 5(b): compressive strength result plain concrete and FRC (coir/glass 0.5:1)

Concrete	Plain in N/mm^2	Coir/glass 0.5:1 in N/mm^2
SAMPLE 1	15.77	14.08
SAMPLE 2	15.73	15.53
SAMPLE 3	15.95	13.68
T-TEST VALUE		0.076716

Table 5(c): compressive strength result plain concrete and FRC (coir/glass 0.5:0.5)

Concrete	Plain in N/mm^2	Coir/glass 0.5:0.5 in N/mm^2
SAMPLE 1	15.77	16.79
SAMPLE 2	15.73	17.68
SAMPLE 3	15.95	16.08
T-TEST VALUE		0.09406

Form the above result it is concluded that the strength of concrete shows higher compression strength in the ratio of glass and coir fiber (1%) compared with the strength of plain concrete. Whereas increasing of fiber content in concrete mix reduces the compression strength of concrete.

2) *Split Tensile Test:* The test is carried out by placing cylinder specimen of dimension 150mm diameter and 300mm length, horizontally between the loading surface of compression testing machine and the load is applied until failure of the cylinder along the vertical diameter. The failure load of the specimen is noted.The failure load of tensile strength cylinder is calculated by using the formula

Tensile strength = 2P/3.14DL

Table 6(a) Tensile strength result plain concrete and FRC (coir/glass 0.5:1.5)

Concrete	Plain in N/Mm^2	Coir/glass 0.5:1.5 in N/mm^2
SAMPLE 1	0.3219	0.2784
SAMPLE 2	0.3762	0.2708
SAMPLE 3	0.3416	0.2985
T-TEST VALUE		0.04531

Table 6(b) Tensile strength result plain concrete and FRC (coir/glass 0.5:1)

Concrete	Plain in N/Mm^2	Coir/glass 0.5:1 in N/mm^2
SAMPLE 1	0.3219	0.3019
SAMPLE 2	0.3762	0.3707
SAMPLE 3	0.3416	0.3834
T-TEST VALUE		0.399163

Table 6(c) Tensile strength result plain concrete and FRC (coir/glass 0.5:0.5)

Concrete	Plain in N/Mm^2	Coir/glass 0.5:0.5 in N/mm^2
SAMPLE 1	0.3219	0.3318
SAMPLE 2	0.3762	0.3428
SAMPLE 3	0.3416	0.3684
T-TEST VALUE		0.478326

From the above result it is concluded that the strength of concrete shows higher tensile strength in the ratio of glass and coir fiber (1%) compared with the strength of plain concrete. whereas increasing of content in concrete mix reduces the tensile strength of concrete.

IV. CONCLUSION

The investigation has been done to identify the effects on workability and mechanical strength properties of concrete due to the addition of glass and coir fibers in different proportions. These FRC sample has been tested and compared with the strength of plain concrete. From the results of the study, it is concluded that, the compressive strength increases gradually in fiber reinforced concrete than concrete without fibers. The fiber reinforced concrete showed an ability to control the cracking under impact loading and is found to absorb substantially higher number of blows when compared with the plain concrete. Fiber reinforced concrete showed an ability to control the cracking under impact loading and is found to absorb substantially higher number of blows when compared with the plain concrete. The strength of theconcrete, increases by using fiber volume of 1% by its weight. The concrete cube with higher volume of fiber shows lesser strength compared with lower volume of fiber. When compared with plain concrete fiber reinforced concrete withstand for long time.

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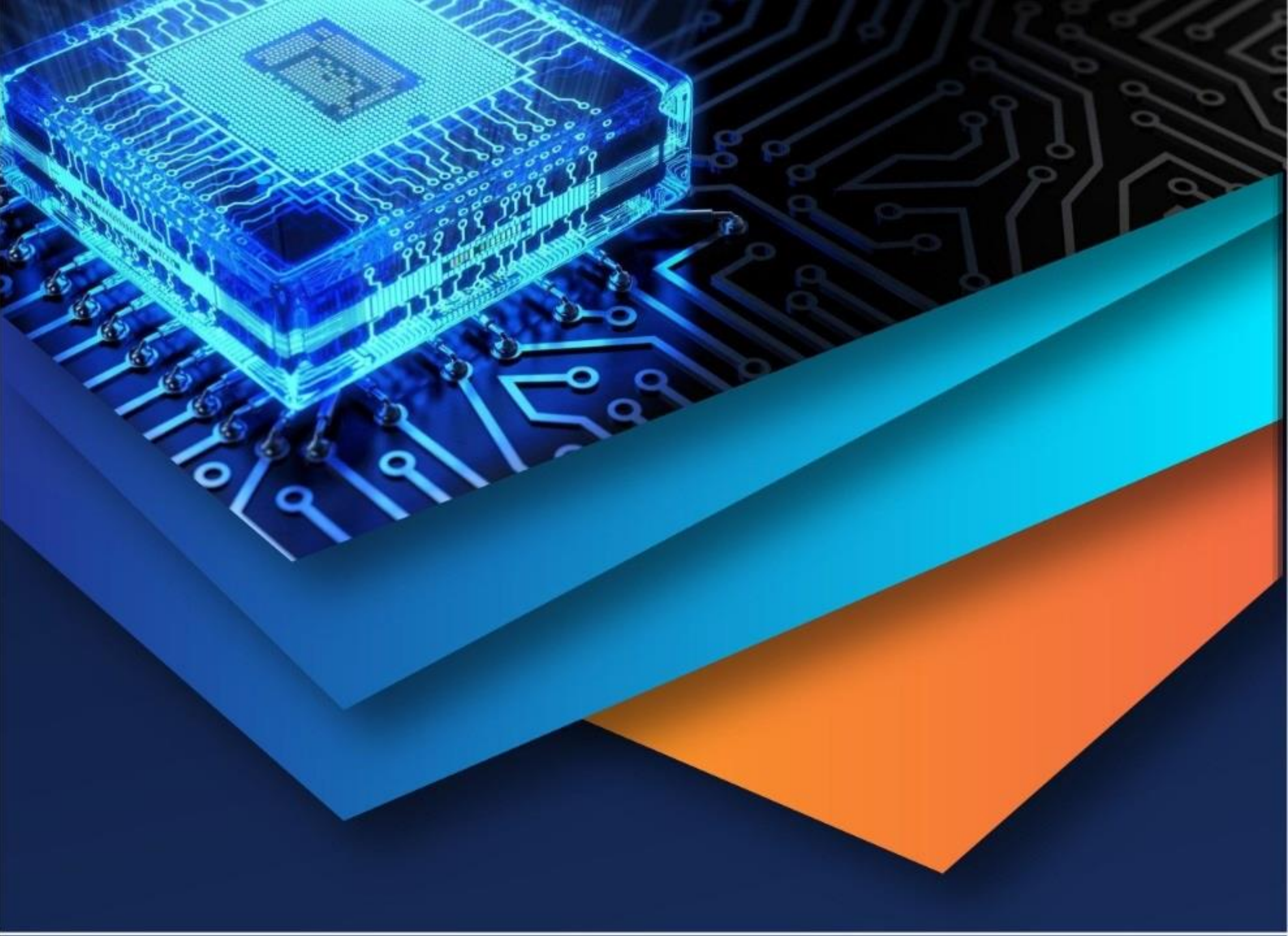

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