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Experimental Study on Concrete using Aramid Fiber

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Abstract: Concrete is the most widely used building material. It has desirable engineering properties, that can be molded into any shape and more importantly is produced with cost effective material. In the engineering industry the improvement of existing materials allows for technological advancement and the construction of more reliable structure without over usage of resources. The sustainable development is the very important one which is so much needed nowadays. The solid waste management is the great challenge in this period. So, the resources have to be used without causing any harm to the environment. The industrial by products are widely used as the replacement in the concrete. we have planned to use the Aramid Fiber has it has various advantages when they are used in the concrete. In this project, we decided to put M25 design mix, so that we can use it in small construction also. The Aramid Fiber is added 0.02%, 0.03%, and 0.04% in the concrete.
Keywords: Aramid fibers, Increases compressive strength, flexural strength & durability.

I. INTRODUCTION

In many buildings reinforced concrete structures were tend to fail due to inadequate maintenance, excessive loading or exposed to adverse environmental conditions. Therefore, strengthening or repairing should be done for those structures to bring back to its original service condition. Some of the strengthening techniques used are steel plate bonding, external prestressing, section enlargement, and reinforced concrete jacketing. These techniques although increase the load carrying capacity it leads to corrosion resulting in failure of strengthening system. To overcome these a new strengthening technique of fiber reinforced polymer (FRP) composites were used. Nowadays, hybrid fiber reinforced polymer composites were mostly used due to their ability to increase the service life of structures and also reduces the maintenance costs. Hybrid fiber reinforced composite structures have different characteristics like easy to apply, resistance to corrosion, high strength. Synthetic Fiber Synthetic fibers are made from synthesized polymers of small molecules. The compounds that are used to make these fibers come from raw materials such as petroleum-based chemicals or petrochemicals. These materials are polymerized into a long, linear chemical that bond two adjacent carbon atoms. Differing chemical compounds will be used to produce different types of synthetic fibers. Synthetic fibers account for about half of all fiber usage, with applications in every field of fiber and textile technology. Although many classes of fiber based on synthetic polymers have been evaluated as potentially valuable commercial products, four of them nylon, polyester, acrylic and polyolefin - dominate the market. These four account for approximately 98 percent by volume of synthetic fiber production, with polyester alone accounting for around 60percent.

A. Additional Material Used

Aramid fibers are organic fibers, made of aromatic polyamides in an extremely oriented form. First introduced in 1971, they are characterized by high toughness. Their Young modulus of elasticity and tensile strength are intermediate between glass and carbon fibers. Their compressive strength is typically around 1/8 of their tensile strength. Due to the anisotropy of the fiber structure, compression loads promote a localized yielding of the fibers resulting in fiber instability and formation of kinks. Aramid fibers may degrade after extensive exposure to sunlight, losing up to 50 % of their tensile strength. In addition, they may be sensitive to moisture. Their creep behavior is similar to that of glass fibers, even though their failure strength and fatigue behavior is higher than Aramid fibers. FRP composites based on Aramid fibers are usually denoted as AR. For strengthening purposes in Civil Engineering carbon fibers are the most suitable. Generally, all fibers are linear up to failure and have higher stress capacity than ordinary steel. The most important properties that differ between the fiber types are stiffness and tensile strength. Aramid fiber is a strong, heat-resistant fiber formed of polymers with repeating aromatic groups branching from a carbon backbone. In the polyamide fibers, at least 85% of the amide linkages are attached directly to two aromatic rings.

Two types of Aramid materials are used in Meta Aramid paper which is used for making honeycomb core materials required for sandwich construction Para- Aramid fibers are made by the solution poly condensation of Di-amines and Di-acid halides. The oriented Para substituted aromatic units provide a rod like polymer. The rod like structure results in a high glass transition temperature and poor solubility. They are not spin able by conventional process and hence they are made by the dry- jet wet spinning of liquid crystalline polymer solutions. Aramid Fiber is also known as Kevlar fiber. Aramid fiber is also high strength, tough and highly oriented organic fiber derived from polyamide incorporating into an aromatic ring structure. Kevlar is used in bullets resistance jacket. This fiber is quite abrasive and under repeated loading they can abrade against each other by weakening the sheets. Aramid fiber is a family of synthetic products characterized by strength which is five times stronger than steel on an equal weight basis and heat-resistance and high tensile strength. Aramid-Fiber-Reinforced Polymer The aramid fiber originates from aromatic polyamide (aramids) and depends on paraphenylene teraphthalamide, which introduces an amide group and benzene rings into polyamide molecules Fibers. Due to strong inter-chain bonding and a high level of crystallization, modulus and tenacity of these fibers are very high. In aramid fibers, 85% of amide linkages are directly attached to two aromatic rings. These fibers have 5–10% more mechanical properties than synthetic fibers. Such fibers are typically used in composite structures for application in aircraft, marine and automobile, rope for offshore oil rigs, and bulletproof vests. Aramid fibers are abrasion-resistant under cyclic loading. They are five times stronger than steel and also heat-resistant. The tensile strength is between 2400 and 3600 N/mm2 with percentage elongation of 2.2% to 4.4%. The tensile modulus is 60 to 120 GPa. Granata and Parvin worked on Kevlar fiber, which is a type of aramid fiber for the strengthening of the beam-column joint. Shell chemical epoxy was used as an adhesive in this study. Pereira and Revilock used an aramid fiber named Kevlar fabric of tensile strength 55% greater than E-glass fiber and shear strength 180% stronger than E-glass fiber.

B. Uses Of Aramid Fibers

1) Significantly reduces the risk of damages caused by chemical reaction.
2) Provides higher strength and ductility.
3) Reducing the risk of reinforcement corrosion.
4) Provides higher resistance to attacks by sulphate and other chemicals.

C. Advantages Of Aramid Fibers

1) The durability of structures can be extended by selecting an appropriate method of strengthening.
2) Aramid fibers are abrasion-resistant under cyclic loading.
3) Due to strong inter-chain bonding and a high level of crystallization, modulus and tenacity of these fibers are very high
4) The penetration of chloride can be decreased. The heat of hydration is less compared to conventional mix hydration.
5) Sensitive to acids and ultraviolet radiation.
6) These make the concrete more chemically stable Gives good surface finish and improves aesthetics
7) The color is more even and light.
8) Lower chances of efflorescence
9) The maintenance and repair cost of structures are reduced thus increasing the life cycle of concrete structures.

D. Significance Of The Project

Concrete is the most extensively used building material in the construction industry, but it faces some problems, such as damage from earthquakes and cracking due to shrinkage and expansion. Due to these problems, concrete suffers from moisture attack, resulting in corrosion of steel reinforcement and loss of structural strength. Such damage can be repaired using FRP materials. Structures can also be strengthened to accommodate changes in load variation or code revisions.

E. Scope Of The Project

1) To increase the strength of concrete.
2) It is economical.
3) To study about the strength resources in the concrete.
4) To reduce the abrasion of the concrete.
5) For sustainable development.

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F. Objectives

1) Preparation of mix design for M25 grade of concrete using Aramid fiber added in the percentages of 0.02%,0.03%, and 0.04%.
2) To study the physical and chemical properties of the materials used in concrete.
3) It improves the compressive strength and durability of concrete.
4) Resistance to absorption.
5) Resistance to organic solvent.
6) No conductivity.
7) Good chemical resistance.
8) No melting point low flammability.
9) Excellent heat and cut resistance.

II. MATERIAL USED

This chapter deals with various materials used like cement, fine aggregate, coarse aggregate, Aramid Fiber and water. The properties and functions of these materialsare described in this chapter.

The materials used in this project are

1) Cement – Maha OPC-53
2) Fine aggregate – M sand
3) Aramid Fiber
4) Coarse aggregate
5) Water

A. Cement

A cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel together.

Figure 1. Vicat apparatus

Table 1. Properties of cement

S NO	PROPERTIES	VALUES OBTAINED
1	Consistency	34%
2	Specific gravity	3.15
3	Initial setting time	34 min
4	Fineness	2%

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B. Fine Aggregate

Fine aggregate are basically sands won from the land or the marine environment. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 4.75mm sieve is said to be fine aggregates. It should be free from organic matter and minerals like chlorine etc. The sieve analysis test shows the sand belongs to zone II.

Figure 2. Gradation of fine aggregate

Fine aggregate can be natural or crushed. River sand used as fine aggregates. The specification require that it should consists of hard, dense, uncoated rock fragments and shall be free from injurious amounts of dust, clay, silt, mica and organic matter, soft and flaky practices. The sand particle should also pack to give minimum water. The present study the sand used conforms to zone II (as per 383 – 1970).

Table 2. Gradation of fine aggregate

IS Sieve (mm)	Weight Retained(G)	Percentage Retained	Cumulative Percentage Retained	Cumulative Percentage Passing	Permissible Limits as PerIS 383(%)
4.75	0	0	0	100	90-100
2.36	64	6.4	6.4	93.6	75-100
1.18	320	32	38.4	61.6	55-90
0.600	182	18.2	56.6	43.4	35-59
0.300	386	38.6	95.2	4.8	8-30
0.150	46	4.6	99.8	0.2	0-10
Pan	2	0.2	100	0	

The fine aggregate belongs to zone II as per IS 383-1970 table 4.

Table 3. Specific gravity of fine aggregate

S.NO	W1(g)	W2(g)	W3(g)	W4(g)	SpecificGravity
1	578	1164	1788	1408	2.86
2	578	1160	1780	1408	2.7
3	578	1164	1788	1408	2.86

W1- empty weight of the pycnometer
W2- weight of the pycnometer and aggregate
W3- weight of the pycnometer and aggregate and waterW4- weight of the pycnometer and water.
The specific gravity of fine aggregate is 2.8

Table 4. Properties of fine aggregate

S NO	PROPERTIES	FINE AGGREGATE
1	Dry rodded density	1726 kg/m3
2	Fineness modulus	3.96
3	Specific gravity	2.8
4	Water absorption	0.7%

C. Coarse Aggregate

In this investigation the thickness of the concrete layer is only about 40 mm hence the 10 mm aggregates to be used for this. The impact value of the aggregate should be 10 to 15% so the aggregate is said to good, strong and durable. The coarse aggregate is the strongest and least porous component of concrete. Presence of coarse aggregate reduces the drying shrinkage and other dimensional change occurring on account of movement of moisture. Coarse aggregate contributes to impermeability of concrete, provided that it is properly graded and mix is suitably designed. The size fraction of the coarse aggregate used is extremely important for determining the optimum amount of paste content to obtain all the necessary characteristics of a flowing concrete. Coarse aggregate in conventional concrete contribute to the heterogeneity of the cement concrete and there is weak interface between cement content, the permeability decreases with higher cement content and for given cement content, the permeability decreases with fineness modulus of sand.

The coarse aggregates were tested according to IS: 383-1970.

Figure 3. Gradation of coarse aggregate

Table 5. Gradation of coarse aggregate

IS Sieve (mm)	Weight Retained(G)	Percentage Retained	Cumulative Percentage Retained	Cumulative Percentage Passing
40	0	0	0	100
20	474	23.7	23.7	76.3
12.5	1440	72	95.7	4.3
10	68	3.4	99.1	0.9
6.3	18	0.9	100	0

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Table 6. Specific gravity of coarse aggregate

S.NO	W1(g)	W2(g)	W3(g)	W4(g)	Specific Gravity
1	578	1090	1746	1408	2.9
2	578	1160	1780	1408	2.7
3	578	1164	1788	1408	2.86

W1- empty weight of the pycnometer
W2- weight of the pycnometer and aggregate
W3- weight of the pycnometer and aggregate and waterW4- weight of the pycnometer and water.
The specific gravity of coarse aggregate is 2.8

Figure 4. Pycnometer

Table 7. Properties of coarse aggregate

CHARACTERISTICS	VALUE
Sieve analysis	As per IS 383, the sample is single sized nominal aggregate
Specific gravity	2.8
Fineness modulus	3.18

These are the values obtained by performing the gradation and specific gravity

D. Aramid Fiber (KEVLAR)

Aramid Fiber is poly para-phenyleneterepthalamide (PPD-T) and is more properly known as para-aramid.

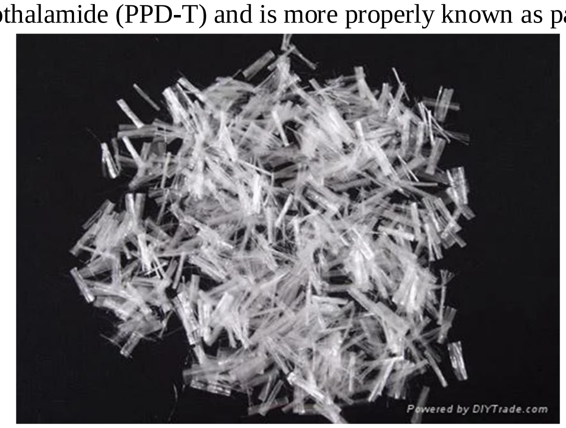

Figure 5. Aramid Fiber

E. Water

1) Water used in concrete plays an important part in mixing, laying, compaction, setting and hardening of concrete. The strength of concrete directly depends on quality and quantity of water used.
2) The functions of water in concrete are as follows:
3) Water is only the ingredient that reacts chemically with cement and thus setting and hardening takes place.
4) Water acts as a lubricant to aggregates and makes the concrete workable
5) It facilitates the spreading of cement over fine aggregates
6) The potable water is used as per IS 456:2000.

III. TESTS ON FRESH CONCRETE

A. Slump Cone Test

Slump cone test is used to determine the workability of fresh concrete Workability is one of the physical parameters of concrete which affects the strength and durability as well as the cost of labour and appearance of the finished product. The concrete is said to be workable when it is easily placed and compacted homogeneously that is without bleeding or segregation. As per IS:1199-1959 the mould for the slump test is a frustum of a cone, 300mm of height. The base is 200mm in diameter and it has a smaller opening at the top of 100mm. The base is placed on a smooth surface and the container is filled with concrete in 3 layers, whose workability is to be tested. Each layer is tamped 25 times with a standard 16mm diameter steel rod, rounded at the end. When the mould is completely filled with concrete, the top surface is struck off by means of screening and rolling motion of the tamping rod. The mould must be firmly held against its base during the entire operation so that it could not move due to the pouring of concrete and this can be done by means of handles or foot-rests brazed to the mould. Immediately after filling is completed and the concrete is levelled, the cone is slowly and carefully lifted vertically, an unsupported concrete will now slump. The decrease in the height of the centre of the slumped concrete is called slump. The slump is measured by placing the cone just besides the slump concrete and the tamping rod is placed over the cone so that it should also come over the area of slumped concrete. The decrease in height of concrete to that of mould is noted with scale (usually measured to the nearest 5mm).

The slump is 100 mm indicate medium degree of workability.

Figure 6. Slump cone test

B. Compaction Factor Test

To determine the relative consistency of freshly mixed concrete by the use of compacting factor test. According to IS:1199-1959, SP:23-1982, the internal surface of the hoppers and cylinder shall be thoroughly cleaned and free from moisture and any set of concrete commencing the test. The sample of concrete to be tested shall be placed gently in the upper hopper using the scoop. The trap door shall be opened immediately after filling or approximately six minutes after water is added so that the concrete fails into the lower hopper. During this process the cylinder shall be covered. Immediately after the concrete has come to test the cylinder shall be uncovered, the trap door of the lower hopper open and the concrete allowed falling it into the cylinder. For some mixes have a tendency to stick in one or both of the hoppers.

If this occurs the concrete shall be helped through the pushing the tamping rod gently into the concrete from the top. The excess of concrete remaining above the level of the cylinder shall then be cut off by holding a trowel in each hand, with the plane of blades horizontally, and moving them simultaneously one from each side across the top of the cylinder, at the same time keeping them pressed on the top edge of the cylinder. The outside of the cylinder shall then be wiped clean. This entire process shall be carried out at a place free from vibration or shock. Determine the weight of the concrete to the nearest 10g. This is known as "weight of partial compacted concrete", Wp. Refill the cylinder with concrete from the same sample in layers approximately 50mm depth. The layers being heavily rammed with the compacting rod or vibrated to obtain full compaction. The top surface of the fully compacted concrete shall bee carefully struck off and finished levelled with the top of the cylinder. Clean up the outside of the cylinder. Determine the weight of the concrete to the nearest 10g. his is known as fully compacted concrete, Wf.The compacting factor = weight of partially compacted concrete / weight of fully compacted concrete.

The compaction factor of the concrete is 0.87, it has a medium degree of workability.

Table 8. Tests on fresh concrete

S NO	TESTS	VALUE
1	Slump cone test	60mm
2	Compaction factor test	0.87

IV. TESTS ON HARDENED CONCRETE

A. *Compression Test*

The concrete mix is prepared as per the given proportion and admixture and water cement ratio. Representative samples of concrete shall be taken and used for casting cubes 15cmX15cmX15cm or cylindrical specimens of 15cm diaX30cm long. The concrete shall be filled into the moulds in layers approximately 5cm deep. It would be distributed evenly and compacted either by vibration or by hand tamping. After the top layer has been compacted, the surface of concrete shall be finished level with the top of the mould using a trowel; and covered with the glass plate to prevent evaporation. The specimen shall be stored at site for 24+1/2hr under damp mating or sack. After that, the sample shall be stored in clean water at 27+2ºC; until the time of test. Specimen shall be tested immediately on removal from water and while they are still in wet condition. The bearing surface of the testing specimen shall be wiped clean and any loose material removed from the surface. In the case of cubes, the specimen shall be placed in a machine in such a manner that the load cube as cast, that is, not to the top and bottom. Align the axis of the specimen with the steel plate, do not use any packing. The load shall be applied slowly without shock and increased continuously at a rate of approximately 140kg/cm2/min until the resistance of the specimen to the increased load breaks down and no greater load can be sustained. The maximum load applied to the specimen shall then be recorded and any unusual features noted at the time of failure brought out in the report.
The specimens are tested on 7,14 and 28 days and the loads are noted.

Table 9. Compressive strength test.

S no	Load in KN	Compressive strength (N/mm^2)
1	432	19.2
2	430	19.1
3	434	19.28

The average compressive strength is 19.1 N/mm^2

Figure 7. Testing of cube

V. MIX DESIGN

A. General

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining the relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. One of the ultimate aims of studying the various properties of the materials of concrete, plastic concrete and hardened concrete is to enable a concrete technologist to design a concrete mix for a particular strength and durability.

B. Requirements For Concrete Mix Design

1) Characteristics strength of the concrete is required.
2) Workability requirement of the concrete.
3) Quality control at site.
4) Weather conditions.
5) Exposure conditions of concrete.
6) Batching and mixing methods.
7) Quality of the materials
8) Special requirements of concrete.

C. Mix Design as Per is 10262-2019

1) *Stipulations For Proportioning*

Grade designation : M25
Type of cement : OPC 53 conforming to IS 8112
Maximum nominal size of aggregate : 20mm
Minimum cement content : 300kg/m3
Maximum water-cement ratio : 0.5
Workability : 100mm (slump)
Exposure condition: Moderate (for reinforced concrete)
Degree of supervision: good
Type of aggregate : crushed angular aggregate
Maximum cement (OPC) content: 450kg/m3

2) Test Data For Materials

a) Cement used : OPC 53 conforming to IS 8112

b) Specific gravity of
   1. cement : 3.15
   2. fine aggregate : 2.8
   3. coarse aggregate : 2.8

c) Free moisture
   1. Fine aggregate : nil
   2. Coarse aggregate : nil

d) Water absorption
   1. Fine aggregate : nil
   2. Coarse aggregate : nil

e) Sieve analysis
   1. Fine aggregate : conforming to grading Zone-II of table 4 of IS 383
   2. Coarse aggregate : conforming to table 2 of IS 383 singled Sized normal aggregate

3) Target Strength For Mix Proportioning

$fck' = fck + 1.65s$

fck'= target average compressive strength at 28 days, fck = characteristics compressive strength at 28 days, s = standard deviation

From table-1, standard deviation, s = 4 N/mm^2

Therefore, target strength = 40 + (1.65x4)

= 31.6 N/mm^2

4) Selection Of Water Cement Ratio

From Table 5 of IS 456, maximum water-cement ratio = 0.50 Based on experience, adopt water-cement ratio as 0.45
0.45 < 0.5, hence okay.

5) Selection Of Water Content

From Table 5, maximum water content for 20mm aggregate= 186 litres (25 to 50mmslump range)
Estimated water content for 100mm slump = (186 + 6/100) 186 = 197 litres

6) Calculation Of Cement

$$\frac{water}{cement} = 0.45$$

(197/0.45) = 437.7 kg/m3

Minimum cement content for exposure condition = 300 kg/m3
437.7 kg/m3 > 300 kg/m3 Hence, okay.

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7) MIX Calculations

a) Volume of concrete $= 1m^3$

b) Volume of cement $= \frac{mass\ of cement}{(specific\ gravity\ of\ cement X 1000)}$

$= \frac{437.7}{3.15} X \left(\frac{1}{1000}\right)$

$= 0.156\ m^3$.

c) Volume of water $= 197\ X\ \left(\frac{1}{1000}\right)$

$= 0.197m^3$

d) Volume of aggregate = 1-(0.138+0.197)

$= 0.665\ m^3$

Mass of coarse aggregate = 0.665 x 0.62 x 2.8 x1000

$= 1154.44\ kg/m^3$

Mass of fine aggregate = 0.665 x 0.38 x 2.8 x1000

$=707.56\ kg/m^3$

Cement: fine aggregate: coarse aggregate: water = 437.7:707.56:1154.44:0.45 The ratio is 1:1.61:2.6

Table 10. Design mix calculated

Material	Ratio
Cement	1
Fine aggregate	1.61
Coarse aggregate	2.6

The trial mixes are investigated based on the mix proportion and the compressive strength result at the end of 7, 14 and 28 days are determined

VI. CONCLUSIONS

The test results are carried out and the results are obtained.

1) Based on the test results, the mix design is calculated and further the process is proceeded.
2) The specific gravity is within the limitation and the gradation process of the aggregate is carried out and they are under the Zone II
3) The fresh and hardened concrete properties of the conventional concrete is tested and the slump value and the compaction factor that the concrete is having medium workability.
4) The compressive strength for 7 days for the conventional concrete is tested and it had attained 80% of the 28 days strength.
5) And the further proceedings and their results in this project will be acquired in the phase II.

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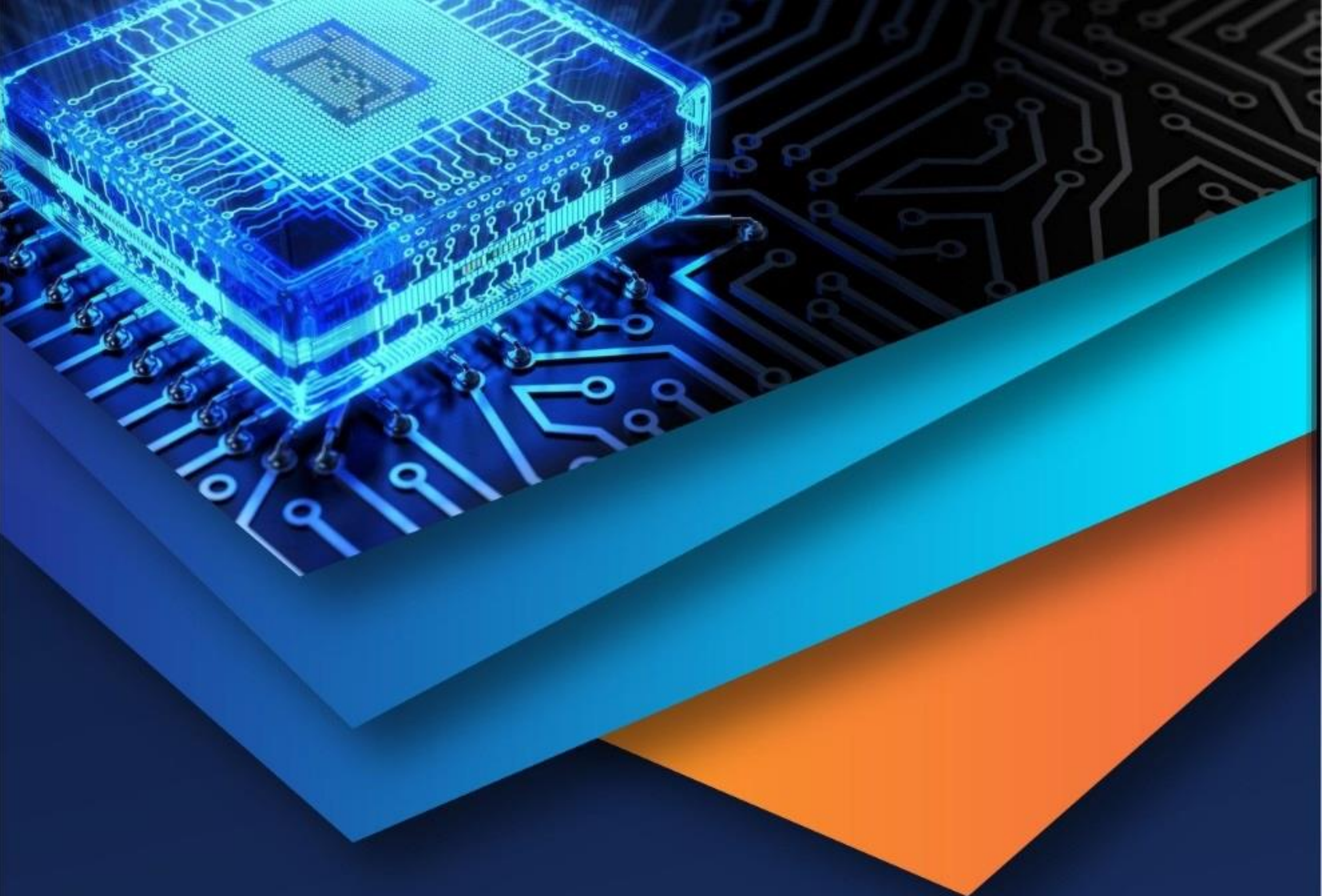

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