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Performance of Fiber Reinforced Concrete from Recycled Pet Plastic Waste- A Study Review

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Abstract: Concrete is a composite material consisting of various ingredients such as cement, coarse aggregate, fine aggregate and has done wonders in the construction industry. The recent use of the concrete has constrained many civil engineers to add some relevant constituents in various proportions to the cement or any other. The environmental degradation from various types of non-bio degradable wastes are not only making the environment hazardous but also are having a serious implications on the human lives and other living things.. In our investigations PET fibers were incorporated in the M20 and M30 grades of concrete by the weight fraction of cement percentages in 2%, 3%, 4% and 5% and then the mechanical property viz. compressive strength as well as flexural strength of the concrete was compared with the conventional concrete and a trend was established which was analyzed as per the civil engineering standards. This paper addresses the results of an investigation on the influence of Recycled PET (R-PET) fibers plastics as reinforcement of cement matrix. In this study, the conventional concrete was reinforced by the plastic fibers obtained from waste plastic bottles. All specimens were tested after curing age 28 days. In this paper the relationship between cube compressive strength for conventional and plastic fibers reinforced concrete were established and compared with standards.
Keywords: compressive strength, PET fibers, waste plastic bottles, Flexural Strength, PET fiber reinforced concrete (PFRC)

I. INTRODUCTION

Concrete is most frequently used man made versatile material comprising of cement, sand, coarse aggregate and water mixed in an appropriate proportion to obtain the desired strength. It has numerous advantages with the properties such as excellent compressive strength, durability, specific gravity etc. due to which it has proved its effectiveness and metal in the vast field of construction industry to build a distinctive infrastructural applications which include bridges, large and small buildings, dams and a variety of other significant structures in the universe. Concrete have many advantageous properties such as good compressive strength, durability and specific gravity and fire resistance. Some of the properties can be enhance by adding fibers with another ingredients of the concrete to improve its weakness. The fibers inclusion in concrete acts as unwanted micro crack arrester. In presence of fibers the crack propagation is delayed which helps in improvement in static and dynamic properties of concrete at normal stages. It is durable, inexpensive and has good compressive strength and stiffness with low tensile strength, low ductility and low energy absorption. The ductility of concrete can be increase by reinforcing with fibers in different form. Much research in developing fiber reinforced concrete on the field is ongoing process.

The consumption of plastic has grown day by day substantially all over the world; it leads to create large quantities of plastic-based waste. Plastic waste is the one of the challenge to dispose and manage as it is non- biodegradable material in nature which is harmful to our beautiful environment. The polyethylene terephthalate (PET) bottles are recycled and used for different purposes. The waste polyethylene terephthalate (PET) bottles were converted into fibers and added in concrete as an additional ingredient of concrete. The cube compressive strength of conventional and plastic fiber reinforced concrete were determined. The present investigation is carried out to study the effect of steel scrap, galvanized iron, polypropylene fibers obtained from industrial waste on various parameters of concrete, so as to produce fiber reinforced concrete. The waste metal or polypropylene fiber reinforced concrete can be denoted as M20F30. Where M denotes mix and 20 is its characteristic compressive strength after 28days. Whereas, F refers to fibers and 30 is the length of the fibers added to the concrete mix. It has been established that the addition of randomly distributed metal or polypropylene fibers coming from industry to brittle cement based materials can increase their fracture toughness, ductility and impact resistance.

This review paper reports the properties of concrete when waste PET bottles are used in fiber form as aggregates in reinforced plain concrete. The aim of the paper is to analyze and study the different experiments, case studies based on researches and experimental works and scientific reports to determine the improvement in selected properties of PET fiber reinforced concrete comparison. Also to convey that the use of PET fibers as reinforcement of cement composites is a promising technique for developing sustainable materials to be applied in the civil construction industry. And hence concrete with waste PET bottle fiber can be used not only as an effective plastic waste management practice but also as a strategy to produce more economic and sustainable building materials in the future.

II. LITERATURE REVIEW

All over the world, a comprehensive review of the work carried out by various researchers in the field of using recycled plastics in concrete is discussed below.

Marzouk et al., 2007: experiment the innovative use of consumed plastic bottle waste in granule form as sand substitution aggregate within composite materials for building application. Various volume fractions of sand varying from 2% to 100% were substituted by the same volume of granulated plastic, and various sizes of PET aggregates. They concluded that substituting sand at a level below 50% by volume with granulated PET, whose upper granular limit equals 5 mm, affected the compressive strength of composites and plastic bottles shredded into small PET particles may be used successfully as sand-substitution aggregates in concrete composites.

Sung Bae Kim et al., 2010: proved structural performance evaluation of recycled PET FRC. A procedure to recycle waste PET bottles is presented, in which short fibers made from recycled PET are used within concrete. To verify the performance capacity of recycled PET fiber reinforced concrete, it was compared with that of polypropylene (PP) fiber reinforced concrete for fiber volume fractions of 0.5%, 0.75%, and 1.0%. The compressive strength, elastic modulus, and restrained drying shrinkage strain were computed experimentally. The test results show that compressive strength and elastic modulus both decreased as fiber volume fraction increased and cracking due to drying shrinkage was delayed in the PET fiber reinforced concrete specimens, compared to such cracking in no reinforced specimens without fiber reinforcement, which indicates crack controlling and bridging characteristics of the recycled PET fibers.

R. N. Nibudey et al., 2013: optimized the benefits of using post consumed waste PET bottles in the fiber form in concrete. The concrete of M30grade with two aspect ratios 30 and 50 of waste plastic fibers were experimented to determine green and harden properties concrete. It was observed that slump, compaction factor and dry density of concrete reduces as compared to normal concrete when fiber content increases and reduction in these values found higher for larger value of aspect ratio. It was observed form test results of compressive, split tensile and flexure test that at 1% of fiber content improvement in strengths was higher for aspect ratio 50 than aspect ratio 30.

The past research encourage that the recycled plastics can be used in concrete for improving its property. The use of plastics in fiber form has given better results than granule forms. The aim of this paper is to explore the possibility of using a waste material like used mineral water bottles in concrete and compare cube compressive strength.

III. RESEARCH FINDINGS BEFORE WORK

A. *Fresh Concrete Properties*

1) *Air Content*: Experiment with waste fibrillated polypropylene fibers was conducted by Bayasi and Zeng [4] in 1993.seven mixtures of various lengths and proportions of fibers were made and the results suggest that air content is proportional to the amount and length of fibers. Especially when volume of fibers exceeded 0.3% increase in air content was significant and before that it was equal to or less than that in control beam.
2) *Workability:* This paper reviews slump test (ASTM C 143-78) and inverted slump test (ASTM C-995). Both these tests are helpful in determining the workability of fresh concrete, where inverted slump test is specifically used in case of fiber reinforced concrete. Bayasi and zeng [4] conducted slump and inverted slump cone tests, to check the effects of addition of polypropylene on concrete. Their results state that inverted slump cone time increased, thus it can be inferred that air entrainment becomes difficult and hence its use in corrosion prone structures should be avoided. Another result yields that fiber volume up to 0.3%, has significant effect on fresh mix workability but it deteriorates as the fiber volume increases. In fact increase in inverted slump cone time was critically affected by 19mm (long fibers) than 12.7mm (short fibers) in the experiment. Soroushian et al., performed experiments to see effect of WPP fibers, which are considered as macro fibers, and found that viscosity of concrete increases due to large surface area of fibers and their ability to absorb cement paste

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B. Hardened Concrete Properties

1) *Compressive Strength:* Experiments were conducted by Mohammed Seddik Meddah, Mohamed Bencheikh [3], where waste fibers of metal and polypropylene were taken and tested as given in [3]. The results show that the addition of short fibers (<30mm) result in decrease of compressive strength and that of long fibers shows no change in compressive strength. Also addition of metal fibers shows no change in compression strength. Since addition of fibers increases pore volume, it can be inferred that high fiber volume lead to high porosity and hence decrease in compressive strength.
2) *Flexural Behavior :* Flexural strength for M20 grade concrete was found to be highest (~2times of control beam) with 1% galvanized wire and 2% lathe scrap. Waste metal fiber reinforcement should a great amount of increase in flexural strength till 3% volume. Whereas, Olivier [11] suggests that there is no such effect of fibers on flexural properties, but it is more dependent on cement matrix properties and Soroushian et al., [5] fortified that waste (macro sized) PP fibers enhance post cracking ductility and flexural toughness.
3) *Durability:* Durability is the most important factor of concrete for long service life, and this paper aims to review durable and sustainable concrete. Brown et al., [13] studied the effects of virgin PP fibers in reactive environment and results showed that these fibers did not show any reduction in tensile properties even when exposed to salt water conditions at various temperatures ranging from 70°C to -7°C for six months.
4) *Permeability:* Permeability of concrete is a major contributor to its durability. Mohammed Seddik Meddah, Mohamed Bencheikh [3], suggested that more the fiber length and characteristics, more air voids will be formed. WPF induces more void spaces in the total volume than the WMF, due to the high surface area of PF than MF. This increase in porosity tends to increase permeability.
5) *Toughness and Impact Resistance:* Considering the experiment conducted by Mohammed Seddik Meddah, Mohamed Bencheikh [3], we find that the Toughness of FRC is considered as its ability to absorb energy across the crack and is found in this experiment by using area under load displacement curve. By finding toughness indices, it was concluded that WPF provided more toughness than MF. Impact resistance is said to be increased with addition of fibers.

IV. MATERIAL AND EXPERIMENTAL METHODOLOGY

A. Material

Portland Pozzolana Cement (Fly Ash based) was used in this experimentation conforming to IS: 1489-1991 (Part I) [11]. The physical properties of cement used in the study are as given in Table 4.1.A

Table4.1.A: The physical properties of Portland Pozzolana Cement

Fineness	Normal consistency	Initial setting time	Final setting time	Soundness (Le-Chat.)	28 days compressive strength
2.7 %,	32 %,	210 minute	330	1.5 mm	50.7 MPa

1) *Aggregates:* Locally available natural sand from river was used in this study as fine aggregate and the crushed stone aggregates were collected from the local query. The maximum sizes of aggregates were 20 mm and 10 mm. The fine and coarse aggregates were tested as per IS: 383-1970 and 2386-1963 (Part I, II and III) specifications [12, 13]. The physical properties of aggregates are as shown in Table 4.1.B and 4.1. C

Table 4.1.B.: The physical properties of fine aggregates

specific gravity	water absorption %,	bulk density Kg/cum	fineness modulus	silt content	grading zone
2.53	1.2 %	1718.52	2.65	0.61 %	II

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Table 4.1.C: The physical properties of coarse aggregates

Max size of aggregates	Specific gravity	bulk density	fineness modulus	Water absorption
20 mm	2.85	1564.2 Kg/cum	7.63	1.15 %
10 mm	2.83	1694.8 Kg/cum	6.42	1.23 %

2) *Plastic Fibers:* The post consumed PET mineral water bottles of single brand were collected from local restaurants. The fibers were cut after removing the neck and bottom of the bottle. The length of fibers was kept 20 mm and the breadth was 1 mm and 2 mm. The aspect ratio (AR) of waste plastic fibers were 35 (AR-35) and 50 (AR-50).The plastic fibers used were having specific gravity 1.34, water absorption 0.00 %. The different fractions for two aspect ratios were used in this experimentation
3) *Water:* Potable water was used for mixing and curing of specimens throughout the experimentation.
4) *Super Plasticizer:* To impart additional workability a super plasticizer AC-PLAST-BV-M4 was used. It is concrete plasticizer with less than 0.05 % chloride content and conforms to IS: 9103-1999. The super plasticizer was added 0.6 %-0.7% by weight of cement to all mix.

Figure: Cube Compaction Factor Test

Figure: Cube Workability Test

B. Experimental Methodology

1) *Concrete Mix:* Based on the trial mixes for different proportion of ingredients the final design mix was selected for M20 and M30 grade of concrete as per IS 10262:2009 [14], the concrete mix proportions is as given in the Table 4.2.1. The plastic fibers were added into dry mix of concrete in the percentages of 0.1 to 3.0% by weight of cement in the increment of 0.5 %. The different cube specimens as per requirements of tests were casted as per code of practices. These specimens were tested after 28 days of curing. Six specimens for 0.3% and three specimens for other volume fractions were cast and tested, the average values of compressive strengths are reported in histogram.

Table 4.2.1: The concrete mix proportions

Grade of concrete	Cement	Fine aggregates	Coarse aggregates (10 mm)	Coarse aggregates (20 mm)	Water
M20	347 Kg	557 Kg	535.7 Kg	803.4.7Kg	180.3 Liter
M30	376 Kg	535 Kg	534 Kg	801 Kg	180.3 Liter

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2) *Properties of Concrete:* The workability of green concrete and compaction factor test for each percentage of plastic fibers shown was determined with the help of slump cone test as in Fig. 3.1 and Fig. 3.2. These tests were carried out at every batch of the concrete and average value is reported.
3) *Specimen Dimensions and Different Tests:* The cubical specimens of size 150 mm x150 mm x 150 mm were casted with different percentages of PET fibers. All the concrete filled molds were compacted on Table vibrator in the laboratory. The specimens were tested under compression testing machine of 2000 KN capacity as per IS 516-195 9[15-16].
4) *Workability and Dry Density:* The following Table 4.2.4 shows the results of Slump and Compaction factor and dry density of reference concrete for M20 and M30 grades. The Figures 2 and 3 shows the behavior of fresh PFRC in slump and compaction factor test results and Figure 4 shows the dry density of PFRC at different volume fractions. The workability of green concrete founds decreases as fiber content increases in both tests and, it was due presence of fibers. It was observed that workability decreases for higher aspect ratio for both M20 and M30 grades. The dry density was also found decreases on increasing plastic fiber content in concrete.

Table 4.2.4: Slump, Compaction factor and dry density of reference concrete (0 %)

Grade of concrete	Slump (mm)	Compaction Factor	Dry Density (KN/cum)
M20	83	0.9129	25.1676
M30	67	0.8768	25.38109

Figure 1: Slump test

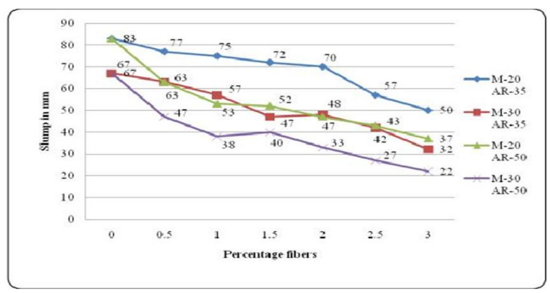

Figure 2: Slump of PFRC

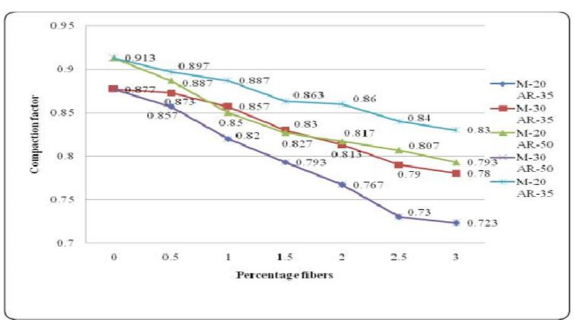

Figure 3: Compaction factor of PFRC

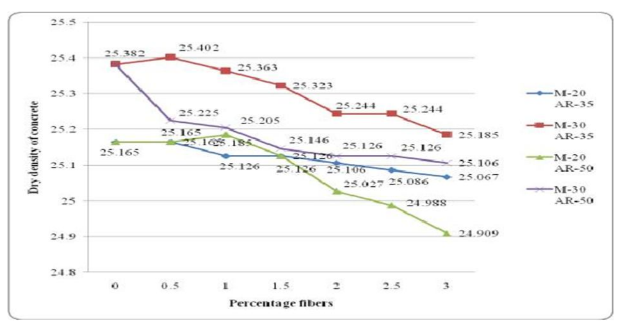

Figure 4: Dry density of PFR

V. COMPRESSIVE STRENGTH

A. *Compression Test Values of FRC*

The compressive strength test is the most appropriate test to evaluate the strength of the normal concrete on addition of PET fibers to the concrete by weight. The compressive strength of normal as well PET fibers concrete composition has been determined at 7 days curing. The standard cube specimen of size 150 mm x150 mm x 150 mm for normal concrete as well as concrete with PET fiber was cast. Once the casting was done and after curing the concrete at 7, 14 and 28 days, the ultimate compressive strength for the average loads of the specimens was obtained as highlighted in the above tables.

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Table 5.1 Average compressive strength for M20 PFRC at 7, 14 and 28 day

S.N.	Volume fraction PET	Compressive strength at 7 days (N/mm^2)	Compressive strength at 14 days (N/mm^2)	Compressive strength at 28 days (N/mm^2)
1	0%	20.46	28.36	32.96
2	2%	22.74	34.52	35.02
3	3%	24.77	36.22	37.74
4	4%	22.58	32.47	33.55
5	5%	23.79	31.68	33.83.

Table 5.2 Average compressive strength for M30 PFRC at 7, 14 and 28 days

S.N.	Volume fraction PET	Compressive strength at 7 days (N/mm^2)	Compressive strength at 14 days (N/mm^2)	Compressive strength at 28 days (N/mm^2)
1	0%	28.85	39.74	42.97
2	2%	30.87	40.82	43.58
3	3%	32.12	43.74	44.98
4	4%	31.41	39.23	43.57
5	5%	29.74	34.34	43.79

VI. RESULTS AND DISCUSSION

In this experimental work detail of the results, trends of various experimental analyses and their effect on the compressive strength with the incorporation of polyethylene terephthalate (PET) fibers in comparison to the conventional concrete were ascertained. The experimental test analysis established that there was reasonable variation in the compressive strength by the addition of PET fibers.

VII. SCOPE FOR FUTURE STUDY

This paper primarily reviews the various effects of addition of fibers in concrete with regard to compression, durability, flexure,, permeability, fresh concrete properties and toughness. Apart from checking the strength variation comparison between the percentages of fiber with respect to the concrete volume is presented. And hence the optimum amount of percentage of fibers with respect to maximizing strength, durability and utility are to be noted. In future, FRC design fundamentals for waste, macro and crimped fibers can be established for both metal and plastic fibers. This has a great future and can give us economical, sustainable and durable concrete for construction work.

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VIII. CONCLUSION

Following are some of the conclusions which can be shown from the research milestones while considering the various grades of concrete and incorporating required amount of pet fibers:

When the different percentages of PET fiber concrete were compared with the conventional concrete in terms of compressive strength of M20 grade for 7, 14 and 28 days, and it was observed that the compressive strength of the concrete initially increased by adding PET fibers from 2% to 4% and then showed a considerable descending trend with the addition of 5% to 6%, .PET fibers. The optimum compressive strength of the concrete was achieved with the addition of 3% PET fibers.

The data trends of different percentages of PET fiber concrete were compared with the conventional concrete in terms of compressive strength of M30 grade for 7, 14 and 28 days, and it was observed that the compressive strength of the concrete initially followed an ascending trend by adding PET fibers from 2% to 4% and then showed a considerable descending trend with the addition of 5% to 6%.PET fibers. The optimum compressive strength of the concrete was achieved with the addition of 3% PET fibers.

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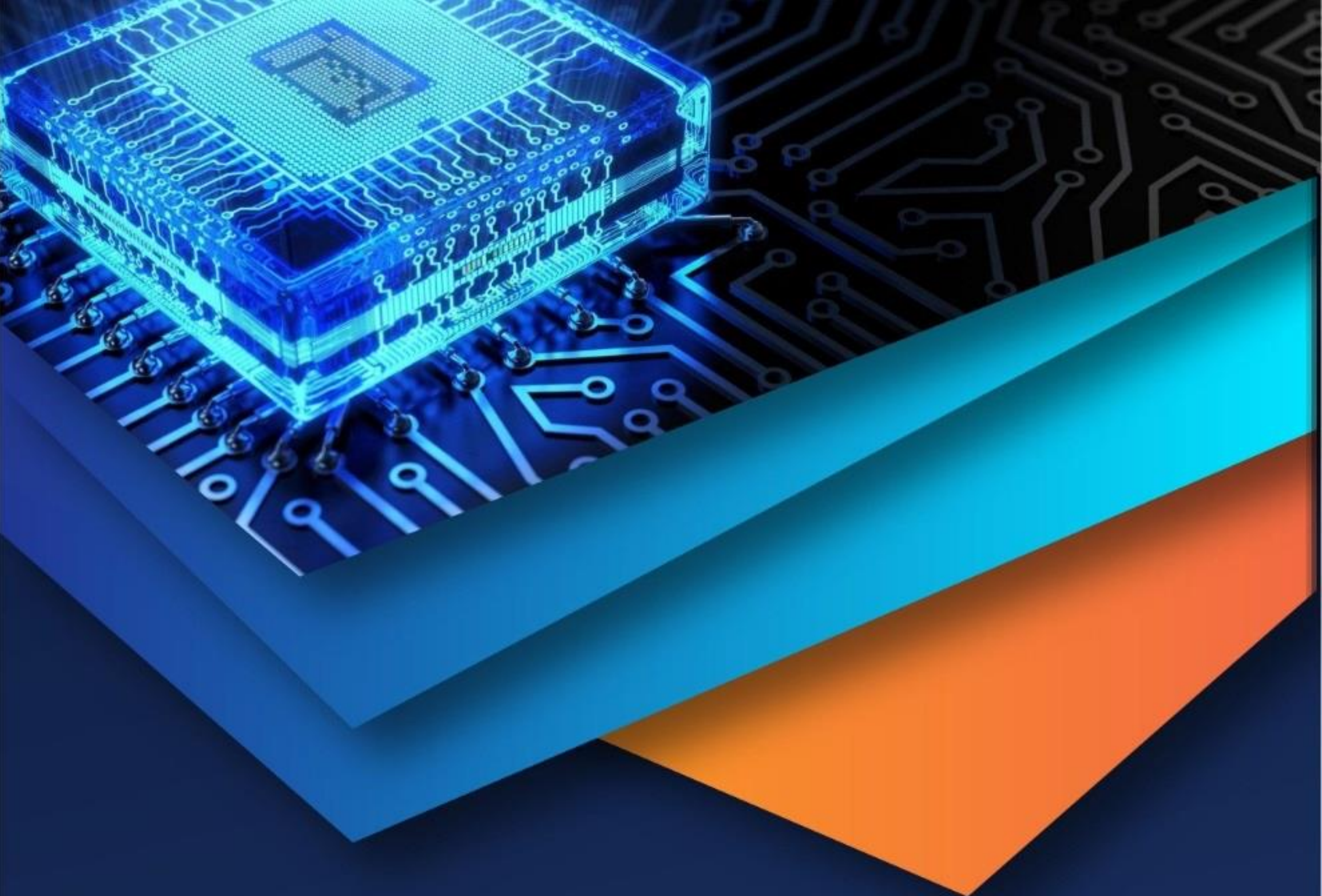

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