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Experimental Study on Fiber Reinforced Concrete by Using Carbon Fiber in Different Aspect Ratios

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Abstract: ***This experimental study investigates the effects of varying aspect ratios of carbon fiber on the performance of fiber reinforced concrete. The research aims to determine how different aspect ratios influence the mechanical properties, such as compressive strength, splitting tensile strength, and flexural strength of the composite material. The study involves preparing concrete specimens with varying proportions of carbon fibers, ranging from short to long aspect ratios and deals with experimental investigations carried out on M20 grade of concrete reinforced with carbon fiber dosages of 5 cm in length & 1 cm in width, 2.5 cm in length & 0.5 cm in width by volume of concrete. Due to its improved mechanical characteristics and increased durability, fiber reinforced concrete (FRC) has attracted a lot of attention in the building industry. Carbon fiber stands out among the numerous kinds of reinforcing fibers for its remarkable strength-to-weight ratio and resistance to corrosion. This experiment looks at how adding carbon fibers to concrete at different ratios affects the strength and durability of the structure. Fibers are used to improve the properties of concrete. The fibers were added at the volumes. Adding carbon fiber to the concrete changes in the mechanical properties of concrete. Hence, we expect the Compressive strength of CFRC increases with increasing fiber content up to a certain percentage, after which increasing fiber content becomes unbeneficial.***

Keywords: Fiber Reinforced Concrete (FRC), Carbon Fiber, Compressive strength, Split tensile strength, Flexural strength, Aspect Ratios

I. INTRODUCTION

Fiber-reinforced concrete (FRC) has gained significant attention in recent years due to its potential to enhance the mechanical properties and durability of conventional concrete. Carbon fibers, known for their high strength-to-weight ratio and excellent mechanical properties, have emerged as a promising reinforcement material for concrete structures. In this experimental study, the focus is on investigating the effect of different aspect ratios of carbon fibers on the performance of M20 grade concrete. By varying the aspect ratios of the carbon fibers, ranging from short to long lengths, the study aims to analyze their influence on the key properties of fiber-reinforced concrete, such as compressive strength, flexural strength, and durability. The experimental investigation involves casing and testing of concrete specimens containing varying proportions of carbon fibers, followed by comprehensive analysis and comparison of results. The findings of this study are expected to contribute valuable insights into the effectiveness of carbon fiber reinforcement in enhancing the performance of M20 grade concrete. By elucidating the role of carbon fibers in FRC and their impact on M20 concrete properties, this study aims to advance the knowledge base in structural engineering and facilitate the adoption of innovative materials and techniques for sustainable and resilient infrastructure development.

II. LITERATURE REVIEWS

A. S. Muthukumaran.et,al (2017)

The Carbon fiber is composed mostly of carbon atoms a widely solution for repairing and strengthening in the field of innovative construction world. They are thin, strong and flexible. It has high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion and Possessing strength up to five times that of steel and being one-third its weight. In this project the carbon fiber is used to strengthen the concrete. The mix design was done for M25 grade concrete. The strengthening of the concrete using CF in the strengthening system provides an economical and versatile solution for extending the service life of concrete structures.

B. Koothan Baskar, et.al (2018)

The performance of conventional concrete is enhanced by the addition of fibers in concrete. Consequently the brittleness in concrete is reduced, and its acceptable ductility is also ensured by this addition. In this paper the strength of concrete cubes, cylinders and beams cast using M25 grade concrete and reinforced with steel and polypropylene fibers is presented. Also hybrid fibers with crimped steel and polypropylene were used in a concrete matrix to study improvements in the strength properties of steel, polypropylene and hybrid polypropylene as well as steel (crimped) fibers of various proportion ie, 0.25%, 0.5%, 0.75%, 1% and 0.5%(0.25% of steel and 0.25% of polypropylene), 0.75%(0.5% of steel and 0.25% of polypropylene, 0.25% of steel and 0.5% of polypropylene) and 1% of various combinations of hybrid fibers for 7, 14 and 28 days. The main reason for synthetic fibers in the concrete matrix is to improve the post cracking response of the concrete to improve the energy absorption capacity and ductility as well as to provide crack resistance and control. The introduction of this type of concrete was brought in as a solution to develop concrete with enhanced flexural and tensile strength. In this paper we analysed and present a comparison between conventional concrete and fibre reinforced concrete, leading to a crackfree structure.

C. Navya H A,et,al (2018)

This paper deals with experimental investigations carried out on M25 grade of concrete reinforced with carbon fiber dosages of 0%, 0.75%, 1.00% and 1.25% by weight of concrete. The strength and durability characteristics are studied. The mechanical properties studied are compressive, split tensile and flexural strengths. The test specimens were also subjected to acid and sulphate attacks and tested for their durability. The results show that there is an increase in compressive, split tensile and flexural strengths of carbon fiber reinforced concrete. Inclusion of 1% carbon fibers showed the maximum enhancement in strength and it can be considered as optimum dosage. When compared to conventional concrete, the crack width also reduced in carbon fiber reinforced concrete.

III. MATERIALS AND ITS PROPERTIES

A. Materials Used

1) Cement (As per IS: 8812 – 1989)
2) Course aggregate (As per IS: 383 – 1970)
3) Fine aggregate (As per IS: 383 – 2016)
4) Water
5) Conplast WL Xtra
6) Carbon fiber

B. Properties

1) Carbon Fiber

Carbon fibers are relatively lightweight, and their incorporation in concrete does not significantly increase the overall weight of structures. This is beneficial for applications where weight constraints are a concern, such as in the construction of lightweight bridge decks. Carbon fibers provide tensile strength to concrete, significantly increasing its ability to withstand tensile and flexural loads. This is especially valuable in structures where cracking and flexural strength are critical, such as bridge decks and pavements. The use of carbon fibers helps control and limit the development of cracks in concrete. By bridging micro cracks that may form in the material, carbon fibers prevent them from becoming larger and compromising the integrity of the structure. Carbon fibers enhance the durability of concrete by improving its resistance to various forms of deterioration, including freeze-thaw cycles, chemical attack, and corrosion. This is particularly important for structures exposed to harsh environmental conditions. Carbon fiber-reinforced concrete can exhibit increased ductility, which means it can deform and absorb energy before failure. This property is essential in earthquake- prone areas, as it helps structures withstand seismic forces. Carbon fibers enhance the toughness of concrete, making it more resistant to impact and sudden loading, which is important for structures that may experience dynamic forces.

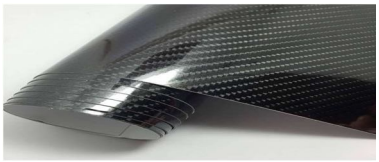


Fig 1: Carbon fiber sheet

2) Mix Design

According to the code book IS 12062:2019 mix proportions for M20 grade and the quantities for $1m^3$ of concrete as follows:

Table 1: Mix design

Grade	Cement	F.A	C.A	Water
Mix M20	403.2	705.6	1281	240
	1.0	1.5	3.0	0.48

Initially, the carbon fiber were to be added to concrete. Subsequently, normal concrete was used for concrete mix. For this project, 3 mixes were done which consist of 1 control mix without carbon fibers and the remaining are concrete mixes that contain different aspect ratios 1 is of 5cm in length and 1cm in width, and the other one is of 2.5cm in length and 0.5cm in width. For each mix, 3 cubes, 3 beams, 3 concrete cylinders were produced as samples for testing.

IV. METHODOLOGY

A. Compression Strength Test

Procedure: Mix concrete ingredients with different aspect ratios of carbon fiber (5cm in length &1cm in width) and (2.5cm in length & 0.5cm in width). Pour the mixture into cube moulds and let them set. Keep the cubes in a moist environment for at least 7 days after curing, test the cubes in a digital compression machine, applying force until a crack appears. Repeat the process for other specimens. Note the maximum force applied to each cube and analyze the compressive strength results obtained for each percentage of carbon fiber reinforcement. Compare the strengths of the different mixes to evaluate the effect of carbon fibers on the compressive strength of concrete. By following this experimental procedure, the compressive strength of concrete cubes reinforced with varying aspect ratios of carbon fibers and assess the impact of Fiber reinforcement on the mechanical properties of the concrete.

Fig 2: Cube under Compression Test

B. Split Tensile Strength Test

Procedure: Make cylindrical concrete samples with addition of carbon fiber of 5cm in length, 1cm in width and 2.5cm in length, 0.5cm in width by total volume of concrete. Keep the cylinders for curing, after curing place the sample in the compression testing machine. Slowly apply the load on the sample until it cracks. Note the the highest loads applied and calculate the split tensile strength. Record the split tensile strength values for each concrete cylinder reinforced with different aspect ratios of carbon fibers. Analyze the data to determine any trends or effects of fiber reinforcement on the split tensile strength of concrete. Repeat the process with other specimens and see how the strength varies with different varying aspect ratios of carbon fiber. This will give the difference of strength with compared to normal concrete and with carbon fiber added concrete.

Fig 3: Cylinder under split tensile test

C. Flexural Strength Test

Procedure: Mix concrete ingredients with different aspect ratios of carbon fiber (5cm in length &1cm in width) and (2.5cm in length & 0.5cm in width). After making the moulds keep them for curing. After curing put the beams in the flexural strength testing machine apply the load gradually until the beam breaks. Note the maximum load applied to the beams to break, now repeat the same process for different specimens. Analyze the results to determine the effect of carbon fiber content on the flexural strength of the concrete beams. By following this procedure, flexural strength tests on beams reinforced with different aspect ratios of carbon fiber and evaluate their performance in terms of flexural strength and ductility.

Fig 4: Beam under flexural strength testing machine

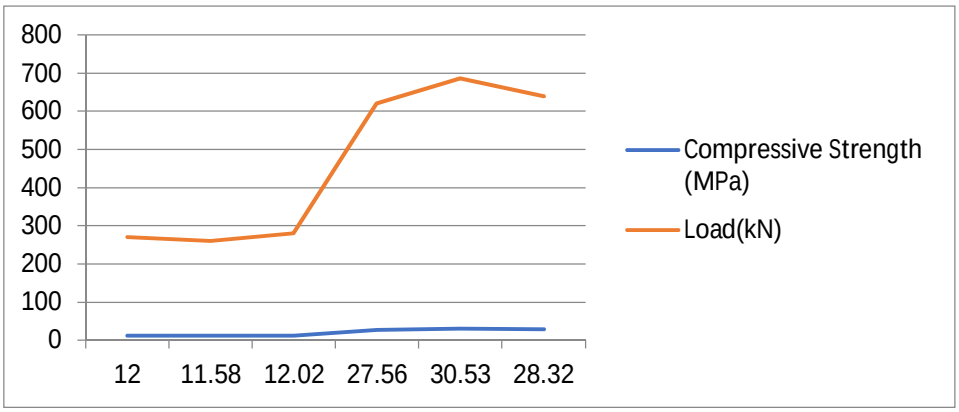
V. RESULTS AND DISCUSSIONS

A. Compression Strength Test

Aspect ratio- 2.5cm length, 0.5cm width

Table 1: Compressive strength results

S.No	Days	Compressive Strength (N/mm^2)	Load(kN)	Average strength (N/mm^2)
1	7	12.00	270.1	11.86
2		11.58	260.6	
3		12.02	280.0	
4	28	27.56	620.1	28.80
5		30.53	687.0	
6		28.32	640.2	



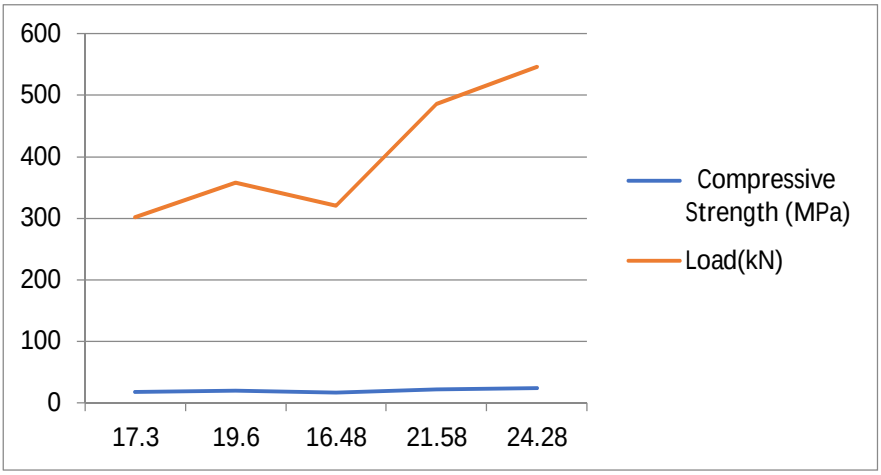
Graph 1: Comparison of compressive strength test

From the above graph, it shows that the strength values is on the X-axis and the load (kN) is on Y-axis. This graph shows the comparison of the values between 7 days and 28 days when the aspect ratio of 2.5cm in length and 0.5cm in width is added. As the load increases, the compressive strength also increases.

Aspect Ratio – 5cm length, 1cm width

Table 2: Compressive strength results

S.No	Days	Compressive Strength (N/mm^2)	Load(kN)	Average strength (N/mm^2)
1	7	17.3	302.1	17.79
2		19.6	357.8	
3		16.48	320.7	
4	28	21.58	485.6	21.96
5		24.28	546.3	
6		20.03	500.2	



Graph 2: Comparison of compressive strength test

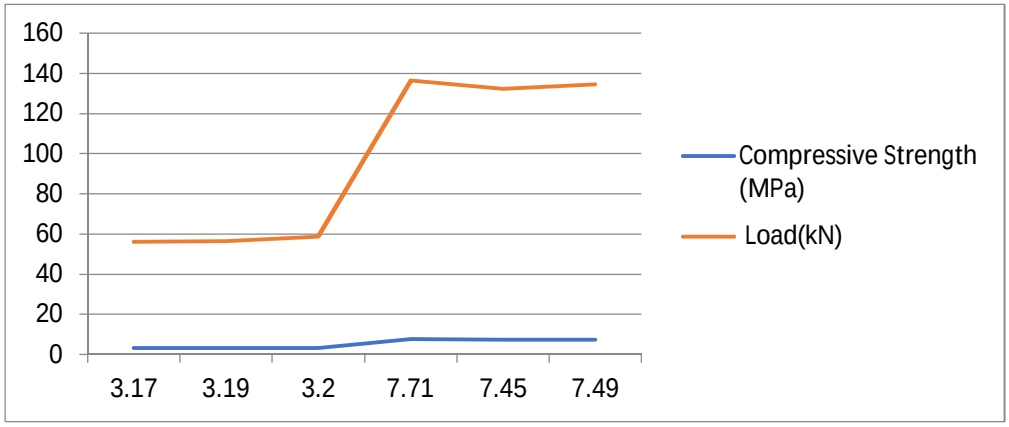
From the above graph, it shows that the strength values is on the X-axis and the load (kN) is on Y-axis. This graph shows the comparison of the values between 7 days and 28 days when the aspect ratio of 5cm in length and 1cm in width is added. As the load increases, the compressive strength also increases.

B. Split Tensile Strength Test

Aspect ratio - 2.5cm length, 0.5cm width

Table 3: Split tensile strength results

S.No	Days	Compressive Strength (N/mm^2)	Load(kN)	Average strength (N/mm^2)
1	7	3.17	56.1	3.18
2		3.19	56.5	
3		3.20	58.8	
4	28	7.71	136.4	7.55
5		7.45	132.3	
6		7.49	134.5	



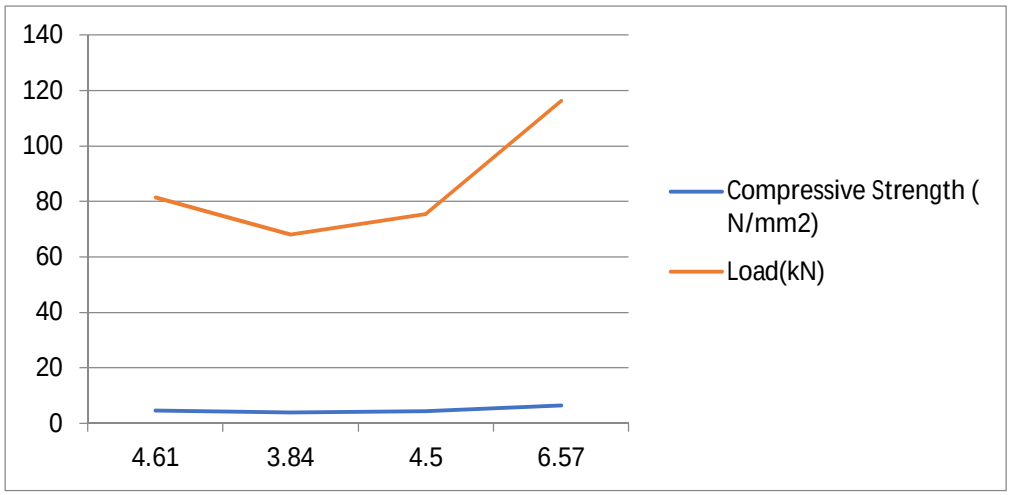
Graph 3: split tensile strength test

From the above graph, it shows that the Split tensile test, the strength values is on the X-axis and the load (kN) is on Y-axis. This graph shows the comparison of the values between 7 days and 28 days when the aspect ratio of 2.5cm in length and 0.5cm in width is added. As the load increases, the compressive strength also increases.

Aspect Ratio – 5cm length, 1cm width

Table 4: Split tensile strength results

S.No	Days	Compressive Strength (N/mm^2)	Load(kN)	Average strength (N/mm^2)
1	7	4.61	81.5	4.31
2		3.84	68.0	
3		4.50	75.5	
4	28	6.57	116.2	6.41
5		6.26	110.7	
6		6.40	115.3	



Graph 4: split tensile strength test

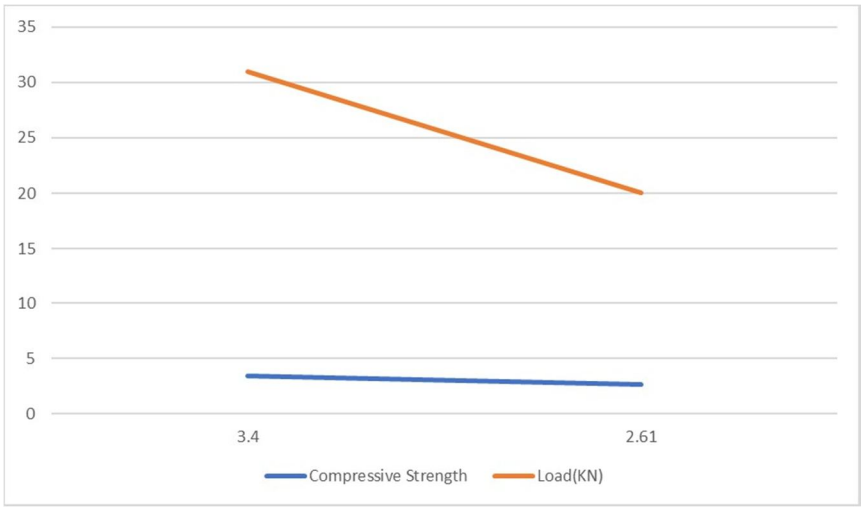
From the above graph, it shows that the Split tensile test, the strength values is on the X-axis and the load (kN) is on Y-axis. This graph shows the comparison of the values between 7 days and 28 days when the aspect ratio of 5cm in length and 1cm in width is added. As the load increases, the compressive strength also increases.

C. Flexural Strength Test

Aspect ratio - 2.5cm length, 0.5cm width

Table 5: Flexural strength results

S.No	Days	Compressive Strength (N/mm^2)	Load(kN)	Average strength (N/mm^2)
1	28	3.40	31	2.00
2		2.61	20	



Graph 5: Flexural Strength test

From the above graph, it shows that the Flexural strength test, the strength values is on the X-axis and the load (kN) is on Y-axis. This graph shows the comparison of the values between 28 days when the aspect ratio of 5cm in length and 1cm in width is added. As the strength increases, the load also increases.

VI. CONCLUSION

The experimental study on fiber-reinforced concrete (FRC) by utilizing carbon fiber in various aspect ratios has yielded valuable insights into enhancing the mechanical properties and performance of concrete structures. Carbon fiber reinforced concrete having aspect ratio of 5cm length, 1cm width has a maximum strength when compared to 2.5cm length, 0.5 width. According to our project, if the aspect ratio of carbon fiber increases then the compressive strength, split tensile strength, and flexural strength increases.

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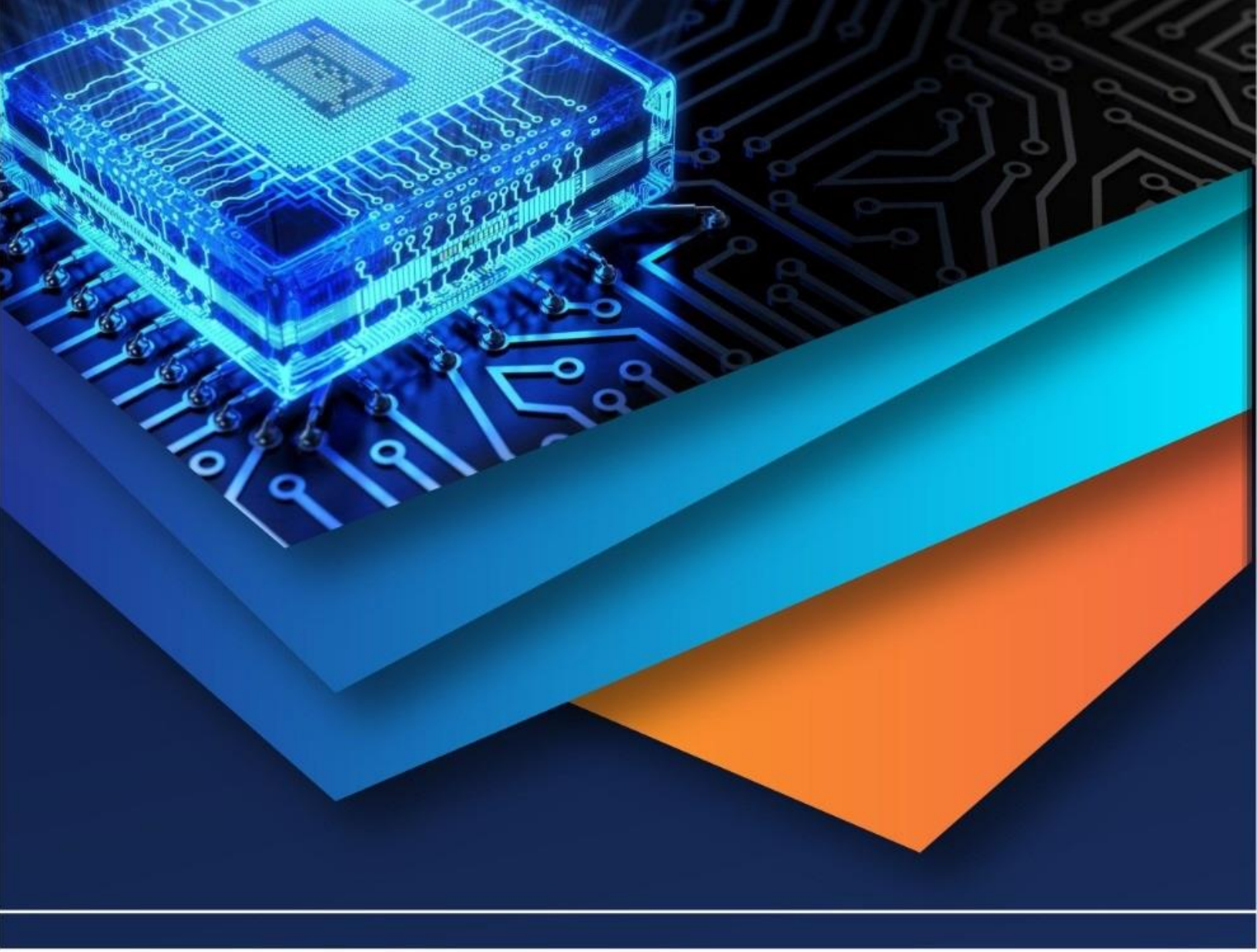

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