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Mechanical Properties of Self Compacting Concrete with Artificial and Natural Fibers

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Abstract: This paper describes the comparative experimental data on the mechanical properties of Steel and Basalt fibre reinforced self compacting concrete under compression strength, split tensile strength and flexural strength. With Steel and Basalt fibre concrete mix M_{25} have been used to cube, cylinder and prism specimens for compressive strength test, flexural strength test and split tensile strength test. The total dosage of fibre are maintained at 1%, 1.2%,1.4% by the volume of fine aggregate. The experimental data demonstrated Steel and Basalt fibre reinforced concrete to be stronger in compression, tensile and flexure in early stages. This paper also present the increase in compressive strength of fibre reinforced concrete by addition of admixture (superplasticizer Master Glenium sky 8587). Specimens were made by the addition of fibres to compare the changes in compressive strength of nominal concrete. Results showed that the hybrid fibre reinforced concrete shows significant enhancement in mechanical properties of Self Compacting Concrete.

Keywords: Steel fibre, Basalt fibre, fibre reinforced concrete, Master Glenium Sky 8587, compressive strength, flexural strength, split tensile strength.

I. INTRODUCTION

Concrete made from Portland cement, is relatively strong in compression but weak in tension and tends to be brittle. The weakness in tension can be overcome by the use of conventional steel bars reinforcement and to some extent by the mixing of a sufficient volume of certain fibers. The use of fibers also recalibrates the behavior of the fiber-matrix composite after it has cracked through improving its toughness.

The plain concrete fails suddenly when the deflection corresponding to the ultimate flexural strength is exceeded, on the other hand fibre reinforced concrete continue to sustain considerable loads even at the deflection considerably in excess of the fracture deflection of the plain concrete. Fibre reinforced concrete has become viable new material used in various construction such buildings, pavements, large industrial floors and runways.

The first use of fibres in reinforced concrete has been dated to 1870's. Since then, researchers around the world have been interested in improving the tensile properties of concrete by adding iron and other wastes. Local interest has been demonstrated through research work performed. In addition to industrial fibers, natural organic and mineral fiberes have been also investigated in reinforced concrete. It must be well noted however that the benefits of adding fibres to concrete in construction, which principally to improve on the residual load-bearing capacity, is influenced by the content, orientation and type of fibres in use.

The world has witnessed rapid increase in the use of fibre reinforced polymer (FRP) materials as a substitute for conventional steel bars in some concrete structures, due to the numerous benefit: high strength, improved toughness, resistance to post crack propagation and light weight amongst others.

Hybrid fibre reinforced concrete is the use of two or more type of fibers in a suitable combination may potentially improve overall properties of concrete and also result in performance of concrete. Hybrid fibre reinforcement can be very efficient for improving the tensile response of the composite.

In such materials, fibres of different geometries can act as bridging mechanism over cracks widths. Recently, many researchers have an orientation to discuss the mechanical properties of the hybrid fibres-reinforced concrete, such as a proper proportion between carbon fibers and polypropylene fibres, glass fibres and polypropylene fibres, or carbon fibres glass fibres to concrete. The addition of steel fibres significantly improves many of the engineering properties of mortar and concrete, notably impact strength and toughness. As a result from previous study this ventures focusing the combination of **basalt** and **steel fibres**. The total dosage of fibres was maintained at 1%, 1.2%, 1.4% by volume of fine aggregate. The M25 grade of concrete was designed by using codal provision IS 10262-2019.

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Table 1: Volume fraction used

SI.no	COMBINATION	VOLUME FRACTION	
1	Hybrid fibre 1	1%	Half of basalt fibre
			Half of steel fibre
2	Hybrid fibre 2	1.2%	Half of basalt fibre
			Half of steel fibre
3	Hybrid fibre 3	1.4%	Half of basalt fibre
			Half of steel fibre

II. MATERIALS AND METHODOLOGY

A. *Materials Used*

1) *Cement:* Portland pozzolana cement of super grade available in local market is used in this investigation. The cement used has been tested for various proportions as per as 1489-1991 with specific gravity of 2.9.
2) *Fine Aggregate:* The purpose of fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent. River sand used conforming to zone 1.Specific gravity of river sand is 2.6 .
3) *Coarse Aggregate:* Crushed granite stones from the local quarry of size 12.5mm conforming to IS 383-1970 was used as coarse aggregate. The specific gravity of 12.5mm coarse aggregate were 2.6 with water absorption of 0.5%.
4) *Water:* The water used in the concrete mix was portable water from the water supply network system; so it should be of good quality and should be free from organic materials, which might have affected the properties of the fresh and hardened concrete. The chlorine content in the water must not be high.
5) *Admixture:* The modified poly carboxylated ether based super plasticizer(Master Glenium Sky 8587) which is reddish brown colour and free flowing liquid and having relative density 1.08 ±0.02 and pH value as ≥6 and chloride ion content < 0.2 % was used as super plasticizer.
6) *Steel Fibre:* Cold drawn crimped steel fiber is manufactured by quality base steel bar, which has excellent mechanical properties including high tensile strength. Hence, the average tensile strength of the reinforced fibre surpasses owing to high strength and uniform distribution of fibres, stresses can be fully dispersed and cracking propagation be effectively controlled.

Table 2: Properties of steel fiber.

SI.NO	DESCRIPTION	RESULT
1	Length	6 mm
2	Diameter	0.015 mm
3	Aspect Ratio	400
4	Tensile Strength	3000 Mpa
5	Density	2.67 g/cm^3

Fig 1: Steel fiber

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7) *Basalt Fiber:* Basalt rock is volcanic rock and can be divided into small particles then formed into continuous or chopped. Basalt fiber has higher working temperature and has good resistance to chemical attack, impact load and fire with less poisonous fumes. The benefits of using basalt fiber are other FRP materials is that they are non corrosive which is a good choice for reinforcing concrete structures exposed to d-icing salts, for example in bridge decks and parking garage elements. Also for concrete exposed to marine environment, such as seawalls, water breaks and buildings are other structures located near water front.

Fig 2: Basalt fiber

Table 4: Properties of basalt fiber.

SI.NO	DESCRIPTION	RESULT
1	Length	30 mm
2	Diameter	0.5mm
3	Aspect Ratio	60
4	Tensile Strength	940 Mpa
5	Density	7850 Kg/m^3

B. Mix Proportion

The control specimens were made to achieve the target mean strength of 25 MPa in 28 days curing. The detailed mixture proportions for the study are presented in table 4, while the volume fractions of various fibers used in mixtures are given in table 1.

Table 4: Detail Mix Proportions.

CEMENT	F.A	C.A
500kg/m^3	652kg/m^3	822kg/m^3
1	1.25	1.64

C. Casting

In the production of the constituent materials were initially mixed without fibers. The fibers were then added in small amounts to avoid fibers balling and to produce the concrete with uniform material consistency and good workability. The fine aggregate, coarse aggregate and binder was added in pan and make a proper mix. The super plasticizer was then mixed thoroughly with the mixing water and added to the mixer. Fibers were dispersed by hand in the mixture to achieve a uniform distribution throughout the concrete, which was mixed further.

III. MECHANICAL PROPERTIES

A. *Fresh Concrete Test*

1) *Flow Table Test:* The flow table test is performed to determine the filling ability of self compacting concrete. It is used to access the horizontal free flow in the absence of obstructions. As per EFNARC standards the spread dia of flow of SCC should in the range of 600mm-800mm.

Fig 3: Flow Table Test

2) *J Ring Test:* The J ring test is performed to determine the passing ability of self compacting concrete. It indicates the blocking effect of SCC with reinforcement bars. As per EFNARC standards the diameter of flow of SCC should be in the range of 0mm-10mm.

Spread diameter $B_j = \frac{\Delta Hx_1 + \Delta Hx_2 + \Delta Hy_1 + \Delta Hy_2}{4} - \Delta H_0$

Fig 4: J Ring Test

3) *V Funnel Test:* The V funnel test is performed to determine the filling ability and viscosity of the self compacting concrete. The maximum size of aggregate is 20mm. As per EFNARC standards the time of flow of SCC should be in the range of 10secs-15secs.

Fig 5: V Funnel Test

B. Hardened Concrete Test

1) *Compressive Strength Test:* For compressive strength test, cube specimens of dimensions 150 x 150 x 150 mm were casted for M25 grade of concrete. The moulds were filled with nominal SCC and fiber reinforced SCC. After 24 hours the specimen were demoulded and were transferred to curing tank wherein they were allowed to cure for 28 days. These specimens were tested in compression testing machine.

Compressive strength = Load /Area (MPa)

Fig 6: Testing of cubes

2) *Tensile Strength Test:* For tensile strength test, cylinder specimens of dimension150mm diameter and 300mm diameter length were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank wherein they were allowed to cure for 28 days. For the nominal SCC and fiber reinforced SCC.

Split tensile strength = $\frac{2\ P}{\pi L D}$

Fig 7: Testing of cylinder

3) *Flexural Test:* For flexural strength test, prism specimens of dimensions 700 x 150 x 150 mm were casted. The specimens were demoulded after 24 hours of casting and were transferred to curing tank were they were allowed to cure for 28 days. For nominal SCC and fiber reinforced SCC.

If a>13.3 cm then,

Modulus of rupture $f_b = \frac{P\ x\ l}{b\ x\ d^2}$

If a < 13.3cm, $f_b = \frac{3P\ x\ a}{b\ x\ d^2}$

Fig 8: Testing of prism

IV. RESULTS AND DISCUSSION

A. Fresh Concrete

For the various mix proportions the concrete was tested in flow table, j ring, v funnel. The workability of SCC while adding fibers that can improve in average ratio but by adding fibers not may not give a great variation than the fiber reinforced SCC was resulted below,

Table 2: Flow table test

SI.no	Fiber combination	Slump flow value (diameter)mm
1	Nominal	610
2	Hybrid fiber 1	590
3	Hybrid fiber 2	585
4	Hybrid fiber 3	560

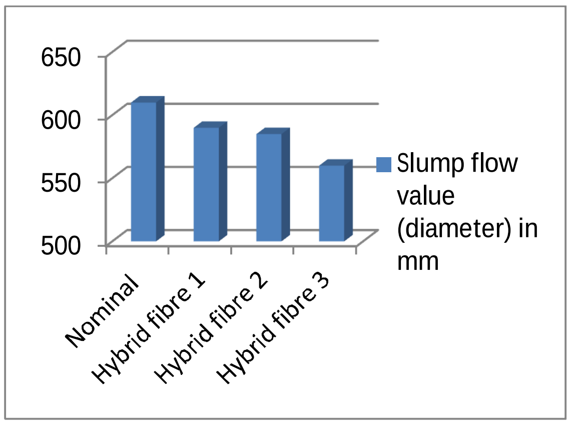

Fig 9: Graph for flow table test.

Table 3: J Ring Test.

SI.no	Fiber combination	Spread diameter (mm)
1	Nominal	2.75
2	Hybrid fiber 1	3.125
3	Hybrid fiber 2	3.5
4	Hybrid fiber 3	4

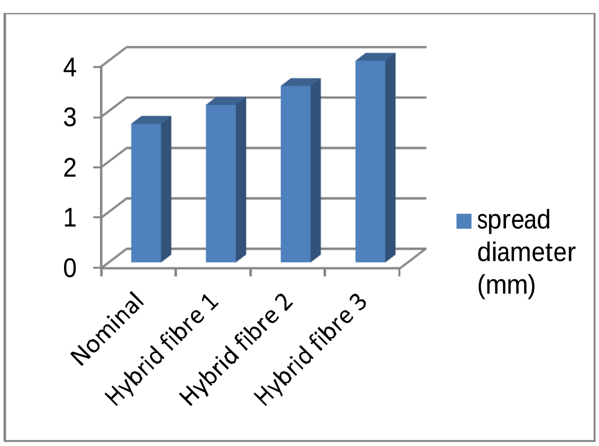

Fig 10: Graph for J Ring test

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Table 4: V Funnel Test

SI.no	Fiber combination	Flow Time in secs
1	Nominal	11
2	Hybrid fiber 1	13
3	Hybrid fiber 2	14.5
4	Hybrid fiber 3	14.9

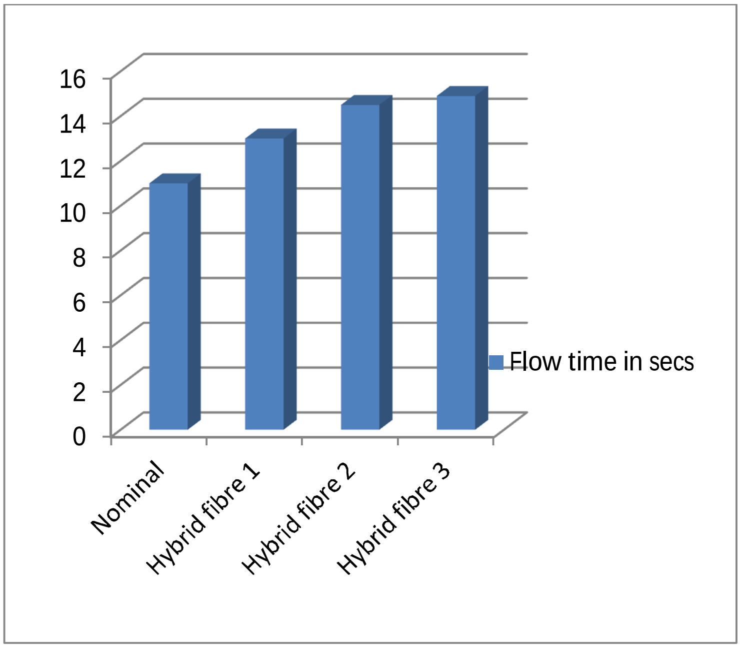

Fig 11: Graph for V Funnel test

B. *Hardened Concrete Test*

Table 5: Hardened concrete test for nominal mix.

Specimens	Curing days	samples	Compressive strength(N/mm^2)	Split tensile strength(N/mm^2)	Flexural strength(kg/cm^2)
Nominal	7	1	17.7	1.84	51.39
		2	18	1.7	50.55
		3	17	1.87	50.97
Nominal	14	1	27.11	2.12	51.98
		2	26	2	52
		3	25.5	1.97	51.67
Nominal	28	1	28.88	2.54	53.88
		2	29	2.32	54
		3	28	2.67	54.33

Table 6: Hardened concrete test for hybrid fiber 1.

Specimens	Curing days	samples	Compressive strength(N/mm^2)	Split tensile strength(N/mm^2)	Flexural strength(kg/ cm^2)
Hybrid fiber 1	7	1	24.88	1.98	51.66
		2	24	2	52
		3	24.2	1.53	51.33
Hybrid fiber 1	14	1	30.22	2.41	52.57
		2	30.5	2.53	52.9
		3	30	2.23	52.76
Hybrid fiber 1	28	1	32.88	2.97	56.51
		2	31.2	3.1	57
		3	32.33	2.83	56.43

Table 7: Hardened concrete test for hybrid fiber 2.

Specimens	Curing days	samples	Compressive strength(N/mm^2)	Split tensile strength(N/mm^2)	Flexural strength(kg $/cm^2$)
Hybrid fiber 2	7	1	25.33	2.12	52.14
		2	26	2.07	52.34
		3	25.71	2.51	52.41
Hybrid fiber 2	14	1	28.44	2.68	53.29
		2	28	2.88	53.11
		3	27.76	2.34	53.55
Hybrid fiber 2	28	1	33.77	3.53	63.22
		2	33	3.48	63.47
		3	32.87	3.79	63.9

Table 8: Hardened concrete test for hybrid fiber 3.

Specimens	Curing days	samples	Compressive strength(N/mm^2)	Split tensile strength(N/mm^2)	Flexural strength(kg/c m^2)
Hybrid fiber 3	7	1	22.22	1.69	46.22
		2	21.3	1.91	46.5
		3	22	1.56	45.9
Hybrid fiber 3	14	1	28	2.12	51.98
		2	28.22	2.11	52
		3	27.51	1.91	51.57
Hybrid fiber 3	28	1	32	2.68	53.38
		2	31.83	2.9	53.07
		3	32.33	2.97	52.97

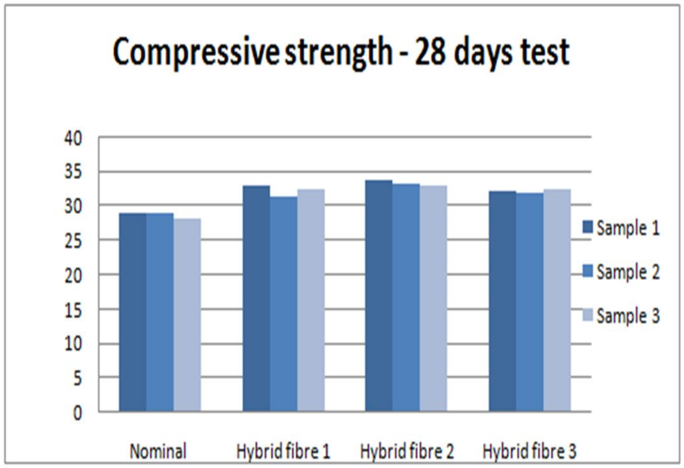

Fig 12: Graph for compressive strength

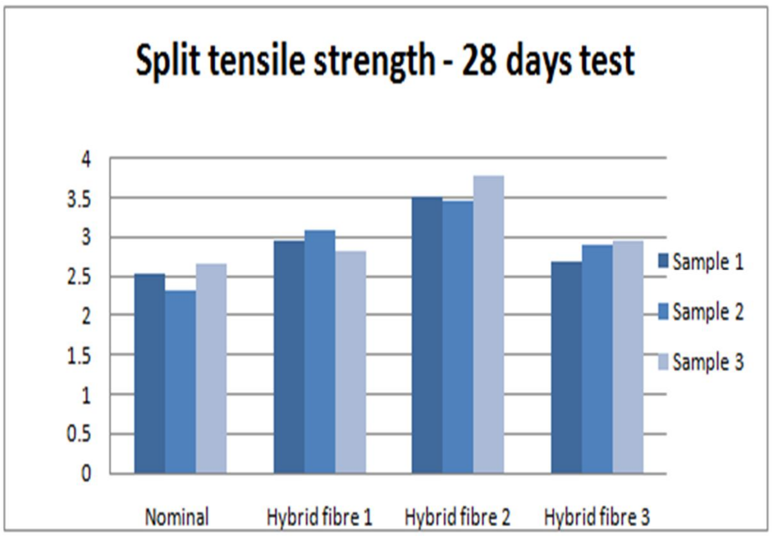

Fig 13: Graph for Split tensile strength

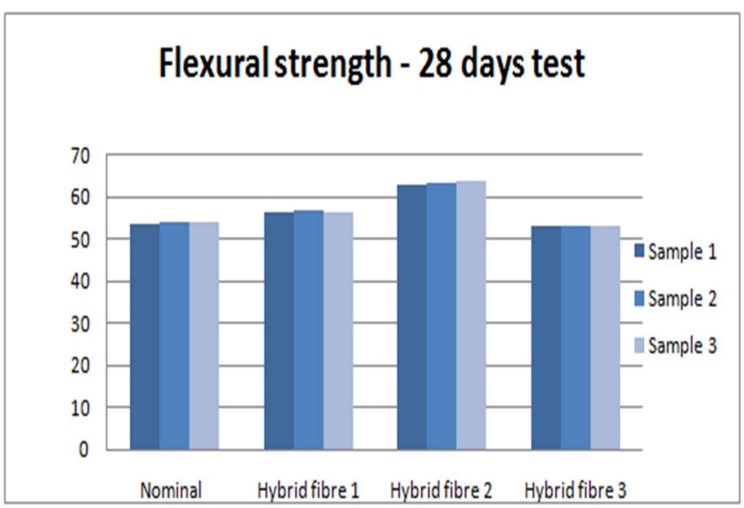

Fig 14: Graph for flexural strength

V. CONCLUSION

The test results showing that at low fiber volume fraction, it is possible to obtain material with enhanced strength and improved toughness from hybrid fibers.

A. The compressive strength of hybrid fiber reinforced SCC was increased 16.92% when compared to control specimens.
B. The tensile strength of hybrid fiber reinforced SCC was increased 38.97% when compared to control specimens.
C. The flexural strength of hybrid fiber reinforced SCC was increased 17.33% when compared to control specimens.

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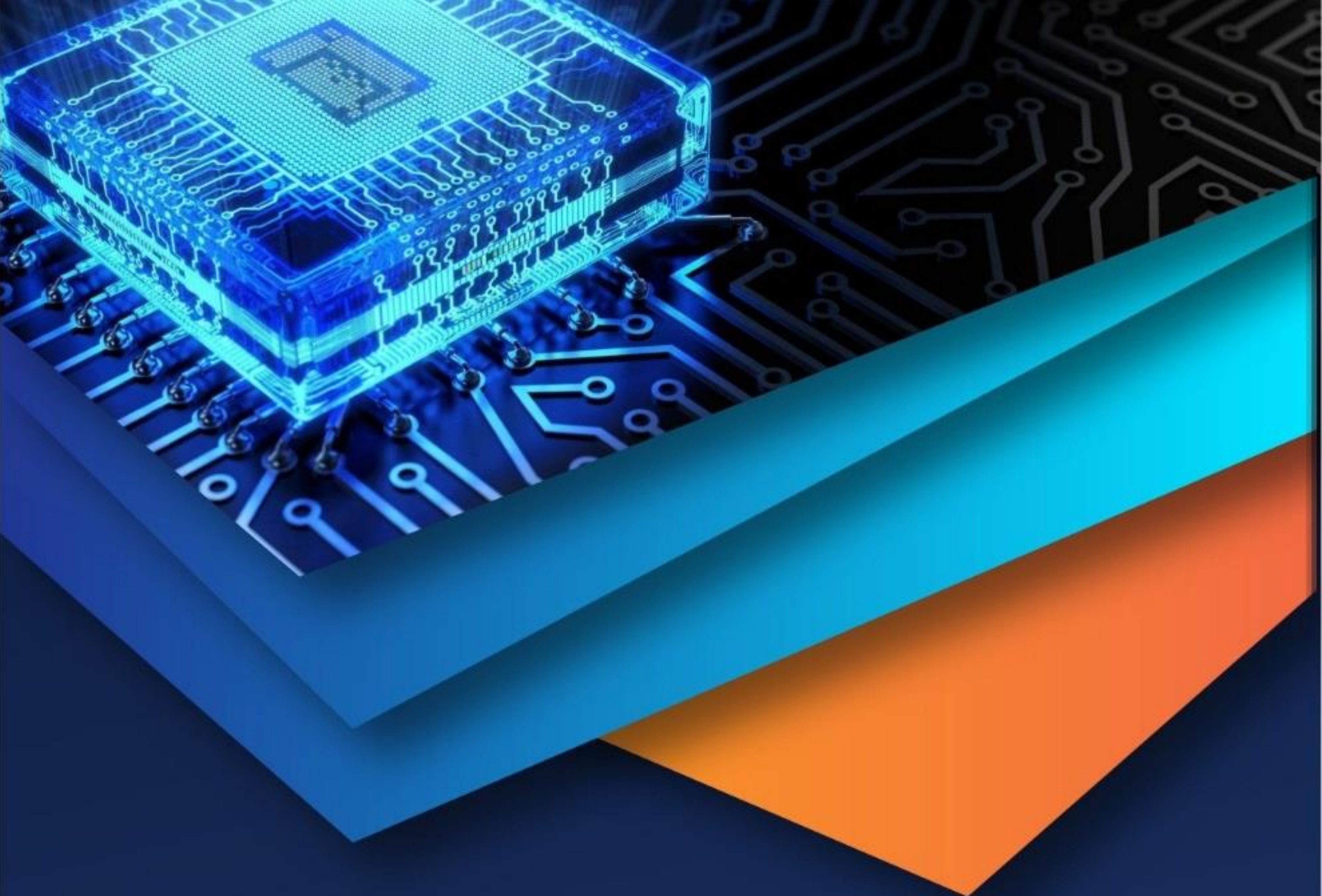

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