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Experimental Study of Partially Replacement of Cement with Fly Ash and Steel Fibre in Concrete

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Abstract: In India, major part of electricity is produced from thermal power plants. These thermal power plants use different types of fuels for combustion. During combustion of coal as a fuel in these thermal power plants, a byproduct namely fly ash is produced. Indian coal has highest ash content as compared to coal found in other countries. There are nearly 85 thermal power plants in India which uses coal as source for power generation and thus produces a large amount of fly ash. This fly ash is disposed in soil, which in turn causes a lot of environmental problems. To overcome this disposal of fly ash into the soil, it can be used in concrete by partially replacing with cement. Because the chemical composition of fly ash and cement is almost identical. The main objective of this thesis is to analyze the behavior of M20 grade concrete with mix design 1:1.48:2.74 and with 0.48 water cement ratio. Here cement was partially replaced by 10%, 20%, and 30% of fly ash of F- class by weight. As concrete shows cracks abruptly when undergoing tension. So to overcome this problem and to enhance the flexural strength of concrete, steel fibers were used. The steel fiber of hook type in percentage of 0.5%, 1%, 1.5% were used to produce M20 grade concrete. Aspect ratio of steel was used as 50. Compression strength test, flexural strength test, split tensile test were performed according to guidelines of Bureau of Indian Standards. The tests were co related with results of normal concrete. Due to addition of steel fiber and fly ash Compressive strength, flexural strength, split tensile strength has increased due to pozzolonic action of fly ash and strong bond formation of steel fiber. The highest value of compressive strength and flexural strength was achieved, when cement was replaced by 10% of fly ash and with addition of 1.5 % of steel fiber. Split tensile strength achieves its highest value at 10% of fly ash and 1 % of steel fiber. Due to addition of fly ash, workability starts increasing. While addition of steel fiber, it starts decreasing. workability achieves its minimum value at 30 % of fly ash and 1.5 % of steel fiber.

I. INTRODUCTION

A. General

The impact of crushed stone aggregates, extraction of the source that are formed in many parts of the country and has created a lot of problems in the environment. It included the loss of forests, noise, and dust blasting, vibration and pollution hazards. In India 70% of electricity is generated from thermal power plants by using coal. From where fly ash is produced as a byproduct. Environmental threats include Air pollution; water pollution and particularly shortage of land for the dumping of that fly ash have taken place by using this coal. In India there is the worst condition for dumping coal. The outcome of Air that comes from coal and lignite that are used in power plants, as the result being light becomes airborne that causes health Problem. The important here is that when it reaches in the atmosphere it cause depletion of Ozone layer. Now to overcome from this problem the best choice is that , this waste material has to be used in other works. In India, there is problem of dumping area for dumping fly ash as majority of electricity is generated from thermal power stations. Full supply generation of fly ash is estimated to be 154 million tonnes in 2001 to 2012. To work on this problem, although fly ash is used as landfills but now fly ash is used as replacement material for cement, also in pavements, base blocks etc. Fly ash can be used in large quantities in embankment fills and in replacement of aggregate. In India the artificial aggregates are not used widely, because of their high cost and easy availability of natural resources. Menakanda in 2008 found that fly ash aggregate produced by normal curing showed comparable result with the concrete produced by normal curing. In the investigation where the properties of fly ash aggregate which are produced by cold bounded technique and that are compared with natural gravels. As the concrete which is made out of these techniques is good idea to replace it with other materials. The effect of using fly ash in industrial buildings are somehow very Representative job as it will have a tremendous change in the universe. Fly ash can be used in different ways, as a partial replacement of cement in construction industry. As fly ash is light, it can be also used as lightweight course aggregate artificially. The method by which artificial aggregate is formed is known as polarization. The composition of fly ash concrete depends upon the different proportions of cement and formation of light weight concrete. It is so much influenced that it is using directly as concrete, in construction industry. The design and construction due to fly ash is very much economic as it reduces the weight of concrete and thus reduces the overall weight of the structure. Because the unit weight of normal concrete is much more than fly ash concrete.

II. MATERIALS & MIX DESIGN

A. Ordinary Portland cement (OPC)

Most of the investigation is being made using ordinary Portland cement. Though all cement conforming to various IS codes are suitable, selection of cement should be based on their compressive strength, fineness and compatibility with other ingredient. Here Khyber OPC 43 grade is used.

The cement used in this experimental work is 43 grades Ordinary Portland Cement. All properties of cement are tested by referring IS 12269 - 1987 Specification for 43 Grade Ordinary Portland cement. The specific gravity of the cement is 3.15. The initial and final setting times were found as 90 minutes and 180 minutes respectively. Standard consistency of cement was 31.25%

1) Chemical Properties of Cement

Table 3.1: Chemical Composition of Cement

Chemical content	Amount (%)
Calcium Oxide (CaO)	60-67
Silicon dioxide (SiO2)	17-25
Aluminium oxide (Al2O3)	3-8
Iron oxide (Fe2O3)	0.5-6
Magnesium oxide (MgO)	0.1-4
Sodium oxide (Na2O)	0.2-1.3
Potassium oxide(K2O)	0.2-1.3
Sulfur Trioxide (SO3)	1.3

B. Aggregates

Aggregates constitute about 70% of total concrete. So the properties of aggregates mainly predominate the properties of concrete. The aggregates are normally divided into two categories, namely fine and coarse aggregates having size of less than 4.75 mm are grouped as fine aggregates, while as aggregates having size of more than 4.75 mm are grouped in coarse aggregates. Fine aggregate normally consists of natural, crushed, or manufactured sand. Coarse aggregates can be made of natural gravel or crushed stone. In the present study the sand confirm to zone II as per Indian standards.

1) *Fine Aggregate:* Locally available sand passed through 4.75mm IS sieve is used. The specific gravity of 2.84 and fineness modulus of 3.895 are used as fine aggregate. The loose and compacted bulk density values of sand are 1094 and 1162 kg/m3 respectively, having water absorption of 1.491%.

Table 3.2: Difference between Physical Properties of Sand & Fly Ash

Properties	Fine Aggregate (Sand)	Fly Ash
Specific gravity	2.70	1.28
Bulk Density (kg/m3)	1808	838
Size (mm)	Below 4.75	Below 4.75
Fineness modulus	2.68	2.70

2) Coarse Aggregate

Crushed aggregate available from local sources has been used. The coarse aggregates with a maximum size of 20mm having the specific gravity value of 2.958 and fineness modulus of 7.136 are used as coarse aggregate. The loose and compacted bulk density values of coarse aggregates are 1467 and 1629 kg/m3 respectively, the water absorption of 1.30%.

C. Fly Ash

Fly ash is a by-product produced from the combustion of coal in an electrical generation station. Fly ash is a natural pozzolan, which means that it is a “siliceous or siliceous-and-aluminous material” that chemically reacts with calcium hydroxide or free lime (CH) that has evolved during reaction of cement and water to form composites having cementitous properties. According to Wentric Henry (2010) the procedure of production of fly ash is given below,

Figure 3.1 Fly Ash

Firstly, coal is crushed into fine powder in grinding mills. This coal fine powder is then transferred into a boiler. In the boiler the coal is undergoing combustion producing heat with a temperature up to 1500 degrees. At this temperature, on-combustible minerals melt in the furnace and fuse together. These minerals are taken away from the burning region by exhaust or flue gases. After a while these minerals are cooled and form spherical glassy particles which are known as ‘fly ash’. The fly ash particles are then collected by mechanical and electrostatic precipitators from the exhaust gases.

Table 3.3: Chemical Properties of Fly Ash

S.No	Property	Formula	% content
1.	Silicon Dioxide	Sio_2	59.04
2.	Aluminum Oxide	Al_2O_3	34.08
3.	Iron Oxide	Fe_2O_3	2.0
4.	Lime	Cao	0.22
5.	Sulphur Trioxide	SO_3	0.05
6.	Magnesium Oxide	Mgo	0.43
7.	Alakalies	NA_2O	0.5
8.	Alakalies	K_2O	0.76
9.	Loss of ignition	LOI	0.63

III. METHODOLOGY

A. Compression Test

This test indicates the compressive strength of the structure. For compression test,cubes of size 150x150x150 mm were used.

1) Preparation of Mould

a) For making cubes, the moulds should be made up of steel or cast iron.

b) Moulds of cast iron with inner surface parallel to each other and machine faced were used.

c) The mould that was used have a metal base plate with a right surface to support the mould.

d) The mould was free of dust and other foreign materials and was oiled on the inner surface to prevent the sticking of mortar.

2) Batching, Mixing & Casting

a) These operations must have to do with proper care.

Fig 4.1: Fiber Matrix

b) The concrete that were used for making cubes was prepared by hand mixing on a well waterproof platform.

c) Also fine and coarse aggregates were mixed on platform. The cement ,fly ash and steel fibers were mixed dry to give uniform color.

d) After that water was added and all the ingredients were mixed with mix proportion M20 thoroughly.

e) Different mixtures were formed in varying quantities of fly ash, cement and steel fibers.

f) The mould were filled with mixtures in three different layers. Each layer was rammed at least. times with a steel bar of 16 mm surface.

Fig 4.2: Compression Testing Machine

g) The surface of cube was trowelled smooth.

h) After 24 hours of casting, the specimen were demoulded and were kept in curing tanks for 7-28 days.

i) *Testing*

i) The cubes were taken out from the curing tanks and were transferred to the laboratory by wrapping in gunny bags. The compression test was performed on universal testing machine

j) The cubes were placed in between the plates of machine and load 140kg/cm2/min was transferred till the spicemen shows failure.

k) The compressive strength was then calculated by this formula Compressive Strength (MPa) = Failure Load/Cross Sectional Area It is evident clear that compressive strength increases upto 24.6 MPa for 7 days by replacing cement by 10% fly ash and adding 1.5% of steel fiber.After increasing the quantity of fly ash ,the compressive strength starts decreasing .

IV. RESULTS & ANALYSIS

A. *Compressive Strength Test*

Table 5.1: Compressive Strength Test

Replacement % Used	Strength in N/mm2		
	7th Day	14th Day	28th Day
0%	15.5	17.3	20.06
10% & 0.5%	18.43	21.25	28.04
10% & 1%	19.4	22.3	28.56
10% & 1.5%	24.06	28.08	34.53
20% & 0.5%	17.28	20.6	27.05
20% & 1%	17.68	22.3	27.4
20% & 1.5%	18.64	24.93	31.20
30% & 0.5%	14.90	17.83	26.61
30% & 1%	15.3	18.4	25.08
30% & 1.5%	13.3	14.53	22.05

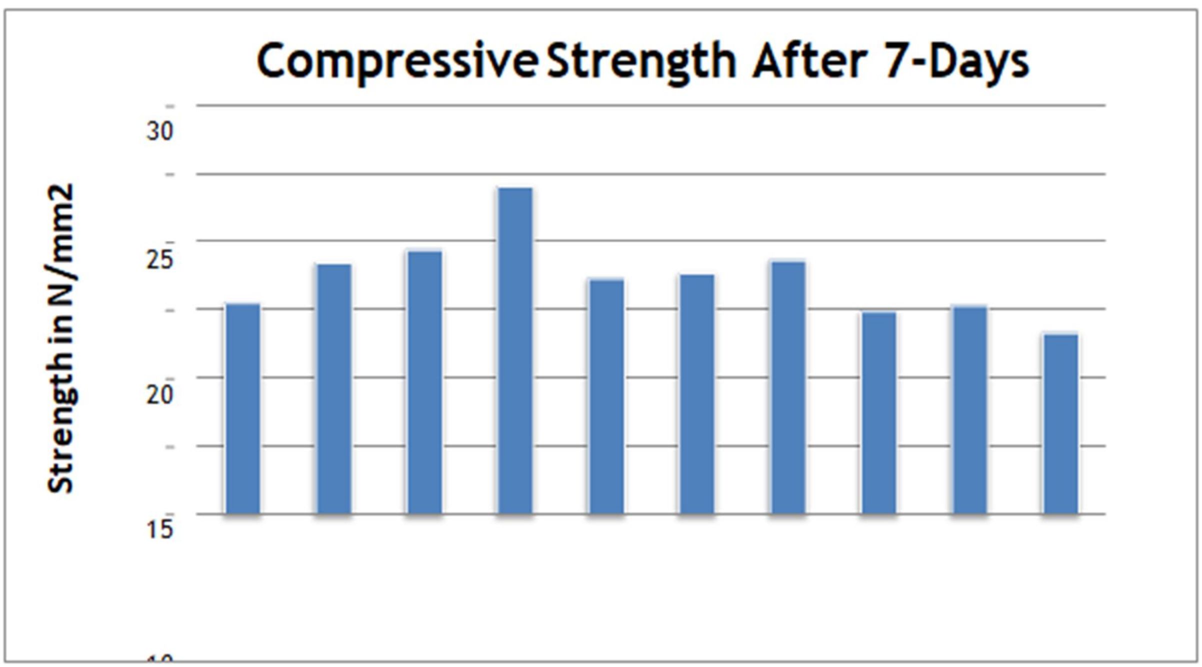

Fig 5.1: Compressive Strength Test After 7-Days

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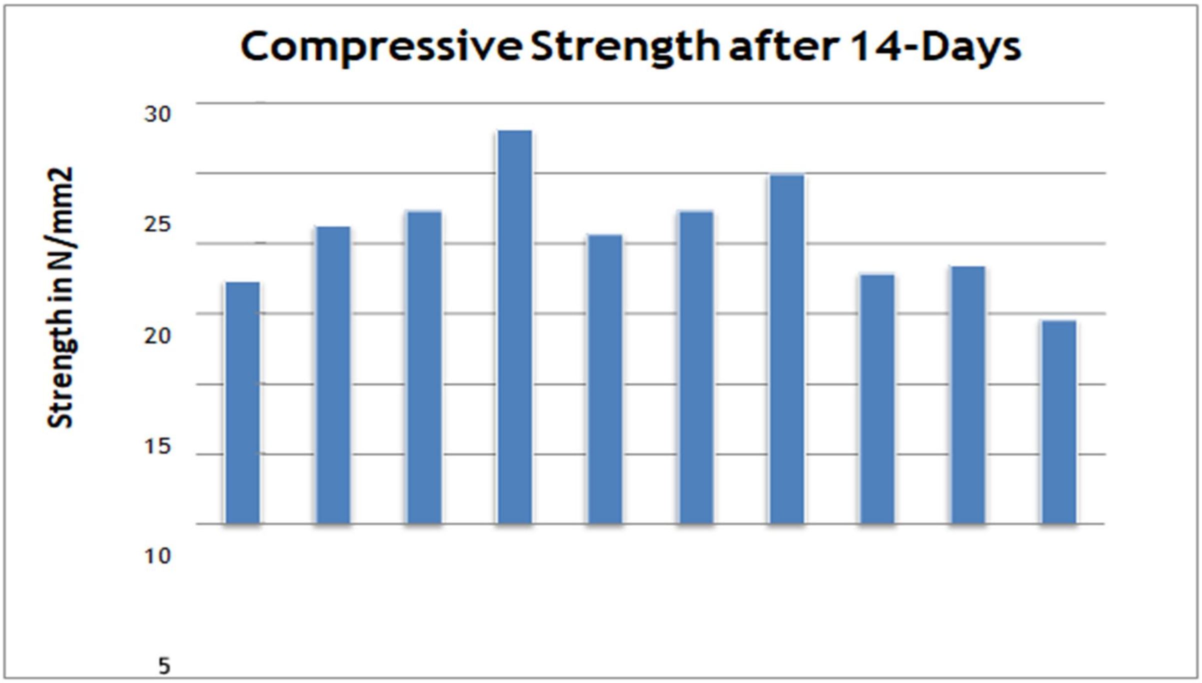

Fig 5.2: Compressive Strength Test After 14-Day

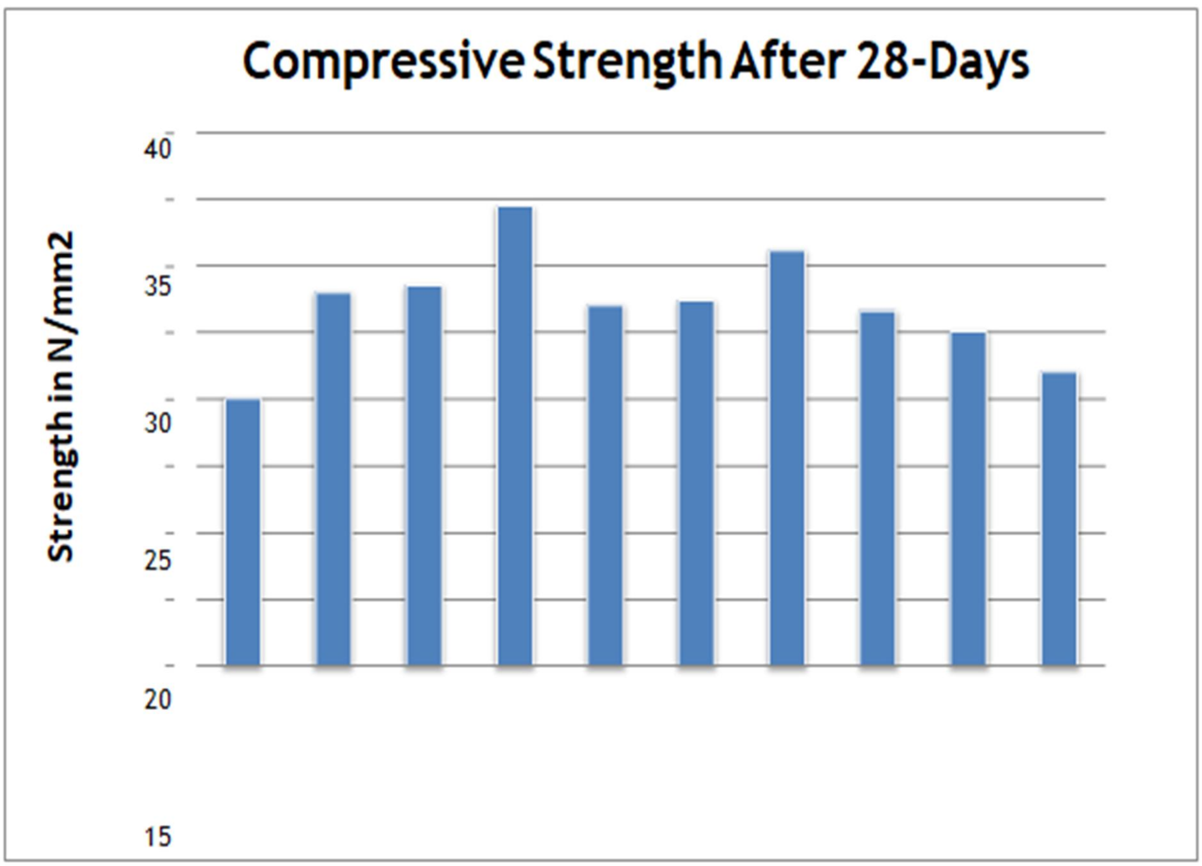

Fig 5.3: Compressive Strength Test After 28-Days

B. Flexural Strength Test

Table 5.2: Flexural Strength Test

Replacement % Used	Strength in N/mm2		
	7th Day	14th Day	28th Day
0%	3.67	4.32	5.4
10% & 0.5%	3.45	4.64	5.76
10% & 1%	4.32	5.31	6.43
10% & 1.5%	6.02	6.24	6.64
20% & 0.5%	2.95	3.64	5.53
20% & 1%	4.06	4.98	6.20
20% & 1.5%	5.3	6.1	6.73
30% & 0.5%	2.87	4.05	5.32
30% & 1%	4.06	4.93	6.05
30% & 1.5%	4.24	6.02	7.75

V. CONCLUSION & FUTURE SCOPE

A. General

One of the main residual product created during the combustion of coal is fly ash. It is generally considered as waste material. This waste material is disposed in soil, which inturn creates different environmental problems. To overcome the disposal of fly ash in soil,it can be used in concrete as partial replacement of cement or as fine aggregates. The utilization of fly ash in concrete as a replacement of cement or fine aggregate has gained a great interest as it increases the durability of concrete and increases its long term strength.

This project was completed with the main purpose of discovering the feasibility of using fly ash as a partial replacement of cement with addition of steel fibers.The addition of steel fibers plays a very important role in increasing strength and minimizing the concrete cracks.

B. Conclusion

As part of the investigation, concrete mixes with different contents of fly ash as replacement of cement and steel fibres were made and cast into concrete cubes, cylinders and beams then cured in water. A slump test was also performed to check the workability of the concrete mixes immediately after the mixing process of the ingredients was completed. From the test results, following conclusions were made:

1) *Compressive Strength:* The compressive strength of concrete reaches highest, when the cement has been replaced by 10% of fly ash and with addition of 1.5% of steel fibre.This is due to the fact that the fly ash acts as pozolonic material and it combines with free lime to form CSH ,which imparts strength to the concrete. Also by adding steel fibers, the bond between different constituents become very strong which in turn imparts strength to the concrete.(refer table 6.1)
2) *Split tensile strength:* The split tensile strength is maximum when cement is replaced by 10% fly ash and addition of 1% steel fiber. (refer table 6.3)
3) *Flexural Strength:* The value of flexural strength increases mainly due to addition of steel fibers and it was recorded highest when cement was replaced by 10% of fly ash and with addition of 1.5% of steel.(refer table 6.2)
4) *Workability:* It goes on increasing continuously when there is increase in the amount of fly ash.This is due to the fact that fly ash being spherical, small, fine particles that required very low content of water to mix with free lime. But by adding steel fiber, the workability goes on decreasing and it reaches minimum for 1.5% steel fiber.(refer table 6.4)

C. Future Scope

1) Comparison of flexural, compressive, split tensile behavior of fly ash & steel fiber reinforced concrete for other grades M30, M40, M50, of normal concrete with that of fly ash concrete with fibers.
2) To determine the flexural shear behavior of high strength fly ash & steel fiber reinforced concrete.
3) To check the durability at different mix proportion of fly ash & steel fiber.

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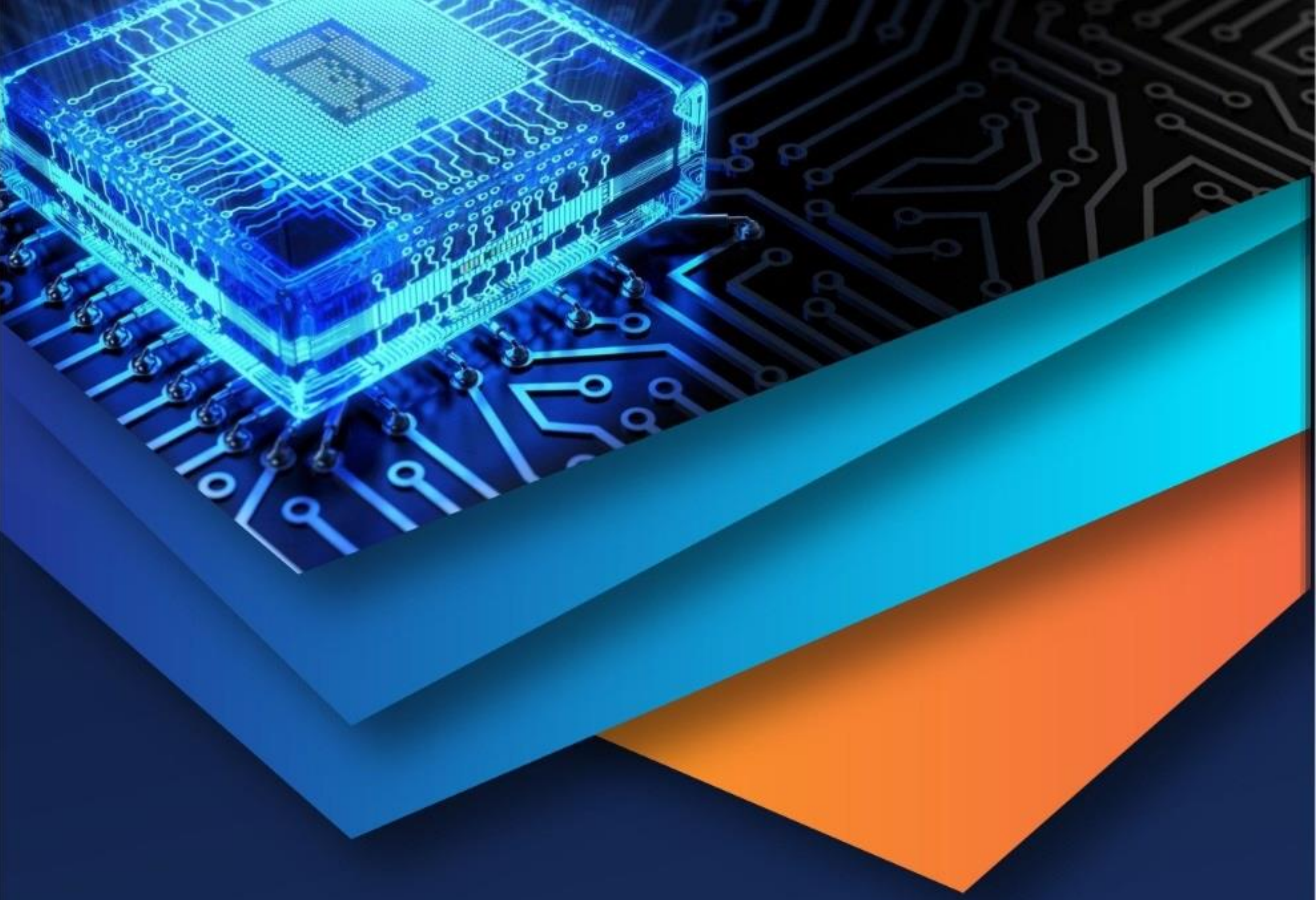

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