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To Study the Effect of Silica Fume and M-Sand on High Performance Concrete

Nurulmustafa Shaikh[1], Udaychand Soni[2], Pranav Rane[3], Ashutosh Yadav[4], Mr. Jaydeep B Chougale[5]
[1, 2, 3, 4, 5]Department of Civil Engineering, University of Mumbai

***Abstract:** The aim of this study is to evaluate the performance of silica fume as a cement replacing material for High Performance Concrete (HPC). Silica fume is very fine pozzolanic material composed of ultrafine, amorphous glassy sphere of (average diameter 0.10 to 0.15 micron) of silicon dioxide (SiO_2) produced during manufacture of silicon or ferro-silicon by electric arc furnaces at temperature of over 2000 ^{0}C is industrial by product which is replaced by cement because of increasing demand of cement in construction industry which compel the large scale production of cement result in depletion of natural resources and also leads to release of significant amount of CO_2 and other greenhouse gases. The tremendous increase in demand for load of sand every year from river beds, stream beds, and pits creates many serious environmental problems, such as meandering of water courses, denudation of river banks, and interference with the natural flow patterns of river and streams. Availability of natural sand is getting depleted and it is becoming costly. To overcome above environmental problems associated with R-sand concrete industry now will have to go for M-sand which will save depletion of natural resources. This paper deal with the study about mechanical properties of concrete in silica fume and M-sand in HPC. In this study, concrete mixes with silica fume at 0%, 10%, and 20% replacement by weight of cement and also varying percentage of R-sand as 0%, 50% and 100% with M-sand on M60 grade of concrete. For each mix standard size of cubes and beams were casted as per Indian standard and tested for compressive strength at the age of 7 and 28 days and flexural strength at the age of 28 days.The result of experiment investigation indicates that the use of silica fume and M-sand in concrete increase the strength & durability at all ages when compared to normal concrete. Hence the use of silica fume & M-sand lead to reduction in cement and R-sand quantity for construction purpose and its use should be promoted for better performance as well as for environmental sustainability.*

***Keywords:** High Performance Concrete, Silica Fume, Manufactured Sand, Compressive Strength, Flexural Strength, River sand.*

I. INTRODUCTION

The HPC is that which is designed to give optimized performance characteristic for a given set of load, usage and exposure condition consistent with requirement of cost, service life and durability. Modern civil engineering construction tends to progress towards more economic design and construction of structure through gradually improved method of design and use of high strength materials. HPC is used for concrete mixture which possess high workability, high early strength, high modulus of elasticity, high density, high dimensional stability, low permeability, high resistance to chemical attack, low heat of hydration, and continued strength development, control slump, low water binder ratio, low bleeding, plastic and shrinkage. HPC is a concrete in which all above given characteristic are developed for a particular application and environment condition subjected during its design life. The pozzolanic material of the smelting process in the silicon and ferro-silicon industrial by product silica fume is found to be most suitable material to be used in concrete as partial replacement of cement because when silica fume are incorporated to concrete the silica present in these materials react with calcium hydroxide released during the hydration of cement and forms additional calcium silicate hydrate (C-S-H) which enhance both the mechanical and durability properties of concrete. R-sand is not readily available nowadays because of banned imposed by government on quarrying of R-sand. M-sand is suited over R-sand the cheapest and easier alternative to natural sand. The M-sand is well graded and does not contain high percentage of organic and soluble impurities such as chlorides sulphates clay dust and silt that adversely effects the setting time strength and durability properties of concrete and reinforcing steel there by reducing life of structure. The use of partial replacement of cement with silica fume and R-sand with M-sand in construction industry, which protect the ecosystem. Major application of HPC is in the area of pavement, long span bridges, high rise building and hydro power structure. In prestressed concrete bridges, concrete should not only have high strength but reduced shrinkage and creep. High performance is being increasingly used for highway pavement due to potential economic benefit that can be derived from the early strength gain of high performance its reduced permeability increased wear of abrasion resistance. The use of HPC in construction shows advantages like reduction in dead loads and reduced size of the columns which gives more rental space and saving in material and cost.

II. LITERATURE REVIEW

Ram Kumar, Jitender Dhaka [1] A detail study of concrete mix of M35 with partial replacement of Silica fumes with varying % of 0,5,9,12 & 15 % by weight of cement. The paper presents a detail experiment study on compressive strength, Flexural strength & Split tensile strength for 7- & 28-days resp.The optimum % of partial replacement of cement with Silica fumes is 12% for compressive & Flexural strength and 9% for Split tensile strength of concrete. The % increase in compressive strength is 17.76%, Split tensile strength is 20.74% & Flexural strength is 40.67%. Ali Alsaman, Canh N. dang, W. Miah Hale [2] Determining the most effective Silica fumes content for developing UHPC using locally available materials, thus minimizing cost of UHPC.Use of 5% Silica fumes increased the compressive strength by 20% replacement of Fly Ash with 3% by volume steel fibers increased the compressive strength by 4-8% with the use of finer sand. M. Mastali and A. Dalvand [3] This paper aims to investigate the effects of replacing cement with silica fume in the reinforced self- compacting concrete with recycled steel fiber. To characterize mechanical properties and impact resistance, the different fiber volume fractions of 0.25%, 0.5%, and 0.75% were tested as per ASTM. The Characteristics with regards of compressive, splitting tensile, and flexural strength were tested. Replacing silica fumes and adding recycled steel fiber reduces the workability of the moistures. Due to replacing cement with silica fumes, the highest rate of gaining compressive strength, splitting tensile strength, and flexural strength are obtained for the reinforced self-compacting concrete with recycled steel fiber of 0.75. when increase in compressive strength,reinforced self compacting concrete mixtures with the recycled steel fiber 0.25% shows the highest rate of gaining split tensile strength and flexural strength. Mohamed Amin & Khaled Abu el-Hassan [4] In this work the HPC without Nano particle was compared with that after addition of Nano particle. Nano materials used Non-ferrite (NF), Nano Silica (NS) & Cu-Zn Ferrite with superplasticizer. They used NS & NF at different ratio of cementitious material replaced by (1,2,3,4,5%). Effect of granite & dolomite of mechanical properties of concrete with partial replacement of coarse aggregate. Mechanical strength was measured at 7,28,90,365 days, Egyptian std. on various grade. The optimum dose of Nano silica is 3% by weight and the optimum dose of Ni ferrite & Cu-Zn ferrite was 2% by weight. With addition of Nano silica & Nano ferrite with partial mixes compressive strength increase to 21% & 17% resp. Split tensile strength increases to 44% to 60% resp. Increasing the amount of NS & NF more than 3% & 2% by weight degrades mechanical properties of concrete. The sample of Nano silica better than Nano ferrite with approx. rate of 10%. The sample of granite give better result than dolomite with approx. rate of 10%. Superplasticizer was used to improve the workability.

Vijender Thakur, Karunesh [5] Experimental investigation on the utilization of Silica fumes with replacement of cement mix with Silica fumes (0,10,15 %) and natural aggregates with recycled aggregate (20,40,50 %) for M45. Compressive and Split tensile strength was carried out at 7 and 28 days. The workability of recycled aggregate concrete mix is lower than natural aggregate concrete. The Compressive and Split tensile strength of concrete decrease with increase in the % of recycled aggregate. RCA based concrete with 10% Silica fumes gives higher compressive strength than normal NCA. Compressive and Split tensile strength is increased with 10-15% replacement of Silica fumes. S. Durai, S.C. Bobahn, P. Muthupriya, R. Venkatasurbramani[6] The HPC mixes with Silica fumes of 0,10 and 20% with addition of glass fiber of dia. 14 micron & 12mm length at various % as 0,0.3 & 0.6% by the volume of cement on M75 grade of concrete. For each mix standard sizes of cubes, cylinders and prisms as per IS were cast and test for compressive, split tensile strength & flexural strength at age of 28 days. From experimental results, the optimum % recommended as 0.3% glass fiber volume with 10% Silica fumes. For optimum % of dosages compression strength is increased by 12.5% split tensile strength is increased by 4.4 % Flexural strength is increases by 0.4%.

III.METHODOLOGY

A. Materials Used

Cement: Ordinary Portland cement of 53 Grade (Ambuja Cement) conforming to IS 8112 -1989**.** The specific gravity of cement was found to be 3.15. The physical properties of cement given in table.

Table no.1**:** Physical Properties of cement

Component	Results	Requirements of IS: 8112
Initial setting Time	115 minutes	Minimum 30
Final setting Time	170 minutes	Maximum 600
Fineness	303 m^2/kg	Minimum 225
Standard consistency	29.5 %	-
Soundness, Le Chatelier's method	1.0 mm	Maximum 10

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B. Fine Aggregate

1) *Natural Sand:* Locally available River sand passing through IS 4.75 mm sieve conforming to grading zone II IS 383-1970 having specific gravity 2.65.
2) *Manufactured Sand:* M- Sand was used as partial replacement of fine aggregate. The M-sand used is from Navdeep construction company brought from Paya Vasai Virar. The bulk density of manufactured sand was 1720 kg/m3, specific gravity and fineness modulus was found to be 2.61 and 3.02 respectively. The percentage of particles passing through various sieve were compared with IS 383-1970 and it was found to be similar of grading zone II.

Table no. 2: Sieve analysis of fine aggregate

Sieve Size	M-sand % passing	(Grading Zone II) % Passing (As per IS 383-1970)
4.75 mm	95.1	90-100
2.36 mm	73.6	75-100
1.18 mm	51.3	55-90
600 microns	37.0	35-59
300 microns	25.7	8-30
150 microns	7.75	0-10

3) *Coarse Aggregate:* The coarse aggregate was used available at Navdeep construction company malad west brought from Paya Vasai Virar. The crushed coarse aggregate with maximum grain size of 20 mm was used having bulk density 1525 kg/m^3 and specific gravity was found to be 2.9.
4) *Silica Fume:* The silica fume was partially replaced for cement. Micro silica (920 grade) conforming to ASTM C 1240 mineral admixture in dry densified form was brought from Elkem India Pvt Ltd Mumbai.

Table no. 3: Physical Properties of Silica Fumes

Properties	Description
Diameter	0.1-0.2 micron
Appearance	Grey
Type Air	Cooled
Specific Surface area	18000 (m^2/kg)

5) *Super Plasticizer:* In order to improve the workability of high-performance concrete, superplasticizer in the form of Sulphonated Naphthalene formaldehyde Polymers complies with IS 9103:1999 commercially available superplasticizer Sika Viscocrete 5210 NS was used specific gravity is 1.109.
6) *Water:* Fresh portable water, which is free from harmful amount oils, alkalis, sugar, salts acid and organic substance, was used for proportioning mix and curing of the concrete.
7) *Mixed Design:* For M60 grade of concrete

Table no. 4: Mix Proportion of concrete

Cement in kg/m^3	Silica fume (By wt. of cement) in kg/m^3	Fine Aggregate R-sand (in kg/m^3)	M-sand (By wt. of R-sand) in kg/m^3	Coarse Aggregate (in kg/m^3)		Water in kg/m^3	Superplasticizer (By wt. of cement) in kg/m^3
				10mm	20mm		
	0%		0%				1.2%
600	10%	658	50%	1036		178	7.2
	20%		100%	414.4	621.6		
1		1.09		1.72		0.29	

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IV. RESULT AND DISCUSSION

Table no. 5: Result of Compressive and Flexural Strength.

Trial Mix	Silica Fume (%)	R-sand	M-sand	Compression Test (N/mm^2)		Flexural Test (N/mm^2)
				Avg 7 Days	Avg 28 Days	Avg 28 Days
1	0	100	0	30.56	60.75	5.95
2	10			41.14	65.7	7.84
3	20			35.56	60.35	6.85
4	0	0	100	36.54	65.53	5.71
5	10			47.75	71.35	8.12
6	20			41.53	66.44	6.79
7	0	50	50	32.73	60.64	5.45
8	10			44.48	67.52	7.86
9	20			37.79	64.21	6.46

1) *Compressive strength:* The test was carried out on 150x150x150mm size of cubesas per IS 516-1959 to obtain compressive strength of concrete at the age of 7 and 28 days. The cubes were tested using CTM of capacity 3000KN the result are presented in figure below

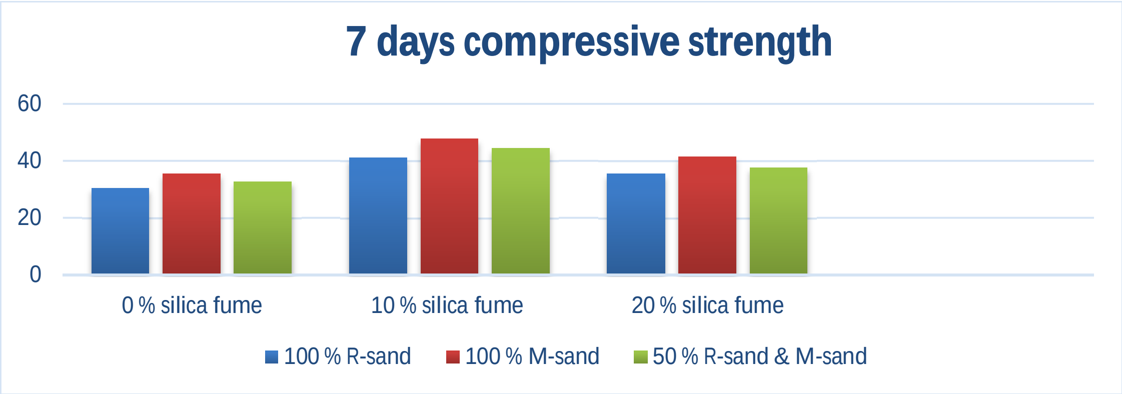

Fig no. 1: 7 days compressive strength (N/mm^2).

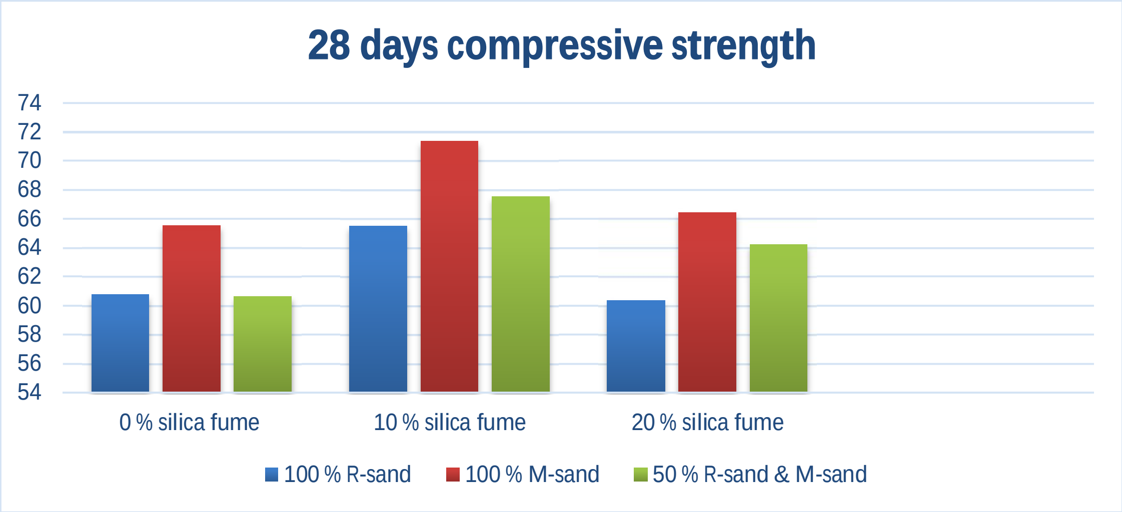

Fig no. 2: 28 days compressive strength (N/mm^2).

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Compressive strength of concrete for 7days for 0% silica fume and 100% R-sand is 30.56 N/mm^2 and for 10% silica fume and 100% M-sand is 47.75 N/mm^2.The 7 days compressive strength shows significant increase in early strength. Compressive strength of a concrete for 28 days for 0% silica fume and 100% R-sand is 60.75 N/mm^2 and for 10% silica fume and 100% M-sand is 71.35 N/mm^2.The increase in compressive strength was 14.85% for 28 days strength of a concrete.

2) *Flexural Strength*: The test was carried out on 700x150x150mm size of beam as per IS 516-1959 to obtain flexural strength of concrete at the age of 28 days. The result are presented in figure below

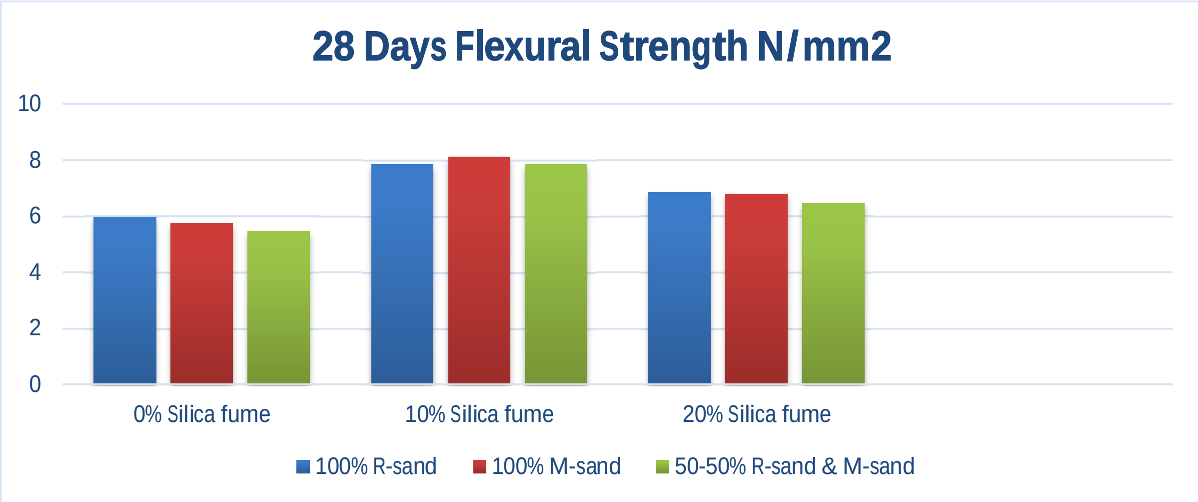

Fig no. 3: 28 days Flexural strength (N/mm^2).

Flexural strength of concrete for 0% silica fume and 100% R-sand is 5.95 N/mm^2 and for10% silica fume and 100 % M-sand gives 8.12N/mm^2. The increase in flexural strength was 26.72% compared to normal concrete.

V. CONCLUSION

A. Cement replacement up to 10% with silica fume and R-sand replacement up to 100% with M-sand lead to increase in compressive strength and flexural strength for about 14.85% & 26.72% respectively as compared to normal concrete.
B. By increasing 10% silica fume there is a decrease in compressive strength & flexural strength.
C. The maximum replacement level of silica fume is 10% and for R-sand is 100% for M60 grade of concrete.
D. The silica fumes can be used effectively in high rise building since high early strength reduced the construction period.
E. Use of silica fume gives significant result on the properties of concrete as compared to normal concrete.

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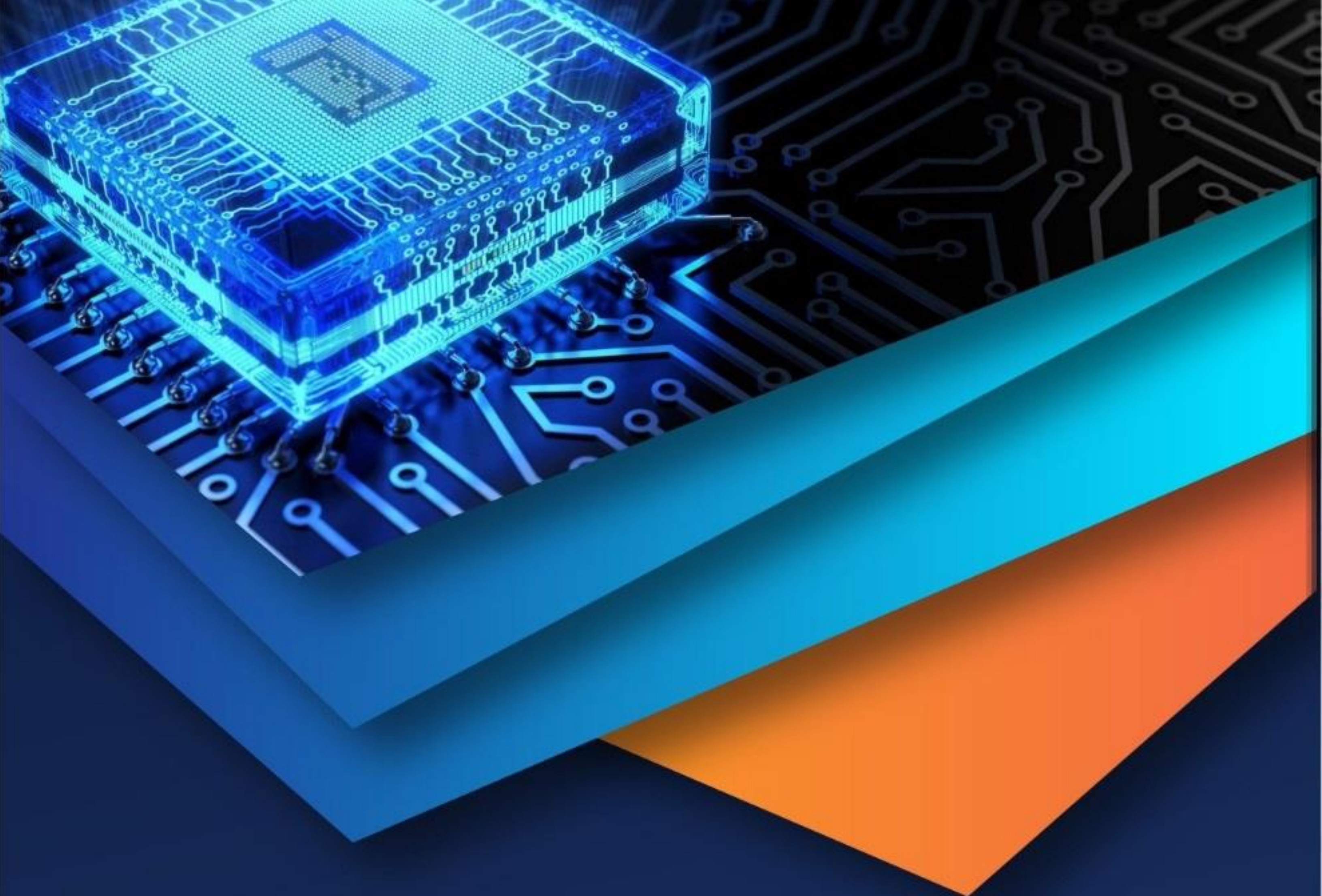

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