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Experimental Investigation of Concrete with Partial Replacement of Cement with Silica Fume and Fine Aggregate with China Clay Waste

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Abstract: China clay is one of the purest clays with the silica content. Extractsion of china clay produces large quantities of waste material during purification process of china clay in India. Due to lots of waste generation problem is created to dispose of the waste and land acquisition. This waste is free from clay. In addition Silica fume is also a by-product of the smelting process in the silicon and ferrosilicon industry and can be used in high performance concrete. This research deals with partial replacement of china clay waste with fine aggregate to 10%, 20%, 30%, 40%, 50% and Silica Fume with cement to 5%, 10%, 15%, 20%. The Properties hardened concrete compressive strength, split tensile strength, flexural strength of cement and fine aggregate replaced concrete of M35 measures in this study. The result showed the increment of Compressive strength, Split Tensile Strength and Flexural Strength using 15% of Silica fume replaced with Cement and 30% China Clay Waste replaced with Fine Aggregate.
Keywords: China Clay Waste, Silica Fume, Concrete, Compressive Strength, Split Tensile Strength, Flexural Strength.

I. INTRODUCTION

The Concrete is the most widely used composite material today. The constituents of concrete are coarse aggregate, fine aggregate, binding material and water. Rapid increase in construction activities leads to acute shortage of conventional construction materials. Many studies were made on the inclusion of waste materials in concrete as ingredients, which has resulted in improved solutions for dealing with environmental issues such as natural source depletion, waste management, etc.

About 14 States produce china clay in larger or smaller quantities. Kerala stands first in rank and production. In Gujarat 19000 tonnes china clay is produced per annum. China Clay is used in the production of many products like Ceramic, Paper, Rubber, Paint, Textiles etc. The Clay content is extracted by either Washing or pulverizing process. These process have generated tonnes of wastage of china clay. In present scenario the wastage from china clay is dumped or dispose to landfill. This wastage is free from clay and contains higher amount of Silica (SiO_2).

Whereas Silica Fume is a by-product of the Silicon and ferrosilicon industry. The reduction of high quality quartz to silicon at temperatures up to 2000˚C produces SiO_2 vapours, which oxidizes and condense in the low temperature zone to tiny particles consisting of non-crystalline silica.

II. MATERIALS USED

A. Cement

Cement is used to work according to IS : 12269 – 2013 Ordinary Portland Cement(OPC) - 53 Grade

Table -I Properties of Cement

Property	Value
Fineness (m^2/Kg)	314
Initial Setting Time (minute)	160
Final Setting Time (Minute)	250
Standard Consistency(%)	30

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B. Coarse Aggregate

Coarse aggregate is used according to IS : 383 – 2016 Specification for Coarse and Fine Aggregate from Natural Sources for Concrete which fraction is from 20 mm to 4.75 mm.

Table-II Properties of Coarse Aggregate

Property	Value
Specific Gravity	2.70
Water Absorption(%)	0.50
Particle shape	Angular

C. Fine Aggregate

Fine aggregate is used to work according to IS : 383–2016 Specification for Coarse and Fine Aggregate from Natural Sources for Concrete which fraction is from4.75mm to 150µ

Table-III Properties of Fine Aggregate

Property	Value
Specific Gravity	2.65
Water Absorption(%)	1.00
Surface Texture	Smooth

D. China Clay Waste

China Clay Waste (CCW) used is largely produced in Kutch district, Gujarat

Table-IV Properties of China Clay Waste

Property	Value
Specific Gravity	2.65
Fineness Modulus	1.89
Surface Texture	Smooth

E. Silica Fume

Silica Fume used is from Rajkot Region.

Table-V Properties of Silica Fume

Property	Value
Bulk Density (Kg/m^3)	317
Specific Surface Area (BET) (M^2/gm)	16.44

F. Water

Normal Potable water is used in concrete mix.

G. Admixture

Superplasticizer is used as per IS 9103:1999.

Table-VI Properties of Superplasticizer

Property	Value
Specific Gravity	1.17
Chloride Content	NIL
PH at 27˚C	6.0-7.0

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III. EXPERIMENTAL PROGRAMME

Based on Trial mix results, The M35 Grade Concrete Mix was designed as per IS: 10262 - 2009. The Design Mix is defined as below.

Cement : F.A. : C.A. : Water
1 : 1.80 : 3.26 : 0.43

In this experimental work, Cubes of 150 × 150 × 150 mm, Cylinders of 150 mm Diameter and 300 mm length and Beams of 100×100×500 mm were casted and Tested for Compressive Strength, Split Tensile Strength and Flexural Strength after 7 and 28 Days of water curing. The Cement was replaced with Silica Fume at 5% 10% 15% 20% and Fine Aggregate was replaced with China Clay Waste at 10% 20% 30% 40% and 50% in Concrete mix. The Testing of specimens was conducted in accordance with IS : 516-1959 and IS : 5816 - 1999.

IV. RESULTS AND DISCUSSION

A. Compressive Strength

Compressive strength test was conducted at 7 days and 28 days. The results obtained from the experimental procedures are tabulated and presented below.

Table-VII: Compressive Strength Results

Mix Designation	Silica Fume (%)	China Clay Waste (%)	Compressive Strength(N/mm^2)	
			7Days	28 Days
M0	0	0	28.67	43.21
M1	5	0	30.27	46.22
M2	10	0	33.82	48.56
M3	15	0	35.56	50.15
M4	20	0	29.39	45.01
M5	0	10	29.26	46.25
M6	0	20	30.21	48.21
M7	0	30	31.53	49.69
M8	0	40	29.38	45.13
M9	0	50	28.55	42.47
M10	10	20	32.08	48.79
M11	15	20	33.15	49.59
M12	20	20	29.68	46.21
M13	10	30	32.48	48.87
M14	15	30	33.01	49.61
M15	20	30	30.39	47.12
M16	10	40	31.72	46.65
M17	15	40	32.18	47.34
M18	20	40	29.21	44.19

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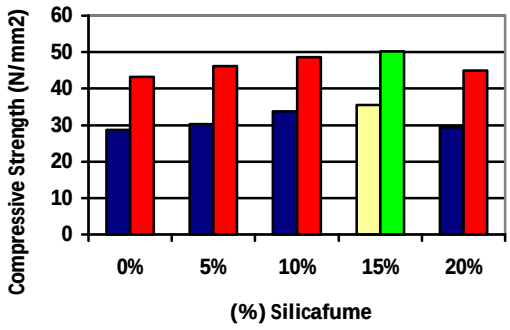

Fig. 1 : Compressive Strength of Silica Fume(SF)

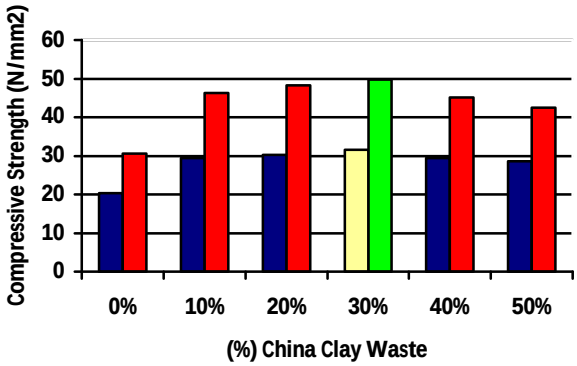

Fig. 2 : Compressive Strength of China Clay Waste(CCW)

The Compressive Strength results at 15% of Silicafume replacement with cement of cubes at 7 and 28 Days shows increment of 50.15 N/mm^2 in compressive strength of concrete compare to Conventional Mix. At 20% Replacement of Silica fume Strength started to decrease. The Results of Compressive Strength of Concrete replacing Fine Aggregate with China Clay Waste Upto 50% showed increased in Strength of concrete at 30% of china clay waste at 28 Days. at 40% and 50% replacement of china clay waste with fine aggregate showed decrease in strength of concrete.

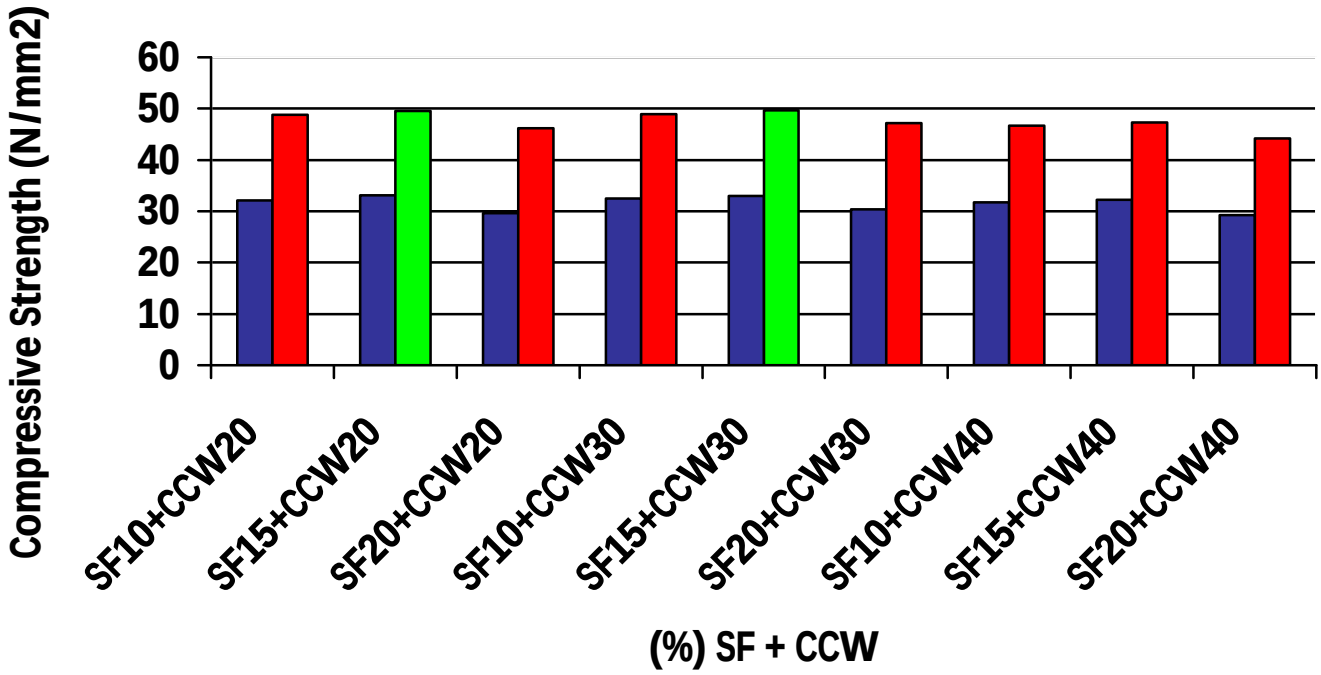

Chart - 3 : Compressive Strength combine CCW + SF

After Getting Optimum results of Compressive strength from Concrete mix of China Clay waste (CCW) and Silica Fume (SF) respectively both materials are used combine at different percentage replacement of both materials. The Optimum result of Compressive strength of combine mix was at 15% of Silicafume with 30% of China Clay Waste 49.61 N/mm^2 and at 15% of silica fume with 20% of China Clay Waste 49.59N/mm^2.

B. Split Tensile Strength

Split Tensile strength test was conducted at 28 days. The results obtained from the experimental procedures are tabulated and presented below.

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Table-VIII: Split Tensile Strength Results

Mix Designation	Silica Fume (%)	China Clay Waste (%)	Split Tensile Strength(N/mm^2) 28 Days
M0	0	0	3.68
M1	5	0	3.72
M2	10	0	3.79
M3	15	0	3.92
M4	20	0	3.81
M5	0	10	3.53
M6	0	20	3.70
M7	0	30	3.76
M8	0	40	3.73
M9	0	50	3.66
M10	10	20	3.74
M11	15	20	3.79
M12	20	20	3.69
M13	10	30	3.76
M14	15	30	3.89
M15	20	30	3.80
M16	10	40	3.73
M17	15	40	3.76
M18	20	40	3.71

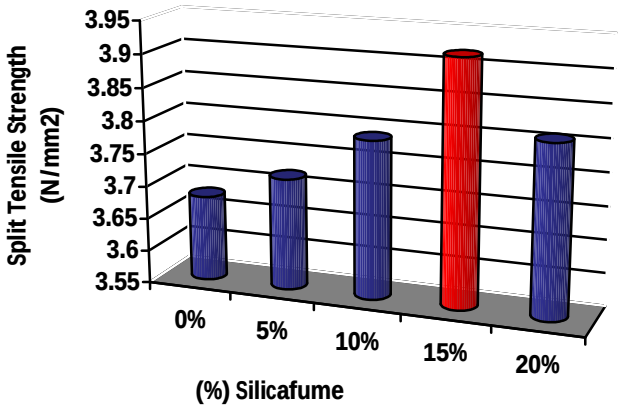

Fig. 4 : Split Tensile Strength of Silica fume(SF)

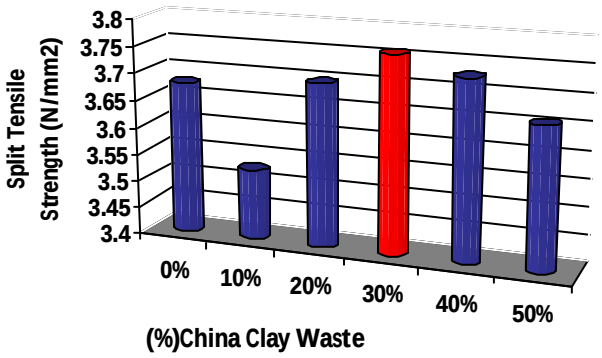

Fig. 5 : Split Tensile Strength of China Clay Waste(CCW)

The Split Tensile Test result at 28 days were taken. It showed optimum value of 3.92 N/mm^2 at 15% replacement of silica fume with Cement in concrete mix. At 20% of replacement with silica fume split tensile strength started to decrease.

Partial replacement of china clay waste with fine aggregate at 10%, 20%, 30%, 40%, 50% showed optimum value of split tensile strength at 30% of replacement 3.76 N/mm^2 at 28 Days. At 40% and 50% split tensile strength started to decrease.

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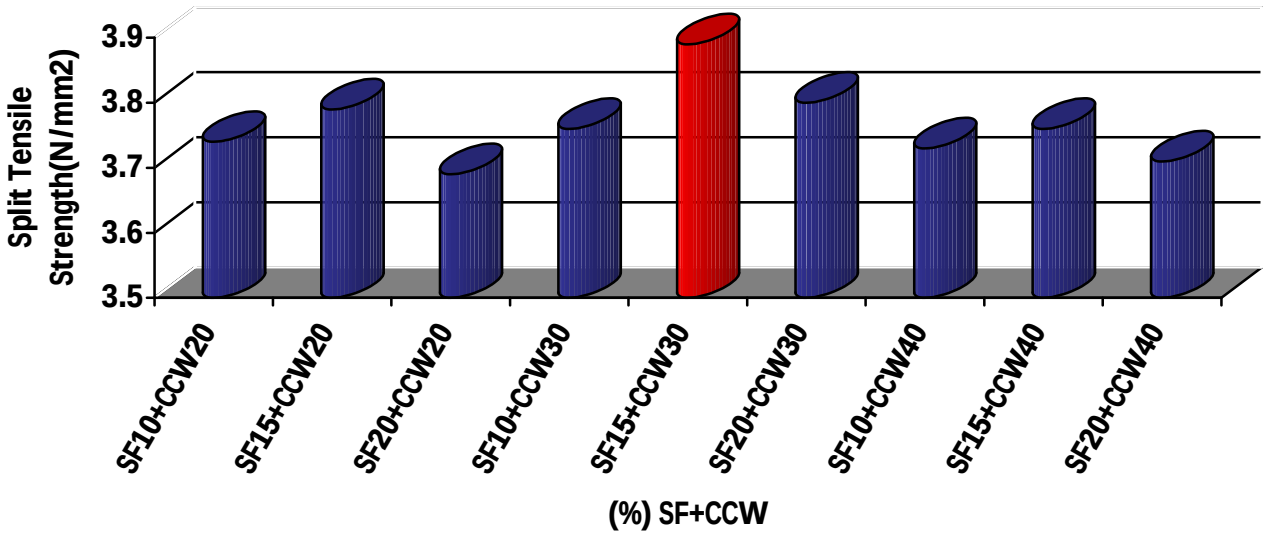

Fig. 6 : Split Tensile Strength of combine CCW & SF

Split Tensile Strength of Concrete at different percentage of silica fume(SF) at 10%, 15%, 20% and china clay waste(CCW) at 20%, 30%, 40% showed optimum value of Split Tensile Strength at combination of 15% SF and 30% CCW of 3.89 N/mm^2 at 28 Days.

C. Flexural Strength

Flexural strength test was conducted at 28 days. The results obtained from the experimental procedures are tabulated and presented below.

Table-IX: Flexural Strength Results

Mix Designation	Silica Fume (%)	China Clay Waste (%)	Flexural Strength(N/mm^2) 28 Days
M0	0	0	4.62
M1	5	0	4.84
M2	10	0	4.96
M3	15	0	5.19
M4	20	0	4.77
M5	0	10	4.75
M6	0	20	4.89
M7	0	30	4.96
M8	0	40	4.61
M9	0	50	4.33
M10	10	20	4.89
M11	15	20	5.04
M12	20	20	4.62
M13	10	30	4.75
M14	15	30	5.10
M15	20	30	4.84
M16	10	40	4.73
M17	15	40	4.87
M18	20	40	4.62

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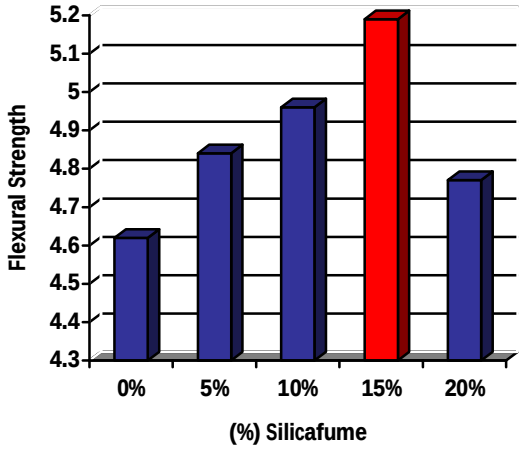

Fig. 7 : Flexural Strength of Silica Fume(SF)

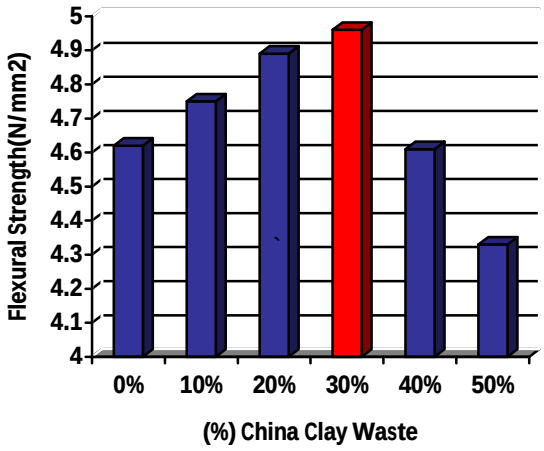

Fig. 8 : Flexural Strength of China Clay Waste (CCW)

The Flexural Strength Test of Silica fume partial replacement with cement at 5%, 10%, 15% , 20% showed increment in value of Flexural Strength at 15% Silica Fume (5.19 N/mm^2) and at 20% of Silica Fume the results showed decrease in flexural strength of Concrete (4.77 N/mm^2).

The Partial Replacement of China Clay Waste (10%, 20%, 30%, 40%, 50%) with Fine Aggregate showed increment in Flexural Strength of Concrete. The 30% replacement of China Clay Waste with Fine Aggregate showed Optimum value (4.96 N/mm^2) of Flexural strength of concrete. At 30% & 40% Replacement of China Clay waste results showed decrement in Flexural Strength.

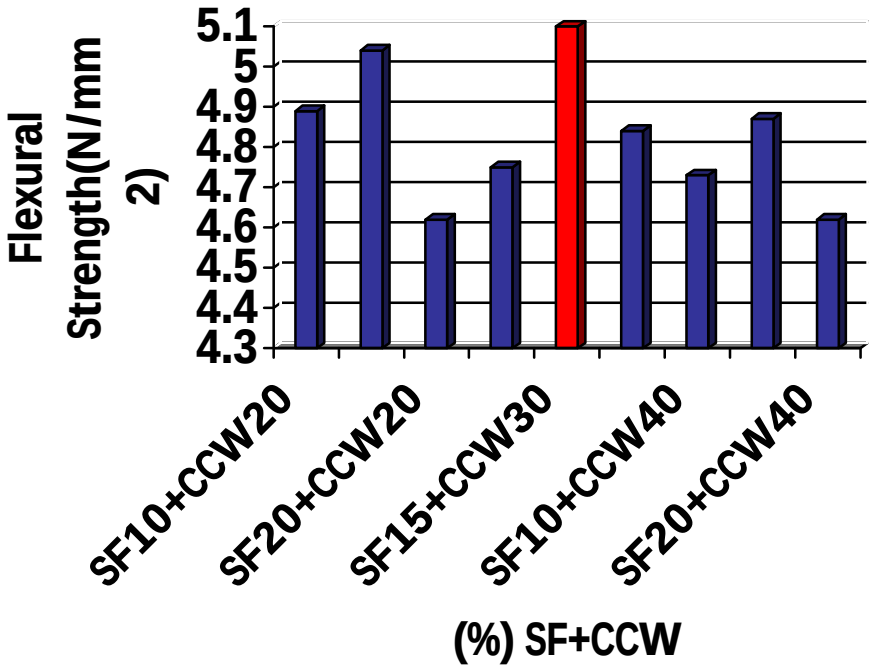

Fig. 9 : Flexural Strength of combine CCW & SF

The Concrete mix containing both Silica fume (10%, 15%, 20%) and China Clay Waste (20%, 30%, 40%) at different percentage of replacement with different combinations. The Optimum result at combine SF 15% with cement and CCW 30% with Fine Aggregate 5.10 N/mm^2 has been noted at 28 Days. The Decrease in flexural Strength seen at combination 15% of Silica fume and 20% of China Clay Waste & 20% Silica Fume and 40% China Clay Waste.

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V. CONCLUSIONS

The Experimental Investigation has evaluated the use if China Clay Waste as Fine Aggregate and Silica Fume with replacement of cement. In addition the effect of combine Silica Fume and China Clay Waste in Concrete mix has been considered.

The results have demonstrated that the use of waste china clay waste and Silica fume in this application is achievable and practically and technically attractive. It is found that 30% replacement of China Clay Waste with Fine Aggregate gives maximum results in Compressive Strength (49.69 N/mm^2), Split Tensile Strength (3.76 N/mm^2) and Flexural Strength (4.96 N/mm^2) at 28 Days.

Using the 15% replacement of Silica Fume with Cement has also shown maximum results of the Compressive Strength (50.15 N/mm^2), Split Tensile Strength (3.92 N/mm^2) and Flexural Strength (5.19 N/mm^2) at 28 Days.

The Combine Concrete Mix of 15% Silica Fume and 30% China Clay Waste has shown maximum results of Compressive Strength, Split Tensile Strength and Flexural Strength at 28 Days.

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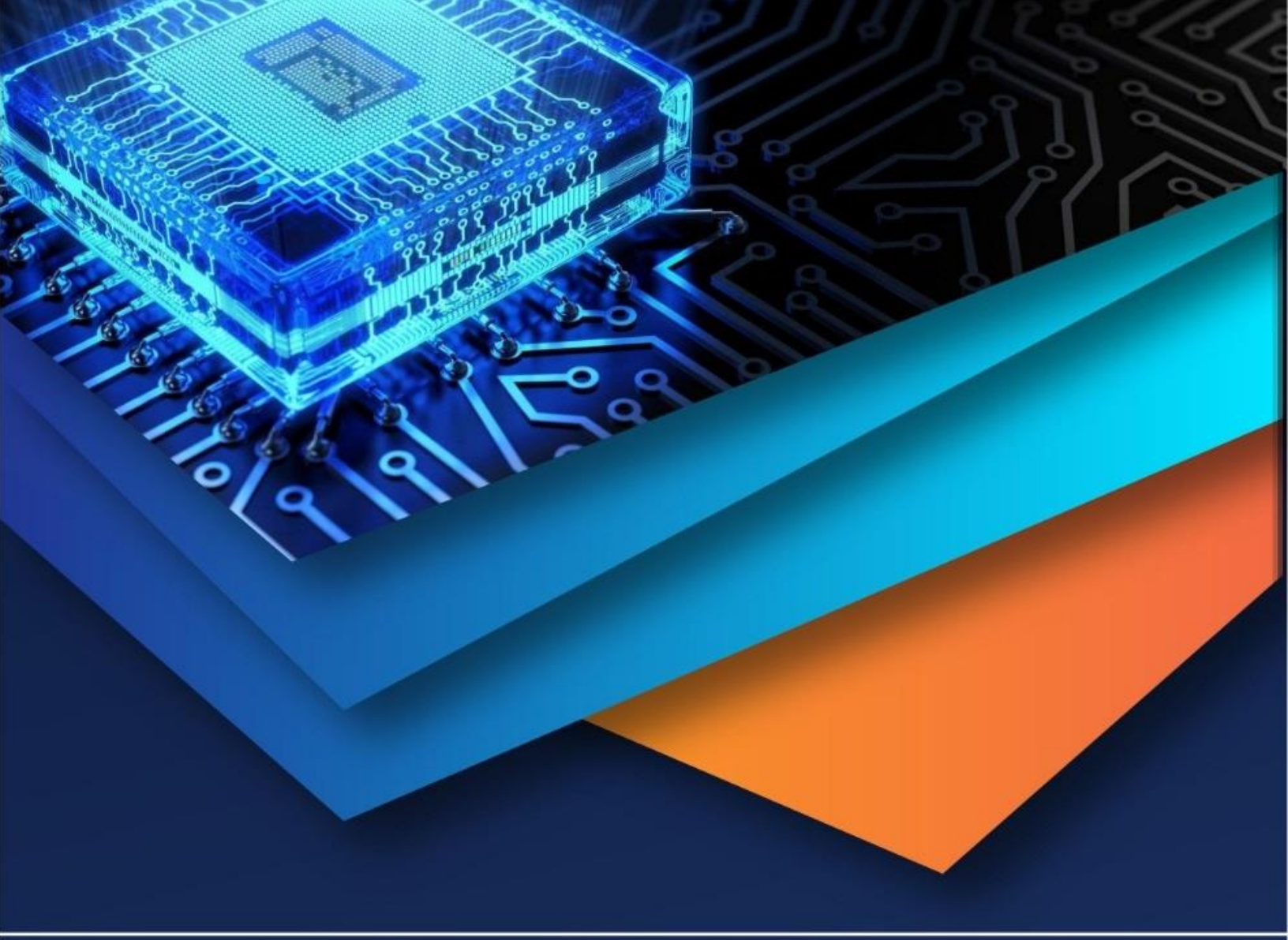

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