iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** VI **Month of publication:** June 2020

DOI: http://doi.org/10.22214/ijraset.2020.6123

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue VI June 2020- Available at www.ijraset.com

Study of Properties of Self-Compacting Concrete with Cement replaced with Aluminum Oxide and Silica Fume

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Abstract: ***Now a days as the urbanization is growing rapidly, there is a need for modern materials for the economic as well as the better quality of construction. As self-compacting concrete itself has various excellent properties such as it is highly flowable, good segregation resistance, low-yield stress, high deformability, and has moderate viscosity. In the below paper, a study of the mechanical and rheological properties of self-compacting concrete (SCC) containing Aluminum oxide and silica fume has been explored. Considering the fresh properties of concrete slump flow test, V-funnel test and L-Box test have been performed. The hard-concrete properties have been conducted by using compressive strength test and splitting tensile strength test. The water absorption of the samples is tested with the water absorption test. Fifteen different amounts of Aluminum oxide (0, 0.25, 0.50, 0.75, 1, 1.25, 1.50, 1.75, 2, 2.25, 2.50, 2.75, 3, 3.25, and 3.50%) as a replacement for the cement were used. The amount of silica fume in all the samples is kept constant. According to the tests, the compressive strength of the specimen containing 2.5% Aluminum oxide as a partial cement replacement after 7, 28, and 90 days is increased by 47, 86 and 84% respectively. The splitting tensile strength of specimens containing 2.5% Aluminum oxide and 10% Silica fume as partial replacement of the cement after 7, 28, and 90 days is increased by 27, 53, and 44% respectively. This is due to the reaction between Aluminum oxide and the cement. The use of 1.75% of Aluminum oxide has reduced the water absorption by 12% and 48% respectively. By using the aluminum oxide and silica fume as a replacement in the concrete mixture in the particular amount, it results in efficient results.***

Keywords*: Self compacting concrete, Aluminium oxide, Silica fume, compressive test, splitting tensile strength, low water absorption, Low-segregation, fresh properties of concrete.*

I. INTRODUCTION

This document is a template. For questions on paper guidelines, please contact us via e-mail. In many projects where the quantity of reinforcement is high and the dimensions of the concrete sections are small, self-compacting concrete can be used as an effective method for the construction.

Self- compacting concrete has a low yield stress, high distortion capacity, good resistance against segregation and tolerable viscosity. When the SCC is poured, it is an extremely fluid mix hence it flows very easily within and around the formwork and it can flow through hurdles and around corners. It mostly levels itself and does not require vibration after pouring and it follows the shape and surface texture of a mold very closely once it is set.

Subsequently, pouring SCC is much less labor-demanding compared to standard concrete mixes. Once the SCC is poured, it is usually similar to standard concrete in specification of its setting and curing time and strength. SCC uses a low proportion of water to become fluid.

It uses less water as compared to the ordinary concrete. Instead, SCC gains its fluid properties from an unusually high proportion of fine aggregate i.e. sand (typically 50%), combined with superplasticizers and viscosity-enhancing admixtures .

Mostly, concrete is heavy and slimy material when mixed. When this concrete is used in construction, it requires the use of vibration to remove air bubbles, and honeycomb-like holes, especially at the surfaces, where air has been cornered during pouring. This kind of air content is not coveted in the concrete. As it weakens the concrete if it is present in it. However, it is arduous and takes time to be removed by vibration, and incompetent vibration can lead to uncharted problems later. Also, some complex forms cannot easily be vibrated.

Hence, SCC is produced to fix this problem as it lacks the need for compaction, therefore downsizing the labor, time, and is a possible source of technical and quality control issues.

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II. LITERATURE REVIEW

As the modernization of the industry is speeding up, the materials that are to be used should also be advanced. Addition of additives make the cement mix more sustainable to the current situation in the market as there is a need for more advanced materials. In this research work, aluminium oxide and silica fume are used in the concrete. As we all know due to the increasing rate of urbanization the use of alumina or aluminium has increased. Alumina is produced from bauxite, an ore that is mined from topsoil in various tropical and sub-tropical regions. In India, the primary aluminium production was 3.39 million tonnes in 2017-2018 while the consumption was 2.08 million tonnes. Alumina conveys quick setting property to the cement but when alumina is added with cement it behaves as a flux and reduces the clinkering temperature which results in weakening the cement. Hence, to maintain the high temperature, alumina should be used in limited quantity.

Silica fume or microsilica, is an amorphous polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles. Pozzolanic reaction occurs between silica fume and the CH, producing additional CSH in many of the voids around hydrated cement particles because of the high surface area of silica fume particles affecting the manoeuvrability of water within concrete, segregation and bleeding of concrete is eradicated.

III.METHODOLOGY

A. Materials Required.

The materials used are gravel, sand, water, cement, AL_2O_3 and silica fume and superplasticizer. River sand with a density of 2600kg/m^3 and 3.2% water absorption is used. Gravel is a crushed stone type with maximum nominal size of 19mm and water absorption of 1.01% and density of 2670 kg/m^3. The cement used is ACC concrete cement of 53 grade. The value of initial setting time and final setting time is 34 min and 365 min, respectively. The water used for the mixing of the concrete is potable drinking water.

The AL_2O_3 used in this experiment is in powder form. The average size of AL_2O_3 particles is 20 mm. The colour of the powder is white. The particles have a specific surface of 138 m^2/gm and a density of 3890 kg/m^3

Components (%)	Cement grade 53	Silica Fume
SiO_2	21.27	94.6
AL_2O_3	4.95	1.32
Fe_2O_3	4.03	0.87
CaO	62.95	0.49
MgO	1.55	0.97
SO_3	2.26	0.1
K_2O	0.65	0.01
Na_2O_3	0.49	0.31

Table 1 Chemical properties of cement grade 53

Component	Amount
AL_2O_3	≥99%
Ca	≤25 ppm
Fe	≤80 ppm
Cr	≤4 ppm
Na	≤70 ppm
Mn	≤3 ppm
Co	≤2 ppm

Table 2 Chemical component of Al_2O_3

The silica fume used in the work is used which is locally available in the market. The chemical properties of 53 grade cement and silica fume is given in table 1. The detail chemical composition of AL_2O_3 is given in the Table 2. The superplasticizer used in the work is POLYTANCRETE SF manufactured in Sunanda chemicals, Mumbai which is mixed in the pre-wetted concrete mix, at a rate of 0.4 to 0.8 % by wt. of cementitious material. The materials required for the work used is as shown in figure 1

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Figure 1- Materials used.

B. Mixed Design Of Concrete

In this research work, to reduce the amount of cement that is used and to keep the adhesive volume of the cement constant, silica fume is used as a partial cement replacement. Previous studies introduced about 10% of silica fume as an optimum percentage of cement replacement. Hence, 10% of silica fume was replaced with cement in all the mix design. The mix design's constituents with their magnitude is given in table 3

Mix	C	W	SF	S	G	AL_2O_3	SP
NA 0	350	168	35	960	920	0	2.76
NA 0.25	314.125	168	35	960	920	0.875	2.86
NA 0.5	313.25	168	35	960	920	1.75	2.93
NA 0.75	312.375	168	35	960	920	2.625	3.03
NA 1.00	311.5	168	35	960	920	3.5	3.35
NA 1.25	310.625	168	35	960	920	4.375	3.46
NA 1.5	309.75	168	35	960	920	5.25	3.89
NA 1.75	308.875	168	35	960	920	6.125	4.03
NA 2.00	308.0	168	35	960	920	7	4.12
NA 2.25	307.125	168	35	960	920	7.875	4.45
NA 2.50	306.25	168	35	960	920	8.75	4.89
NA 2.75	375.305	168	35	960	920	9.625	4.92
NA 3.00	304.5	168	35	960	920	10.5	4.65
NA 3.25	304.40	168	35	960	920	9.765	4.64
NA 3.5	304.10	168	35	960	920	9.102	4.60

Table 3 -Mix properties of specimens(kg/m^3)

The concrete was prepared in the concrete mixer. Initial, gravel and sand were mixed in the concrete mixer, after the mix becomes homogenous half of the amount of water was mixed as per the mix design which was used, and the mixing was continued. After proper mixing of the mix, cement, silica fume and 10% of the mixing water was added to the mixture and the mixing was being continued in the concrete mixer. Finally, AL_2O_3 and the remaining water was added. For obtaining the SCC, the superplasticizer 8was added gradually. Adding the additives during the mixing may not be suitable for the desired chemical effects may sometime require to delay.

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C. Fresh Concrete Tests



(a) (b) (c)

Figure 2-Fresh concrete tests.

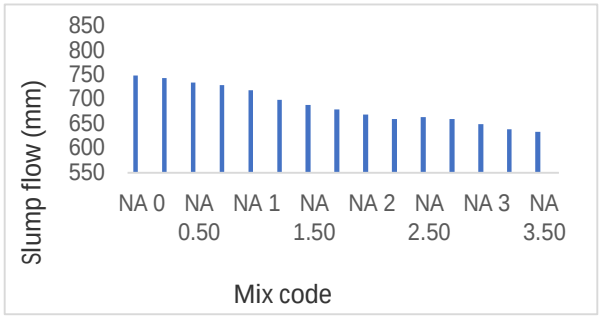
a. slump flow **b**. L-box **c**. V-funnel

Fresh concrete tests were carried out for this experiment were slump flow, T-50, V-funnel and L-box as shown in the above figure 2 The flowability of the SCC is determined by the slump flow test, viscosity is determined with T50 and V- funnel. However, the passing ability was resolved through the L-Box test. In the slump test, SCC is measured after flowing of concrete on the slump plate which shows the fluidity of the concrete. With L-box test, the height of the fresh SCC is measured after passing through the specific intervals between the steel bars, and the flow is measured in one way, and its passing power and blockage are estimated. The V-funnel is measured for determining the filling ability and concrete viscosity.

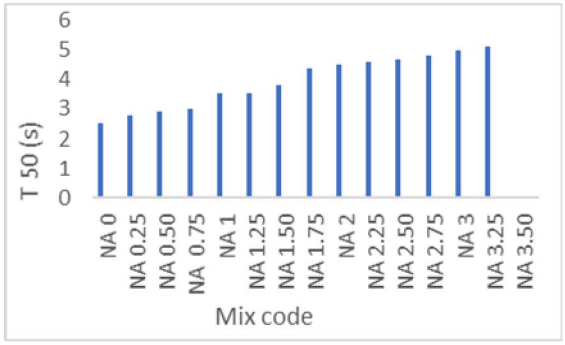
D. Hardened Concrete Test

Compressive strength, tensile strength and water absorption percentage test were conducted to investigate the mechanical and physical behaviour of concrete specimens. Compressive strength and tensile strength tests were carried out at 7,28 and 90 days. Water absorption test specimens were tested after 28 days of curing condition.

IV. RESULTS

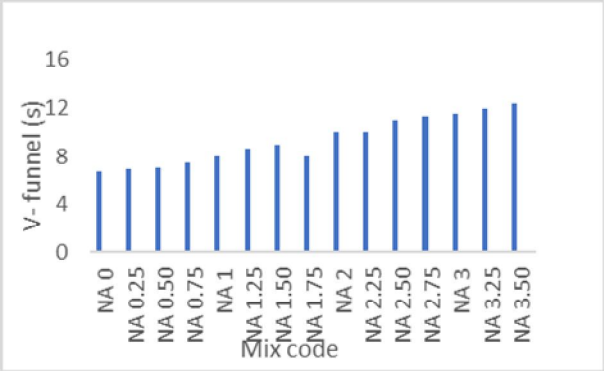


(a)

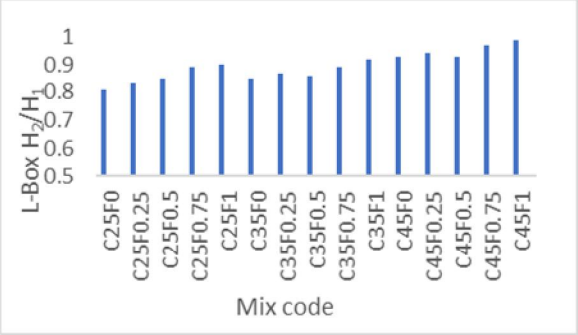


(b)

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(c)



(d)

Fig. 3 Fresh concrete test results **a** slump flow, **b** T50, **c** V-funnel, **d** L-box

A. Fresh Concrete Tests

Fresh concrete test results are presented in figure 3. The Slump flow test is evaluated with the observation of concrete spreading diameter, which shows the yield stress of fresh concrete. According to the Indian standards, if the average value of the 2 dimension is less then550 mm, then the yield stress of the fresh concrete is high and its workability is low and if the average value of the 2 diameter is greater than 850 mm, the yielding stress is low and there is a possibility of segregation. The slump flow of all the mixes ranged from 663 to 749 mm, which is very suitable for regular concrete work. It is observed that the all the mixes had very good flowability due to good aggregate gradation, proper mixing and suitable amount of plasticizer. The mixes which contained AL_2O_3 and silica fume were observed then their slump was less than the controlled specimen this is due to the softness of AL_2O_3 and silica fume. Aluminium dioxide and silica fume enhanced the properties of the concrete like filling, bonding and evenness of the concrete, and it also reduced its diffusion diameter of concrete in slump flow.

Good workability is obtained with the use of super plasticizer.

The self-compacting concrete should be checked in terms of viscosity. The viscosity is tested with the use of V-funnel passing time and T50 test. the concrete passing through the V-funnel showed homogeneity of concrete in all cases,

The L-box test evaluated the blockage due to the presence of the bars and indicated the passing ability of SCC through the tight intervals through the bars. The stoppage ratio in all the mixtures was in the range of 0.8-1. The mixtures with this range will have a good passing ability. All the fresh concrete test was carried out in an appropriate time interval from the addition of super-plasticizer and the super-plasticizer did not lose its effect.

B. Hardened Concrete Tests

In the experiment, the compressive and tensile strength were conducted at the age of 7,28, and 90 days in the presence of various percentages of AL_2O_3. The result is given in the table 4. Compressive strength of the concrete was increased by increasing the amount of AL_2O_3 and increasing the age of concrete. According to the table 4, the compressive strength of the specimen containing 2.5% AL_2O_3 after 7,28, and 90 days is increased by 48,88, and 86% respectively. The reason for this increase in the strength is due to the reactivity of AL_2O_3 with Portland cement during the hydration process of cement. As AL_2O_3 is in fine powder form, it fills the cavities in the cement gel and improves the compressive strength. The percentage increase in compressive strength

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The percentage increase in the splitting tensile strength in comparison with the control specimens is presented in Table 4.
The water absorption of the specimens after 28 days for 13 concrete mixtures is presented in Figure 6. As it is observed, the more the use of AL_2O_3 in all mixtures the less is the water absorption process.

Mix	Compresive strength (Mpa)			Spliting tensile strength(Mpa)		
	Days			Days		
	7	28	90	7	28	90
NA 0	20.7	25.66	28.89	2.74	2.84	3.63
NA 0.25	21.88	26.84	30.07	2.81	2.91	3.7
NA0.50	23.76	28.72	31.95	2.84	2.94	3.73
NA 0.75	24.61	29.57	32.8	2.85	2.95	3.74
NA 1	25.62	30.58	33.81	2.86	2.96	3.75
NA 1.25	25.79	30.75	33.98	2.87	2.97	3.76
NA 1.50	26.68	31.64	34.87	2.93	3.03	3.82
NA 1.75	27.57	32.53	35.76	3.14	3.24	4.03
NA 2	28.64	33.6	36.83	3.34	3.44	4.23
NA 2.25	29.31	34.27	37.5	3.36	3.46	4.25
NA 2.50	30.29	35.25	38.48	3.54	3.64	4.43
NA 2.75	29.52	34.48	37.71	3.44	3.54	4.33
NA 3	29.41	34.37	37.6	3.35	3.45	4.24
NA 3.25	29.13	34.09	37.32	3.25	3.35	4.14
NA 3.50	28.99	33.95	37.18	3.15	3.25	4.04

Table 4- Hardened Concrete Test Results- (compressive strength and tensile strength)

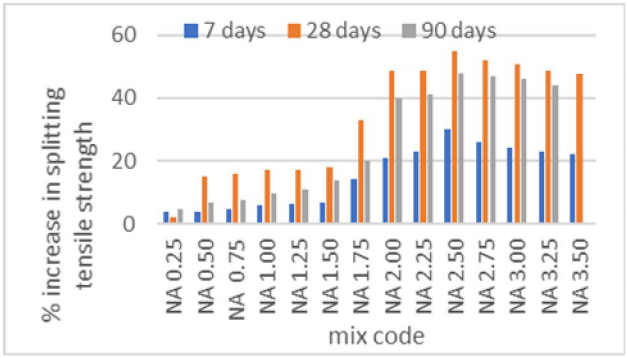


Figure 4- Percentage increase in splitting tensile strength

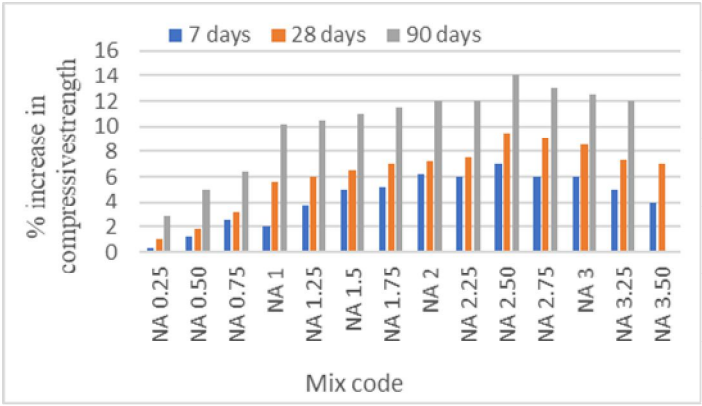


Figure 5- percentage increase in compressive strength

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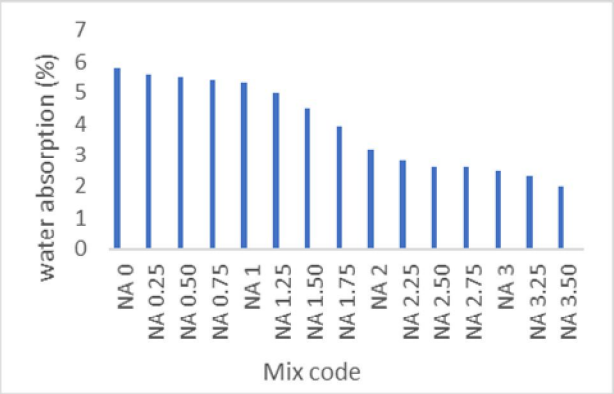


Figure 6- Percentage indicating the water absorption

V. CONCLUSION

In the above research, the behaviour of mechanical and rheological properties of Self-compacting concrete containing AL_2O_3 and silica fume are studied. Compressive strength, tensile strength and water absorption percentage test were conducted to investigate the mechanical and physical behaviour of concrete specimens. According to the results obtained from the experiments, the following conclusion can be presented as:

A. Increasing the AL_2O_3 reduced the fluidity, increases the yield stress, and reduces the filling ability of Self compacting concrete. The properties of the fresh SCC are achieved by using super-plasticizer. Good workability is achieved by the addition of super-plasticizer.

B. The increase in AL_2O_3 powder increases the homogeneity and consistency of concrete. Due to the higher effective surface and more water absorption, AL_2O_3 reduces the efficiency and increases the strength against fluidity and viscosity.

C. Compressive strength is increased by the increasing amount of AL_2O_3 and increasing age of concrete, it is maximum when AL_2O_3 amount is 2.5% and after that the reduction in the compressive strength is observed.

D. The surface area gets cracked of the specimens without no AL_2O_3 in comparison with the specimens containing AL_2O_3, this is due to the powder form of AL_2O_3 which affects the concrete matrix and reduces its cracking.

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V. CONCLUSIONS

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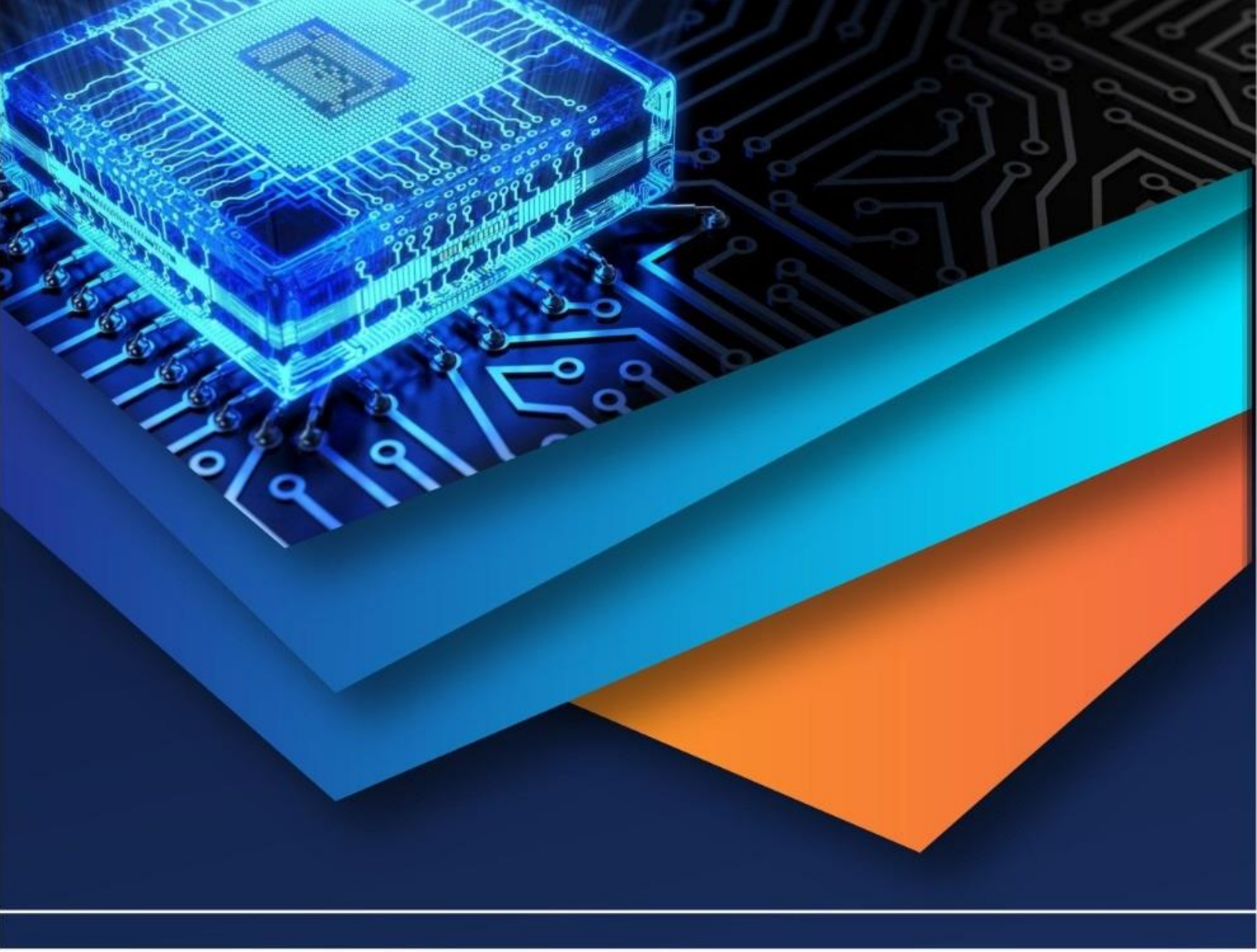
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