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Experimental Investigation to Check the Properties of Concrete by Using Clay and Alum as Supplementary Cementitious Materials

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Abstract: ***Concrete is one of the most popular construction materials used since hundred years ago. Concrete production needs natural resources like water, coarse aggregates, fine aggregates and cement, whose production is costly due to natural resources and energy required.***

Cement manufacturing is recognized to be major source of CO_2 emission in atmosphere and responsible for air pollution. Several studies have been carried out to investigate the possibility of using dissimilar materials for partial replacement of cement in concrete to reduce pollution and achieve healthy environment.

By considering all these aspects and need, Alum, Kaolin clay and Bentonite clay can be beneficial as partial replacement of cement in concrete. The present paper is an effort to quantify the 7 and 28 days cementitious efficiency of Alum, Kaolin clay and Bentonite clay in concrete at the various replacement levels with the help of literature review found and studied. This paper consists of a complete study of concrete strength by partial replacing the cement by using clay and Alum.

These all replacements have been tested for 7 and 28 days to conclude the strength parameters. Utilization of natural materials as partial replacement of cement with an intention to develop an Eco-friendly concrete having similar or higher strength.

Keywords: Alum, Kaolin clay, Bentonite clay, Ordinary Portland cement (Grade 53)

I. INTRODUCTION

Every year, there are huge demands of components of the raw materials for the production of Ordinary Portland cement concrete turning into to extensive exploring natural resources. Efforts have been made to recycled, cheaper, environment friendly materials worldwide to produce durable, high strength life cycle, cost effecting long lasting concrete. Therefore, it is always encourages to find new technologies for the construction industries.

The construction industry has taken considerable strides forward over the last two or three decades with regard to trials in the use of one or another Cementitious materials generally identified as Pozzolanas, for the compounding of various cement based products. These have not only resulted an improving the compressive strength value attained thereby but also in qualities like ability to set and harden under water. Among these coal fly-ash, blast furnace slag, rice hulk ash, silica fume, or meta-kaolin are the most common ones. Other like gypsum, gypsum fines, Portland cement, cement kiln dust, lime dust, stone dust, and Calcined clay are also in use, due to economic and environmental concerns, different methods of making cement products are being considered. It is thought that some substances like Alum, Kaolin clay and Bentonite clay will be beneficial to some properties of Portland Cement Concrete (both fresh and hardened).Such as segregation and compressive strength since the particles of Kaolin are fine so when it is wet, it is sticky and preventing the segregation and suspending the aggregate uniformly. Bentonite clay is having swelling properties so when it is wet, it swells and filled up the air voids in concrete to avoid cracks in concrete. Alum (Aluminium sulphate) is mostly used as an accelerator for concrete. Alum is a major component in concrete accelerator and wide application in concrete as waterproofing agent, expansive and accelerator.

II. SCOPE AND OBJECTIVES

A. Scope

Environmental pollution is the major issue due to emission of different environmental pollutants, during the process of cement manufacturing thus affecting the quality. The cost of the cement and other materials is also increasing day by day. So it has become necessity to find an alternate material for cement that cement can be replaced fully or partially.

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B. Objectives

The main objectives are

1) To study about the effects of Alum individually (a chemical compound), Kaolin and bentonite clay mix (pozzolona materials) and

2) Combination of these three materials means chemical compound and pozzolona materials together on concrete.

3) This is tend to enhance the properties of concrete and to minimize the use of conventional materials at some extent

III. MATERIAL SPECIFICATIONS

A. Ordinary Portland cement

The main binder used in this experimental study is Ordinary Portland cement of 53 Grade conforming to IS 12269:1987 was used. The properties of cement were tested as fineness 5%, Normal consistency 30%, initial and final setting time 45 min and 330 min by considering IS 4031:1968

B. Fine aggregates

Fine sand passing through 4.75 mm IS sieve, conforming to grading Zone-II of IS 383-1970 was used. Physical properties were fineness modulus- 2.39, specific gravity-2.65, and Water absorption – 1.4%.

C. Coarse Aggregates

Coarse aggregates with nominal size 20 mm as per IS: 2386-1963(part-I, II, III) were used. The physical properties of aggregates were fineness modulus-7.28, specific gravity- 2.76, water absorption-1.47%.

D. Alum

Alum is prepared from its naturally occurring minerals such Alunite, and Retinitis, but in India these do not occur in appreciable quantities. Aluminium Sulphate commercially known as Alum is white powder, having many industrial uses. Basically Al2 (SO4)3 is a chemical agent and mostly used in water purification, pH regulation of garden soil, and other commercial or industrial applications. Alum (Aluminium sulphate) is a major component in concrete accelerator and wide application in concrete as waterproofing agent, expansive and accelerator. Chemical properties and chemical composition of Alum as given in table no.1 and table no.2

Table no.1.Chemical properties of Alum

Sr.no	Properties	Values and content
1	Molecular formula	$[(A1_2(SO_4)_3 \cdot 18H_2O)]$
2.	Specific gravity	2.34-2.45
3.	Density	2.71 g/ml

Table no.2.Chemical composition of Alum

Al_2O_3 (%)	PH	Insoluble matter (%)
16.2	3.2	0.12

E. Kaolin Clay

Kaolin clay commonly referred to as china clay, is a clay that contains 10-95% of mineral Kaolinite and usually mainly consists of Kaolinite (85-95%).Kaolin usually contains Kaolinite, Quartz, Mica and in less quantity Quently, Feldspar, Illite, Montemorillonite, Ilmenite, Anastase, Haematite, Bauxite, Zicron, Rutil, Kyanite, Silliminate, Graphite, Attapulgite and Holloysite. Kaoline is insoluble in water but darkens and develops an earthy odour when wet. Basically Kaolin clay is odourless. Kaolin is basically very fine clay so it is added after the water and initial mixing. This was done to keep the kaolin from the coating in aggregate or clumping together. Partical size of kaolin clay is between silica fumes and the fly ash. Fly ash partical size is almost 25-26µ and silica fumes partical size is nearer to 0.3-0.4µ and Kaolin clay partical size is 1.5-2.0µ. So when this clay is mixed with cement in concrete as fine particles, it increases the shrinkage and reduces compressive strength so it is used with sand and water for better results. When it is wet, it sticks, preventing the segregation of aggregates and suspending the aggregate uniformly. Chemical and physical properties of Kaolin clay are given in table no.3. Chemical composition of Kaolin clay is given in table no.4.

Table no.3.Chemical and physical properties of Kaolin clay

Sr. no	Properties	Values and content
1.	Molecular formula	$Al_2SI_2O_5(OH)_4$
4.	Specific gravity	2.65
5.	Liquid limit	54%
6	Plastic limit	29.2%
9.	Colour	White, yellowish, greyish

Table no.4.Kaolin clay powder Chemical composition (Weight %)

SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	TiO_2	Na_2O_3	LOI
49.7	35.1	0.6	0.2	0.07	1.36	0.95	0.08	11.8

F. Bentonite Clay

Bentonite is a rock formed of high colloidal and plastic clays. This rock mainly composed of montemorillonite, a clay mineral of smectite group. Smectite group is subgroup of phyllosilicate group and silicate group.Bentonite usually forms from weathering of volcanic ash, most often in the presence of water. The transformation of volcanic ash to bentonite clay basically takes place in presence of water only. In addition to Montemorillonite, Bentonite also contains Feldspar, Biotite, Kaolinite, Illite, Cristoballite, Pyroxene, Zircon and Crystalline Quartz. Bentonite clay is having two types: Sodium Bentonite and Calcium Bentonite. Sodium bentonite is usually referred to as bentonite, whereas calcium bentonite is called Fuller's earth. Bentonite feels greasy and soap like in touch. Freshly exposed bentonite is white to pale green or blue, turns darken with the time to yellow, brown or red. Sodium Bentonite [Al_2 H_2 Na_2 O_{13} Si_4] is usually termed as Bentonite. Sodium bentonite, also called swelling bentonite; and calcium bentonite, also called non-swelling bentonite. It has ability to form thixotrophic gels with water, an ability to absorb large quantity of water with an increase in volume of as much as 12-15 times its dry volume. Swelling property of sodium bentonite clay is shown in figure no.1. Also chemical, physical properties and chemical compositions are given in table no.5 and 6.

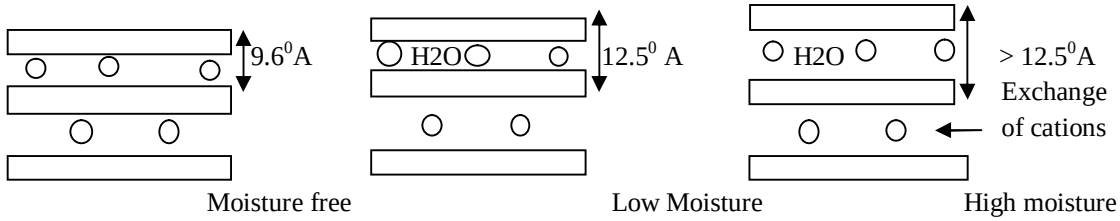

Fig no.1.Swelling action of sodium bentonite clay

Table no.5.Chemical and physical properties of sodium Bentonite clay

Sr.no	Properties	Values and content
1.	Molecular formula	[$Al_2H_2Na_2O_{13}Si_4$]
2	Specific gravity	2.55-2.67
3	Bulk density	1810 kg/m3
4	Water absorption	1%
5	Fineness modulus	3.07
7.	Colour	White,yellow colour
8.	Swelling capacity	60%

Table no.6.Chemical composition of bentonite clay

SiO2(%)	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	Other	Heat loss
49.634	21.118	3.235	3.591	0.65	0.449	2.091	0.498	0.44	8.22

G. Water

According to IS 3025(part 21)-2009, water to be used for mixing and curing should be free from injurious or deterious materials. Potable water is generally considered satisfactory. In the present research work, water available within campus is used for both mixing and curing purposes.

IV. CONCRETE MIX DESIGNING

Based on trial mixes for different proportions of ingredients, the final design mix was prepared for M20 grade concrete as per 10262-2009. The mix proportion was 1:1.72:2.93 with water cement ratio 0.5.

Table no. 7. Concrete mix design

Sr no.	Materials	Kg/m3 of concrete
1	Cement	396
2	Fine aggregates	684
3	Coarse aggregates	1162
4	Water	186

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V. CASTING OF SPECIMENS

The specimens were casted as per calculated mix design. In casting of specimens, Alum, Kaolin and Bentonite mix and Alum, Kaolin clay and Bentonite clay mix were used in proportions as given below-

Alum was used as 3%, 5% and 7% for replacement of cement.

Kaolin clay and Bentonite clay mix was used as 3%, 5% and 7% for replacement of cement.

Alum, Kaolin clay and Bentonite clay mix was used as 3%, 5% and 7% for replacement of cement. These all replacements were done by considering weight of cement.

The different specimens like cubes, cylinders and beams as per requirement of work were casted. Cubes of size 150 mm X150mm X 150mm, cylinders of sizes 150 mm X 300mm and beam of sizes 100mm X100mm X 500mm.the samples were kept in a water tank for 7 and 28 days curing.

Fig no. 2.Casted specimens

VI. SPECIMEN DESIGNATION

9 replacements were prepared, which varied according to the following parameters: specimens are casted according to their adding percentages in concrete.

Specimen cast without adding Alum, Kaolin clay and Bentonite mix and Alum, Kaolin clay and Bentonite mix are designated as M-0, where M represents the Mix or addition. Mixes are as given in table no.8

Sr no	Mixing percentages	Alum	Mixing percentages	Kaolin clay and Bentonite clay mix	Mixing percentages	Alum, Kaolin clay and Bentonite clay mix
1	M-0	0%	M-0	0%	M-0	0%
2	M-3A	3%	M-3KB	3%	M-3KBA	3%
3	M-5A	5%	M-5KB	5%	M-5KBA	5%
4	M-7A	7%	M-7KB	7%	M-7KBA	7%

Table no. 8. Mix percentages of materials

VII. TESTING OF SPECIMENS

Workability test of conventional concrete and cementatious materials mixed concrete were performed with the help of slump cone apparatus and Compressive strength, split tensile strength were found on compression testing machine while flexural strength were found on universal testing machine.

Fig no. 4.testing of cube

VIII. RESULT AND DISCUSSIONS

A. Workability Test

Workability of concrete mixtures was measured by performing slump cone test.

The variation in slump of different % replacement of Alum, Bentonite clay and Kaolin clay mix and Alum, Kaolin clay and Bentonite clay mix in concrete is given as below-

Table no.9.Workability in terms of slump (mm)

Sr no.	Mix proportions	Slump values in mm		
		Alum	Kaolin clay + bentonite clay mix	Kaolin clay + bentonite clay +Alum mix
1	0%	68	68	68
2	3%	70	66	67
3	5%	72	65	65
4	7%	7 1	62	63

When cement is replaced with different proportion of Alum in concrete, the workability is increased with increasing adding percentages of Alum. No segregation and bleeding were observed. Hence the addition of Alum reduces the water demand of OPC and enhanced the workability because water –cement ration is kept constant for all proportions.

When cement is replaced with different proportions of Kaolin clay and bentonite clay mix in concrete, the workability is decreased with increasing adding percentages of Kaolin and Bentonite clay mix. No segregation observed but bleeding was observed. This is due to extra fineness of both clays in concrete mix. Bleeding was observed because of excess water addition and extra fine structure of clay. When cement is replaced with different proportion of Kaolin clay and bentonite clay and Alum mix in concrete, the workability is decreased with increasing adding percentages of Kaolin, Bentonite clay and Alum mix. If adding proportion of alum is increased, it may cause workability increase. But adding percentages of bentonite clay is high as compared to others, concrete respond more like bentonite concrete and shows decreases result

.

B. For OPC

Test results of strength parameters for conventional OPC cubes, cylinders and beams are as given below

Sr no.	Days	Compressive strength	Split tensile strength	Flexural strength
1	7	14.35	2.10	3.22
2	28	28.25	2.48	4.25

Table no. 10. OPC tests results

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C. Compressive Strength

We have tested cubes specimens of Alum, Kaolin clay and Bentonite clay mix and Alum, Kaolin clay and Bentonite clay mix for various proportions for 7 and 28 days. And the results are as given below-

Days	7 days			28 days		
Mix proportions	Alum	Kaolin clay + Bentonite clay mix	Alum+ Kaolin clay+ Bentonite clay mix	Alum	Kaolin clay + Bentonite clay mix	Alum+ Kaolin clay+ Bentonite clay mix
M-3	13.68	13.10	13.69	28.56	28.264	28.92
M-5	15.10	14.35	14.56	29.5	29.006	29.261
M-7	14.658	15.50	15.68	28.96	29.460	29.86

Table no.11.Results of compressive strength of materials

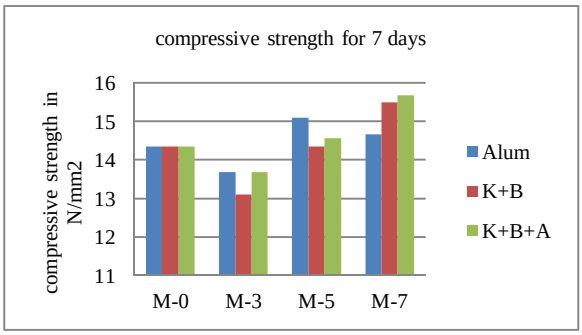

Fig no.5.Compressive strength for 7 days

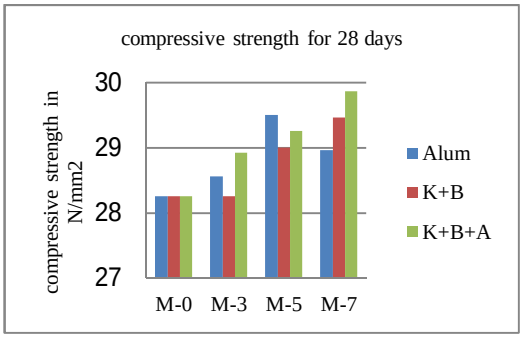

Fig no.6.Compressive strength for 28 days

1) 5% of Alum replacement with cement gives better result for compressive strength for 7 days and 28 days.
2) 7% of Kaolin and Bentonite clay mix replacement with cement gives better result for compressive strength for 7 and 28 days.
3) 7% of Alum, Kaolin and Bentonite clay mix replacement with cement give better result for compressive strength for 7 and 28 day.

D. Split Tensile Strength

We have tested cylinder specimens of Alum, Kaolin clay and Bentonite clay mix and Alum, Kaolin clay and Bentonite clay mix for various proportions for 7 and 28 days. And the results are as given below

Days	7 days			28 days		
Mix proportions	Alum	Kaolin clay + Bentonite clay mix	Alum + Kaolin clay +Bentonite clay mix	Alum	Kaolin clay + Bentonite clay mix	Alum + Kaolin clay + Bentonite clay mix
M- 3	2.18	2.05	2.13	2.45	2.50	2.60
M-5	2.24	2.15	2.20	2.65	2.53	2.72
M-7	2.20	2.25	2.35	2.55	2.62	2.80

Table no.12. Split tensile strength for 7 and 28 days

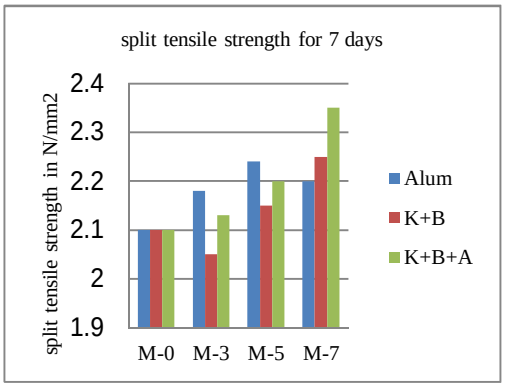

Fig no.6.Split tensile strength for 7 days

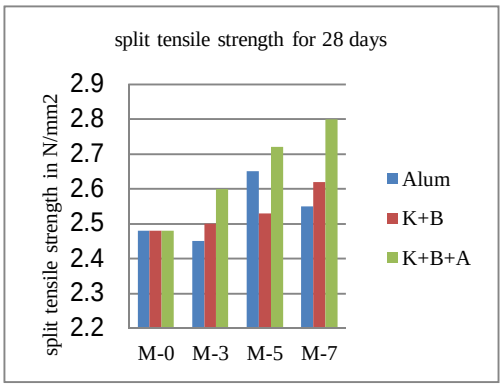

Fig no.7. Split tensile strength for 28day

1) 5% of Alum replacement with cement gives better result for split tensile strength for 7 and 28 days.
2) 7% of Kaolin and Bentonite clay mix replacement with cement give better result for split tensile strength for 7 and 28 days than 3% and 5% replacement.
3) 7% of Kaolin and Bentonite clay mix replacement with cement give better result for split tensile strength for 7 and 28 days than 3% and 5% replacement.

E. Flexural Strength

We have tested of beam specimens of Alum, Kaolin clay and Bentonite clay mix, and Alum, Kaolin clay and Bentonite clay mix of various proportions like 3%, 5% and 7% for 7 and 28 days. And the results are as given below-

Days	7 days			28 days		
Mix proportions	Alum	Kaolin clay + Bentonite clay mix	Alum + Kaolin clay + Bentonite clay mix	Alum	Kaolin clay + Bentonite clay mix	Alum + Kaolin clay + Bentonite clay mix
M-3	3.255	3.32	3.36	3.82	3.96	4.05
M-5	3.52	3.38	3.46	4.35	4.16	4.25
M-7	3.35	3.42	3.60	4.20	4.40	4.50

Table no.13. Flexural strength for 7 and 28 days

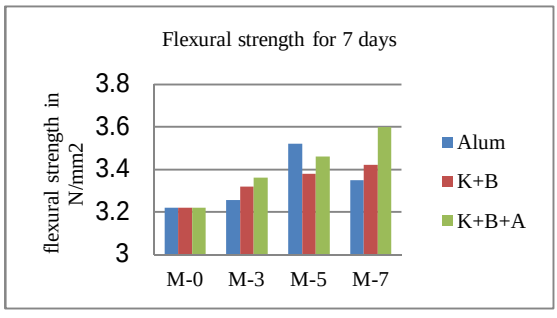

Fig no.8.flexural strength for 7 days

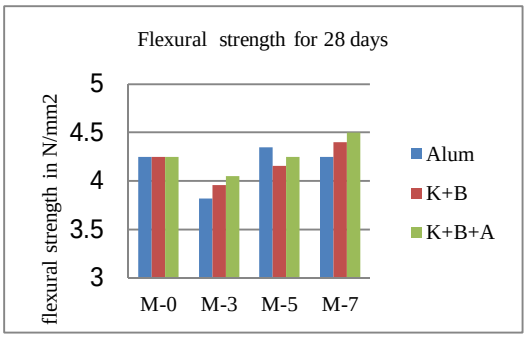

fig no.9.Flexural strength for 28 days

1) 5% of Alum replacement with cement gives better result for flexural strength for 7 and 28 days.
2) 7% of Kaolin and Bentonite clay mix replacement with cement give better result for flexural strength for 7 and 28 days than 3% and 5% replacement.
3) 7% of Kaolin and Bentonite clay mix replacement with cement give better result for flexural strength for 7 and 28 days than 3% and 5% replacement.

IX. CONCLUSIONS

According to results of tested specimens of Alum, Kaolin clay and bentonite clay and combination of Alum, Kaolin clay and Bentonite clay and without addition of any admixture in concrete also gives little better result than OPC concrete.

A. 5% of Alum gives better results in compressive strength, split tensile and flexural strength. By addition of Alum with 5%, increases compressive strength,tensile strength and flexural strength by 0.3-1.75 N/mm2

B. 7% of Kaolin and Bentonite clay mixture addition gives best result in compressive strength, tensile and flexural strength. By addition of this combination, little higher by 1 n/mm2 in strength observed

C. 7% Kaolin clay, Bentonite clay and Alum mixture gives best result in compressive, tensile and flexural strength. By addition of this combination, strength gets little higher by 1.53 N/mm2 as compaired to OPC strength properties.

D. Workability of Alum mixed concrete gives better result for increasing percentages of Alum mix while Kaolin clay and Bentonite clay mix concrete and Alum, Kaolin clay and Bentonite clay mix concrete show decreasing result as percentages of mixing increases.

E. Alum, Kaolin clay and Bentonite clay mixed concrete may give better results as mixed along with admixtures. Addition of admixtures may increase workability of concrete.

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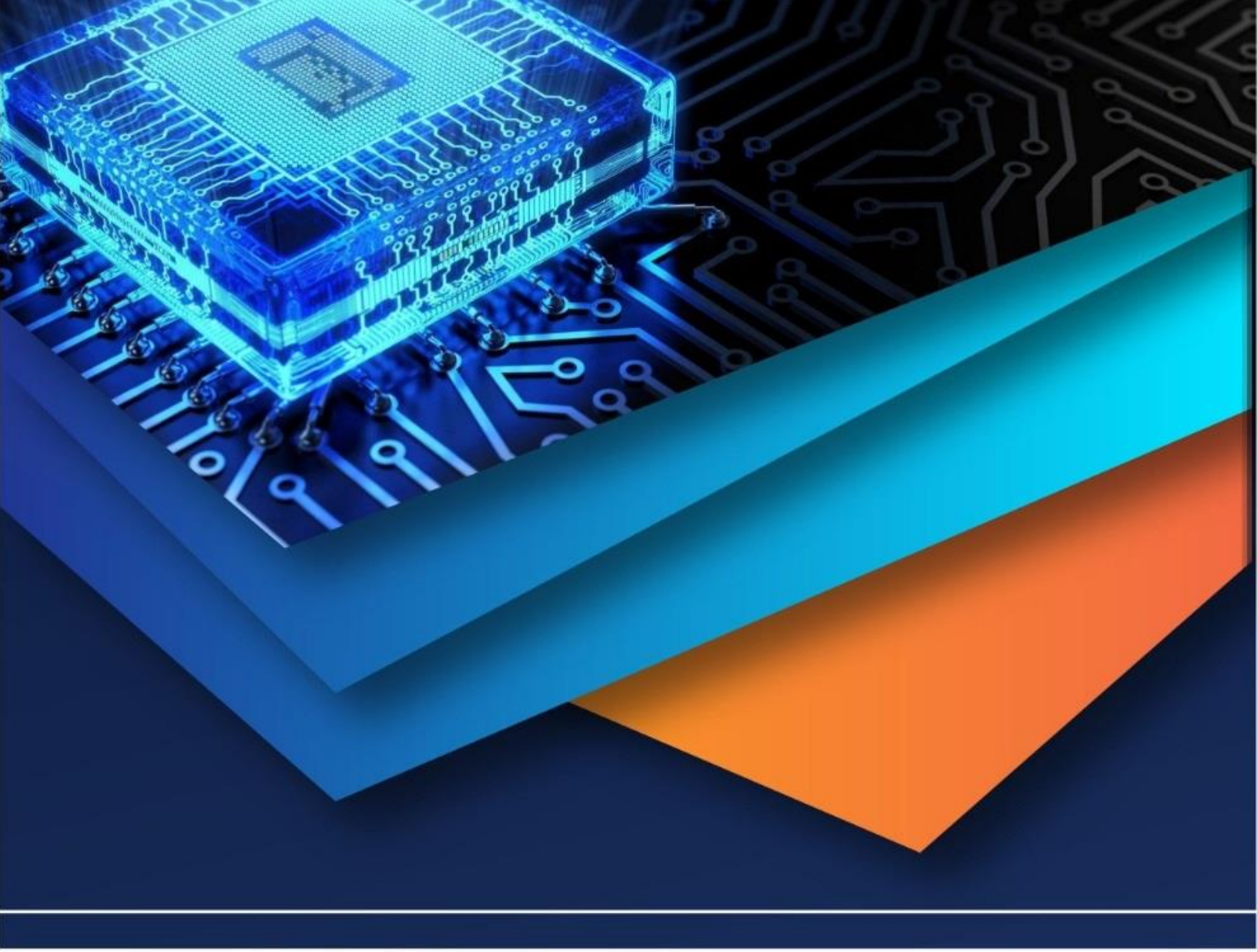

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