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An Alternative for Cement as a Binder – A Comparative Study Based on Compressive Strength and Shear Strength

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Abstract: ***Manufacturing industry is an evergreen industry with opportunities for research and development. One of the important steps in manufacturing is sand casting. Metals are cast into different shapes by pouring molten metal into mould cavities and removing the mould material after the metal has solidified. The mould material commonly used is sand with necessary amount of binders, additives and moisture. Different types of binders will affect characteristics like strength of mould, permeability and refractoriness. Binders play a very key role on the strength of the mould as well. The different types of Binders commonly used are cement, clay, bentonite etc. In this paper, two binders cement and boiler ash shall be compared to check its shear and compressive strength using the universal testing machine. Boiler ash is being used here to check if a waste material can be used to substitute cement as a binder in sand casting. This substitution from cement to ash is highly necessary as the cement industry consumes a lot of non-renewable resources, so this will help to keep a check on the consumption of non-renewable resources. The other reason is to use a waste material like ash in vital processes of manufacturing. The use of a waste product helps clean the environment by avoiding unnecessary dumping. The paper mainly concentrates on shear and compressive strength as these two are the most important factors for the stability of the mould and quality of the cast. The procedure to be followed is to prepare different specimens with cement as the only binder in different percentages, then to prepare a specimen with ash as the only binder in different percentages. The third category will have the combination of ash and cement as the binder in the specimen. The three categories will be compared to see if boiler ash can substitute cement.***
Keywords: Manufacturing, Universal testing machine, Binder, Compressive strength, Shear strength, Mould, Casting

I. INTRODUCTION

With a constant use of foundry in manufacturing process, it becomes highly necessary to use the most optimal products to get the best results. The most used combination in green sand moulding is Silica sand + moisture + binders + additives. The use of binder affects the properties of the mould the most as it produces the cohesion to bind the sand particles imparting strength to the sand. When the molten metal is poured into the sand mould, it is being subjected to various types of forces: tensile, compressive and shear. The reason to concentrate mainly on compressive strength and shear strength is because the stability of cast is high if the compressive and shear strength of the mould is high India is known as the country of industries and the initial step for any of these industries is foundry[1]. Foundry is the most used manufacturing process to produce intricate parts with low cost compared to other manufacturing process, majorly during mould preparation using green sand clay[3]. Binders are the materials used to exhibit their binding properties in sand moulding, commonly used binders used in industries are clay, bentonite, sodium silicate etc. Metal casting is one of the earliest metal shaping method known to human kind. As time passed on there is drastic change in casting the metal, by using more waste products[4]. The binders have certain properties like binding the sand particles of the mould as soon as possible. The harden the mould in a very less time. [5]Cement is a commonly used binder in the foundry industry and in this paper we will compare compressive and shear strength of cement and ash. Major reason for this comparison is to find certain alternative for cement.

II. LITERATURE SURVEY

Aman Singh , Jinendra Singh Chauhan , Pushpendra Kumar Jain (2018) [1] noted that fly ash from thermal and graphite industries are very effective for dry sand molding.They compared the structure of ash and river sand and determined that the permeability and compressibility results are good.

H Srividya Kulkarni , Srivishnu Bharadwaj , Sricharan sudarshan S , Akshay S and Ghaleppa (2018) [2] in their experimental study show that fly ash of type F can replace shell sand by 18% by weight and, fly ash of class C can replace shell sand to 15% by weight without compromising on quality of the casting.

Anca Duta,Cristina Cazan,Mihaela Cosnita (2011) [3] researched about fly ash as a reinforcement agent in developing composites based on recycled rubber and plastics.It shows that using a low amount of fly ash in composites increases the compression by almost three times.

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P. Munusamy,R. Balaji,C. Sivakandhan (2017) [4] in their experimental analysis show that the compression strength of the green sand with fly ash increases up to 14 % and for the clay it increases with the increase in the addition of clay,also aluminium casting components of moderate surface finish are obtained.

P. Karunakaran, C. Jegadheesan, P. Dhanapal, and P. Sengottuvel (2014) [5] found out that several physical properties of sugar industry fly ash and molding sand were similar,their study revealed that 24% fly ash addition to molding sand produced satisfactory surface finish of castings.

Warid Wazein Ahmed Zailaini, Mohd Mustafa Al Bakri Abdullah, Mohd Remy Rozainy Mohd Arif Zainol, Rafiza Abd. Razak, and Muhammad Faheem Mohd Tahir (2017) [6] researched strength of fly ash based geopolymer mortar. It showed that fly ash based geopolymer mortar with 0.5 ratio has a very high strength.It showed observations to prove good binding between sand and geopolymer binder.

.Professor Jerry Sobczak, Mr. Robert M purgert, Balinski andrzej,Darlak Pawel, Stole Maciej, Dr. Natalie Sobszak(2002) [7] have prepared a report on use of fly ash as an aggregate for foundry sand mold and core production. This shows that fly ashes when added upto 20% gives castings of satisfactory quality.

Dr S L Patil, J N Kale,S suman(2012) [8] researched on compressive strength of fly ash concrete.it showed that workability of cement concrete mix increased from 25mm for 0% fly ash to 120mm for 25% fly ash. This research shows that cement having high proportions of fly ash can be near to properties of pure concrete.

III. METHODOLOGY

The objective is to compare the compressive and shear strength of a model by using ash and cement in different percentage with varying moisture content.

The different binders used for the test are- Cement and Furnace ash.

1) *Step 1:* The required amount of silica sand, moisture and the binder are taken and mixed properly.
2) *Step 2:* 150 grams of the mixture is taken into the mixing jar.
3) *Step 3:* The mixing jar is placed below the ramming machine and rammed properly (5 times) to get the required shape of the specimen.
4) *Step 4:* The specimen is placed between the compressive shackles of the universal sand testing machine.
5) *Step 5:* The hand wheel is rotated till the specimen gets destroyed and the compressive strength values are noted.

IV. RESULTS AND DISCUSSIONS

A. *Sand + Moisture + Cement*

The required amount of sand is mixed with a required percentage of cement and moisture. The mixture is rammed and then tested. The following are the results obtained. The maximum compressive strength obtained is 255 g/cm^3. The variation of the percentage of binder and moisture gives us different results.

Sand (g)	Moisture (%)	Cement (%)	Compressive strength (g/cm3) Trial 1	Compressive strength (g/cm3) Trial 2	Average compressive strength value (g/cm3)
168	6	10	180	170	175
158	6	15	190	200	195
148	6	20	260	260	255
164	8	10	140	140	135
154	8	15	180	160	170
144	8	20	180	200	190

Table 4.1: Sand + Moisture + Cement

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1) *Graph:* Variation of compressive strength of sand with cement as a binder with 6% moisture (as shown in blue line) and 8% moisture (as shown in orange line). As we can see in the graph below, for 6% moisture, the compressive strength values increase from 180 to 255 g/cm^3 as the percentage of cement increases from 10 to 20 %. For 8% moisture, the value of compressive strength increases from 135 to 190 g/cm^3 when the percentage of cement increases from 10 to 20%.

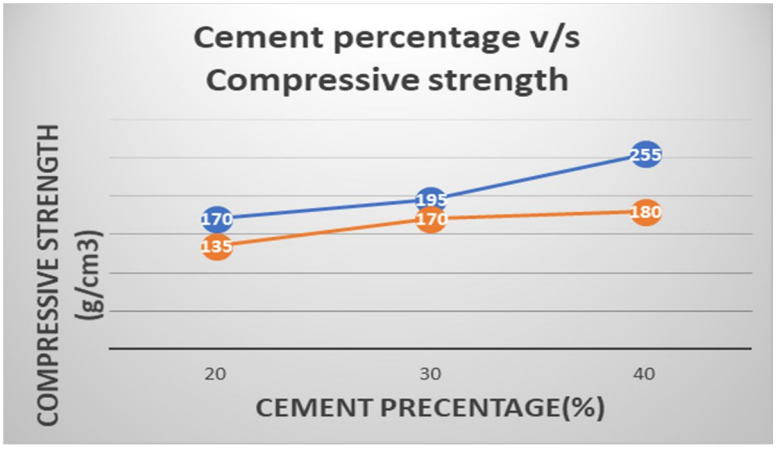

Figure 4.1 Graph between cement percentage and compressive strength

B. Sand + Moisture + Furnace ash

The required amount of sand is mixed with a required percentage of ash and moisture. The mixture is rammed and then tested. The following are the results obtained. The maximum compressive strength obtained is 380 g/cm^3. The variation of the percentage of binder and moisture gives us different results.

Sand (g)	Moisture (%)	Ash (%)	Compressive strength (g/cm3) Trial 1	Compressive strength (g/cm3) Trial 2	Average compressive strength value (g/cm3)
168	6	10	180	200	190
158	6	15	300	320	310
148	6	20	380	380	380
164	8	10	180	180	180
154	8	15	200	220	210
144	8	20	340	320	330

Table 4.2: Sand + Moisture + Furnace ash

1) *Graph:* Variation of compressive strength of sand with ash as a binder with 6% moisture (as shown in blue line) and 8% moisture (as shown in orange line). As we can see in the graph below, for 6% moisture, the compressive strength values increase from 190 to 280 g/cm^3 as the percentage of cement increases from 10 to 20 %. For8%moisture, the value of compressive strength increases from 180 to 330 g/cm^3 when the percentage of cement increases from 10 to 20%.

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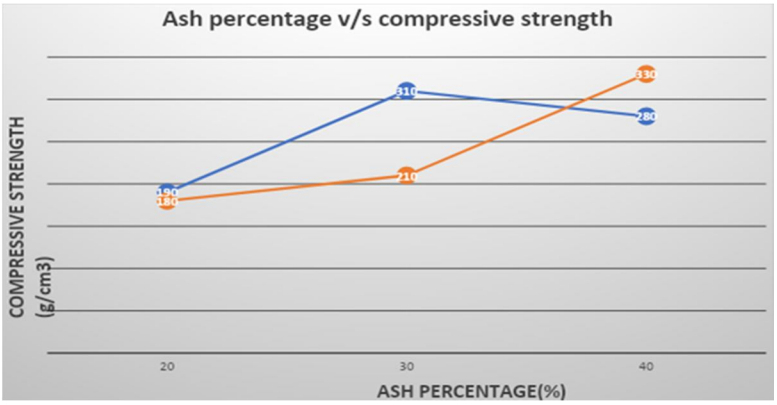

Figure 4.2: Graph between ash percentage and compressive strength

C. Sand + Moisture + Furnace ash (50%) + Cement(50%)-

The required amount of sand is mixed with a required percentage of ash and cement and moisture. The mixture is rammed and then tested. The following are the results obtained. The maximum compressive strength obtained is 270 g/cm^3.

Sand (g)	Moisture (%)	Cement (%)	Ash (%)	Compressive strength (g/cm3) Trial 1	Compressive strength (g/cm3) Trial 2	Average compressive strength value (g/cm3)
168	6	5	5	180	180	180
158	6	7.5	7.5	260	280	270
148	6	10	10	200	200	200
164	8	5	5	140	120	130
154	8	7.5	7.5	180	180	180
144	8	10	10	220	220	220

Table 4.3 : Sand + Moisture + Furnace ash(50%) +Cement(50%)

1) *Graph:* **V**ariation of compressive strength of sand with ash(50%)+cement(50%) as a binder with 6% moisture (as shown in blue line) and 8% moisture (as shown in orange line). As we can see in the graph below, for 6% moisture, the compressive strength values increase from 180 to 200 g/cm^3 as the percentage of cement increases from 10 to 20 %. For 8% moisture, the value of compressive strength increases from 130 to 200 g/cm^3 when the percentage of cement increases from 10 to 20%.

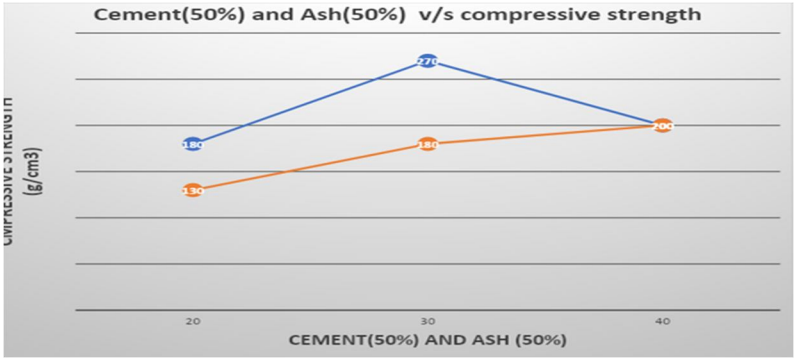

Figure 4.3: Graph between 'Ash + Cement' percentage and compressive strength

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D. Sand + Moisture + Cement

The required amount of sand is mixed with a required percentage of cement and moisture. The mixture is rammed and then tested. The following are the results obtained. The maximum shear strength obtained is 150 g/cm^3. The variation of the percentage of binder and moisture gives us different results.

Sand (g)	Moisture (%)	Cement (%)	Shear strength (g/cm3) Trial 1	Shear strength (g/cm3) Trial 2	Average shear strength (g/cm3)
168	6	10	100	80	90
158	6	15	140	160	150
148	6	20	120	140	130
164	8	10	100	100	100
154	8	15	80	80	80
144	8	20	140	140	140

Table 4.4 shear strength :sand +moisture +cement

1) *Graph:* Variation of shear strength of sand with cement as a binder with 6% moisture (as shown in blueline) and 8% moisture (as shown in orange line). As we can see in the graph below, for 6% moisture, the shear strength values increase from 90 to 130 g/cm^3 as the percentage of cement increases from 10 to 20 %. For 8% moisture, the value of shear strength increases from 100 to 140 g/cm^3 when the percentage of cement increases from 10 to 20%.

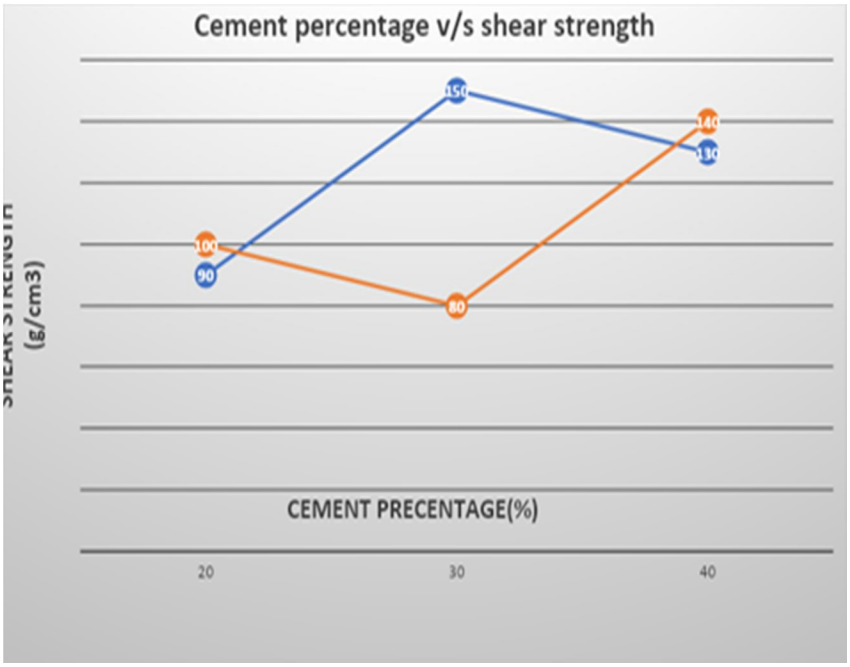

Figure 4.4: Graph between cement percentage and shear strength

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E. Sand + Moisture + Furnace ash

The required amount of sand is mixed with a required percentage of ash and moisture. The mixture is rammed and then tested. The following are the results obtained. The maximum shear strength obtained is 350 g/cm^3. The variation of the percentage of binder and moisture gives us different results.

Sand (g)	Moisture (%)	Ash (%)	Shear strength (g/cm3) Trial 1	Shear strength (g/cm3) Trial 2	Average shear strength (g/cm3)
168	6	10	140	120	130
158	6	15	180	160	170
148	6	20	340	360	350
164	8	10	120	120	120
154	8	15	200	200	200
144	8	20	260	260	260

Table 4.5: Sand + Moisture + Furnace ash

1) *Graph:* Variation of shear strength of sand with ash as a binder with 6% moisture (blue line) and 8% moisture (orange line). As we can see in the graph below, for 6% moisture, the shear strength values increase from 130 to 260 g/cm^3 as the percentage of cement increases from 10 to 20 %. For 8% moisture, the value of shear strength increases from 120 to 260 g/cm^3 when the percentage of cement increases from 10 to 20%

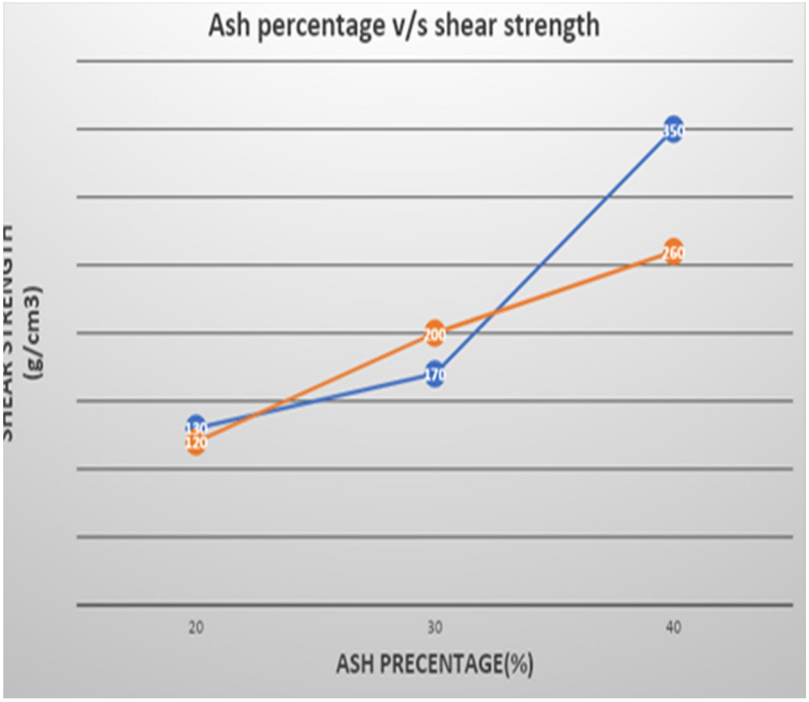

Figure 4.5: Graph between ash percentage and shear strength

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F. Sand+moisture+furnace ash(50%)+cement(50%)

The required amount of sand is mixed with a required percentage of ash and cement and moisture. The mixture is rammed and then tested. The following are the results obtained. The maximum shear strength obtained is 210 g/cm^3.

Sand (g)	Moisture (%)	Cement (%)	Ash (%)	Shearstrength (g/cm3) Trial 1	Shear strength (g/cm3) Trial 2	Average Shear strength value (g/cm3)
168	6	5	5	180	180	180
158	6	7.5	7.5	260	280	270
148	6	10	10	200	200	200
164	8	5	5	140	120	130
154	8	7.5	7.5	180	180	180
144	8	10	10	220	220	220

Table 4.6 : Sand + moisture + Furnace ash(50%)+cement(50%)

1) *Graph:* Variation of shear strength of sand with ash(50%)+cement(50%) as a binder with 6% moisture (as blue line) and 8% moisture (orange line). For 6% moisture, the shear strength values increase from 100 to 210 g/cm^3 as the percentage of cement increases from 10 to 20 %. For 8% moisture, the value of shear strength increases from 100 to 120 g/cm^3 when the percentage of cement increases from 10 to 20%.

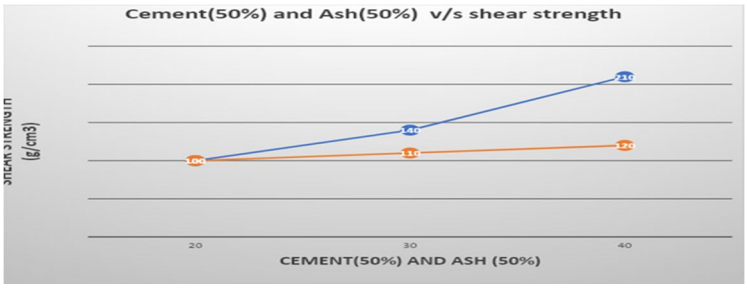

Figure 4.6: Graph between 'Ash+Cement' percentage and shear strength

V. CONCLUSIONS AND FUTURE SCOPE

Analysis of different parameters like permeability, refractoriness, tensile strength which also are also very important properties of moulding sand. Analyse various other binders and find the most optimal binder for foundry purpose.Compressive and Shear strength of moulding sand with cement and Furnace ash as the binder was analysed.

The results obtained are as follows

A. For Compressive Strength

1) *Cement as a binder* – The highest value of compressive strength – 255 g/cm^3 with 6% moisture and 20% cement. The lowest value of compressive strength – 135 g/cm^3 with 8% moisture and 10% cement.
2) *Furnace ash as a Binder*- The highest value of compressive strength – 380 g/cm^3 with 6% moisture and 20% cement. The lowest value of compressive strength – 180 g/cm^3 with 8% moisture and 10% cement.
3) *50 percent of Cement and Ash*- The highest value of compressive strength – 270 g/cm^3 with 6% moisture and 15% cement. The lowest value of compressive strength – 130 g/cm^3 with 8% moisture and 10% cement.
4) Therefore, the compressive strength of Furnace ash is higher than cement.

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B. For Shear Strength

1) *Cement as a Binder* - The highest value of shear strength – 150 g/cm^3 with 6% moisture and 15% cement. The lowest value of shear strength – 80 g/cm^3 with 8% moisture and 15% cement.

2) *Furnace ash as a Binder* - The highest value of shear strength – 350 g/cm^3 with 6% moisture and 20% cement. The lowest value of compressive strength – 120 g/cm^3 with 8% moisture and 10% cement.

3) *Cement (50%) + Furnace Ash (50%)* - The highest value of shear strength – 210 g/cm^3 with 6% moisture and 20% cement.

4) The lowest value of compressive strength – 100 g/cm^3 with 8% moisture and 10% cement. Therefore, the shear strength of Furnace ash is higher than cement.

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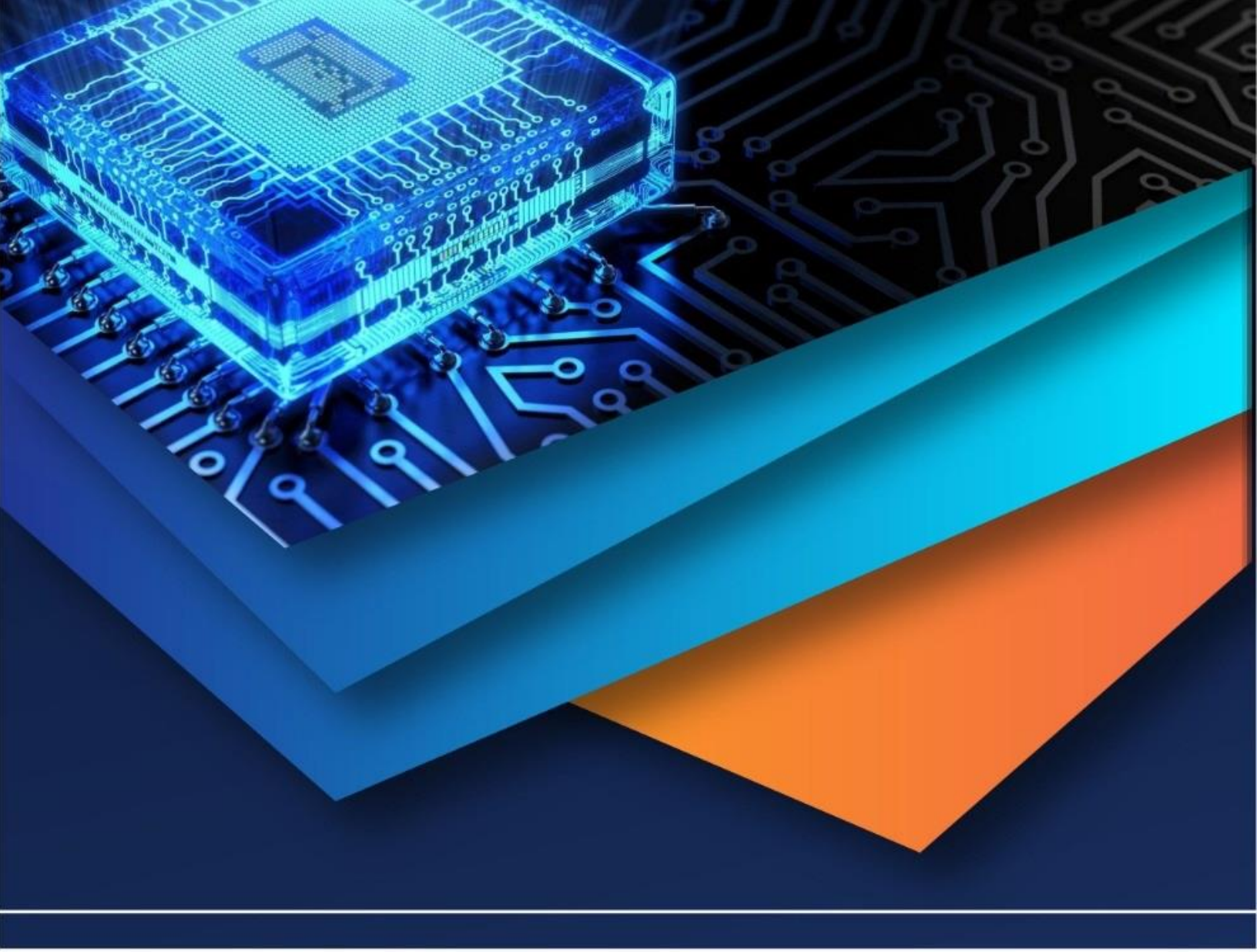

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