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Revolutionizing Construction - Harnessing the Power of Brick Kiln Dust as a Sustainable Cement Alternative

Suehail Aijaz Shah[1], Dr. Umer Mushtaq[2]
Government Polytechnic College Budgam, Nagam – Chadoora, Budgam JK(UT), India

Abstract: The concrete industry stands as the preeminent colossus within the realm of industrial domains. The building and construction industry, a primary contributor to environmental issues, is constantly seeking innovative approaches to enhance sustainability. Bricks forming the building block of the building structures are being manufactured worldwide. A substantial volume of fine particle dust is produced during the production step in the form of leftovers. This dust is the by-product of firing clay bricks at high temperature and the residual ash of the induced fuel. Brick Kiln dust poses environmental challenge due to disposal complexities. Commonly, the only established method of disposal is through land-filling, which can contribute to environmental concerns. This experimental investigation explores the transformative potential of utilizing Brick Kiln Dust as sustainable alternative to convention cement. BKD, obtained from a kiln situated in District Budgam, Jammu and Kashmir, was incorporated into concrete mixes at varying proportions (5%, 10%, 15%, 20%, and 25%) as a replacement for cement. Through the use of rigorous testing on mix samples, this study examined the effect of BKD on concrete workability as well as compressive and split tensile strength. The results were compared to identify the optimal dosage for achieving a balance between reduced cement consumption and maintaining structural integrity. The results showed that adding BKD not only significantly decreased the amount of cement used, but also demonstrated that it was a workable and sustainable substitute. This research not only addresses the environmental concern associated with BKD but also contributes to the ongoing efforts to develop sustainable construction practices.
Keywords: Brick Kiln dust, Compressive strength, Workability, Split tensile strength.

I. INTRODUCTION

The construction sector is a massive pillar that shapes the modern era's skylines and landscapes. The building industry creates a story of advancement and creativity with each brick laid, each carefully positioned beam, and every structure that rises from the earth, weaves a narrative of progress and innovation. Concrete, cement, aggregates, and bricks are among several materials utilized in the construction industry, these resources serve as the sector's backbone. In addition to consuming a variety of natural resources, the manufacture of these products leaves behind a number of environmental leftovers, some of which are hazardous to the environment. Bricks and concrete are among the fundamental building materials mostly used for the construction purpose, forming the large fraction of the construction material used in construction project. Production of Brick is a meticulous prcess that transforms raw material into a crucial building material, typically crafted from clay. The clay undergoes crushing and screening to achieve the desirable consistency following moulding and shaping the clay into brick through drying – air drying or passing them through the controlled air chamber, to reduced moisture content. The crucial firing stage takes place in the kilns, subjected to high temperature that vitrify the clay particle and impart strength. Cooling follows to prevent thermal shock. Brick Kiln dust byproduct of the process of making bricks in kilns, is usually made up of minerals found in the raw materials used to make bricks, as well as fine particles and residues left over after burning coal or other fuels. When bricks are being manufactured, the dust from the brick kiln is considered as a waste product. The main ingredients of the clay used for the production of bricks are silica (50–60%), alumina (20–30%), and various carbonates and oxides. Brick's pozzolanic characteristic is caused by clay. Although clay by itself lacks pozzolanic qualities, it acquires them throughout the brick-making process when it is burnt alongside lime[2]. District budgam is centrally located district of Kashmir valley. The lush green paddy fields of Budgam district are kashmir's exhilarating landscape. Out of 282 brick kilns operating in the Kashmir valley, 232 are situated in Budgam district [1], functioning over 4,447 kanals of agricultural land. During the manufacturing process huge chunk of Brick kiln Dust is generated. This material is disposed of and used in landfills, which poses a risk to the environment and possibly human health.

The mineral composition of BKD can vary depending upon the characteristics of brick kiln dust can vary depending on factors such as the type of kiln, raw materials used and combustion process.BKD typically contains various compounds, including silica, alumina, iron oxide, and traces of heavy metals. When the BKD is not properly managed, it comes in contact with the top soil, thus contaminating it. This contamination may affect the soil fertility and impact the agricultural growth of the associated crop. Even the fine particles in the BKD can become airborne if not adequately controlled. Inhalation of these particles may pose respiration heath risk to workers and nearby resident, contributing towards the air pollution. Leaching of BKD may affect the water quality of the water table or nearby water bodies, even due to the runoff from the storage piles or improperly disposed BKD. Thus all these factors may ecologically contribute altogether impacting and disrupting the local ecosystems. Cement concrete is another used material used in large quantityOne of the most expensive ingredients in cement concrete is cement. Therefore, many researchers have explored the economical use of such substances to tackle environmental and financial issues by utilizing a variety of waste and innovative components in the concrete mix. The IS Method was used to prepare the concrete mix design for this experiential investigation. Further this study examined the properties of concrete by partially replacing the cement fraction by Brick Kiln Dust. Various properties of the modified concrete were evaluated and compared. The results revealed the possibility of utilization of BKD in the concrete mix, with improved performance. Therefore, utilization of BKD as partial substitution of cement will be a good alternate for BKD disposal problem, environmental concerns for the safe disposal of BKD, cement consumption in concrete production and also to the economical aspect of project cost as well.

II. MATERIAL

A. Cement

Cement in the form of fine powder is used as the binder for the cement concrete. Cement when mixed with other materials and water sets and hardens and binds other materials together. Locally available OPC 43 Grade ordinary Portland cement was used for this experimental setup. The cement procured was from the fresh batch and was physically test before its utilization in this investigation.

TABLE I

PHYSICAL PROPERTIES OF CEMENT

S. No	Properties	Result
1	Fineness modulus	4.38 %
2	Consistency	32 %
3	Initial setting time	74 minutes
4	Final setting time	392 minutes

B. Fine Aggregate

River sand, was used as the filler material. The sand obtained was procured Buchroo a Village in Chadoora extracted from Doodganga river and confirmed to Indian Standard Speccifications. After being passed through a 4.75 mm sieve and cleaned to get rid of any clay particles, it is used for further investigations.

TABLE III

PHYSICAL PROPERTIES OF FINE AGGREGATES

S. No	Properties	Result
1	Specific Gravity	2.61
2	Water Absorption	0.79 %
3	Zone	III

C. Coarse Aggregate

We utilized nominally 20mm-sized coarse aggregate that was easily and readily accessible locally for our experimental work. The crushed angular aggregates were obtained from local crusher zone of district Budgam. Physical properties tested as per Indian Standard specifications are enlisted below.

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TABLE IIIII
PHYSICAL PROPERTIES OF COARSE AGGREGATES

S. No	Properties	Result
1	Shape	Angular
2	Nominal Size	20 mm
3	Specific Gravity	2.63
4	Water Absorption	1.15 %
5	Crushing Value	21.73

D. Water

Water supplied through the municipal means for the drinking purpose was used for the production of concrete. The container to be used for storing of water should be free from oil or any other harmful impurities.

Fig. 1 Raw Material used for the concrete mix.

E. Brick Kiln Dust

Brick Kiln dust was collected from a nearby brick kiln in the vicinity of Budgam's Ichgam belt, which is close to Chadoora town. Before its utilization in the experimental work the obtained BKD was grinded in the Loss Angles Apparatus for 30 minutes along with the iron balls. The BKD after grinding was then sieved in order to obtain the BKD with free from lumps and much finer particle. On an average the BKD retained about 6.25% on 90µm sieve.

TABLE IVV
PHYSICAL PROPERTIES OF BRICK KILN DUST

S. No	**Properties**	**Result**
1	Colour	Reddish Brown
2	Water Absorption	18.94 %

III.MIX DESIGN & SAMPLING

The mix proportion was calculated as per the IS code 10262:2009. The amount of material to be utilized was calculated at a fixed water-to-cement ratio of 0.43. The reference mix for M30 was prepared according to the IS Mix design code of practice and the mix ratio and the amount of materials calculated per meter cube of concrete is given below, in Table v.

TABLE V
MIX PROPORTION FOR REFERENCE CONCRETE

	Water	Cement	Fine Aggregate	Coarse Aggregate
For 1m3	189	438	712	1157
Ratio	0.43	1	1.63	2.64

The experimental modification to the concrete was done by the inclusion of Brick Kiln Dust into the concrete mix. This substitution was done with respect to the weight of cement. The different mix which were casted with different substitution level of cement by BKD are tabulated in Table VI below.

TABLE VI
MIX PROPORTION FOR DIFFERENT MIX

Mix	Cement	Brick Kiln Dust		Fine Aggregate	Coarse Aggregate	Water
	kg	%	kg	kg	kg	kg
REF	438	0	-	712	1157	189
5BKDC	416.1	5	21.9	712	1157	189
10BKDC	394.2	10	43.8	712	1157	189
15BKDC	372.3	15	65.7	712	1157	189
20BKDC	350.4	20	87.6	712	1157	189
25BKDC	328.5	25	109.5	712	1157	189

After the mix for each mix proportion was prepared, the workability check was conducted by calculating the slump values. Further the concrete was placed in cube moulds and cylinder moulds respectively for the preparation of samples to verify the compressive and split tensile strength. For each mix 18 samples – 9 cubes and 9 cylinders were prepared, in total 108 samples were prepared for this investigation. Additionally a fraction of fresh concrete was collected for workability check. The sampling was done by first placing the green concrete in the moulds and demolding them after 24 hours. The samples were coded with the mix induction and placed in the curing tank upto respective ages of testing.

IV. EXPERIMENTAL SETUP

A. Workability

Slump test was carried with all the prepared mixes. Slump test provides valuable information about the concrete's ability to flow and consolidate properly during placement. The test was carried in accordance to IS 1199:1959. Each layer of the slump cone was compacted down and levelled using a tamping rod. After removing the mould, the concrete slumps or settles, and the difference in height between the original mould height and the slumped concrete is measured. The measurement indicates the workability of the concrete mix.

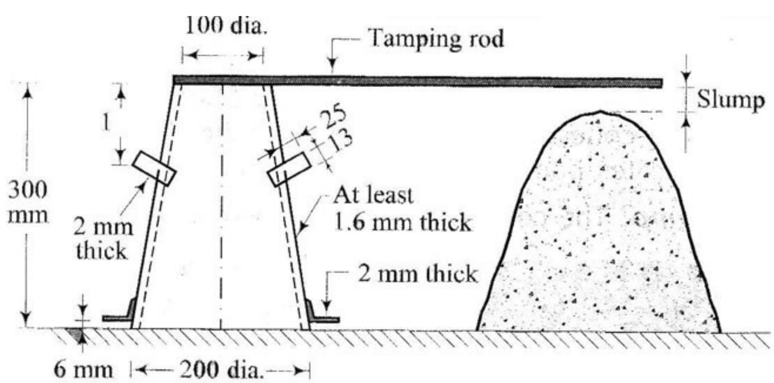

Fig. 2 Schematic for Slump Test for prepared Concrete.

B. Compressive Strength

The concrete's compressive strength was evaluated through the cube test. IS 516:1959 was followed when conducting the testing. Concrete samples of standard dimensions – cube of 150 mm each side were prepared for each mix and tested at respective age after curing the sample in water. After that, the cube samples are put under compressive loading in a compressive testing machine until a failure happens. By dividing the greatest load at failure by the cube's cross-sectional area, the compressive strength could be computed.

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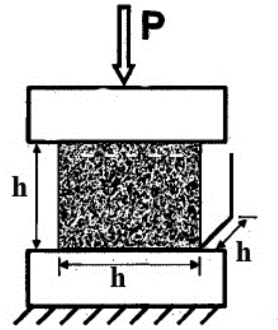

Fig. 3 Schematic for Compressive Strength Testing of Concrete.

C. Split Tensile Strength

The split tensile strength of concrete was assessed through the cylinder testing. The Splitting Tensile Strength of Concrete is comprehensively outlined by the Indian Standard IS 5816:1999. Concrete samples of standard dimensions - 150 mm dia and 300 mm in height were prepared for each mix and tested at respective age after curing the sample in water. The cylindrical samples are carefully positioned in a testing machine designed for split tensile strength assessment. A compressive force is applied diametrically at a uniform rate until the specimen fractures along the defined plane. The failure load is recorded and the split tensile strength is subsequently calculated using the prescribed formula outlined in IS 5816:1999.

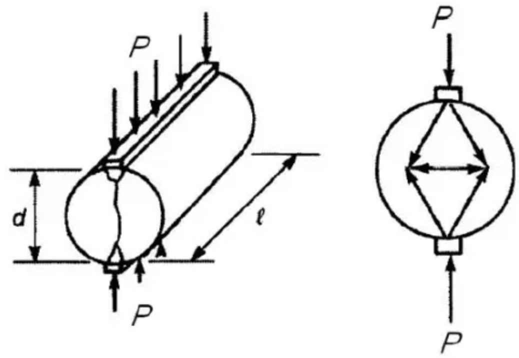

Fig. 4 Schematic for Split Tensile Strength of Concrete.

V. RESULTS & DISCUSSION

A. Workability

Slump value was observed for each mix, after the mixing was completed with fraction of quantities as per Table – V. The portion of concrete sample was collected from the batch and investigated for slump value. The reference concrete showed the slump value of 82 mm. For successive mix the fraction of cement was replaced by BKD. Figure-5 illustrates the different slump values obtained for different mix proportion in accordance to different BKD substitution.

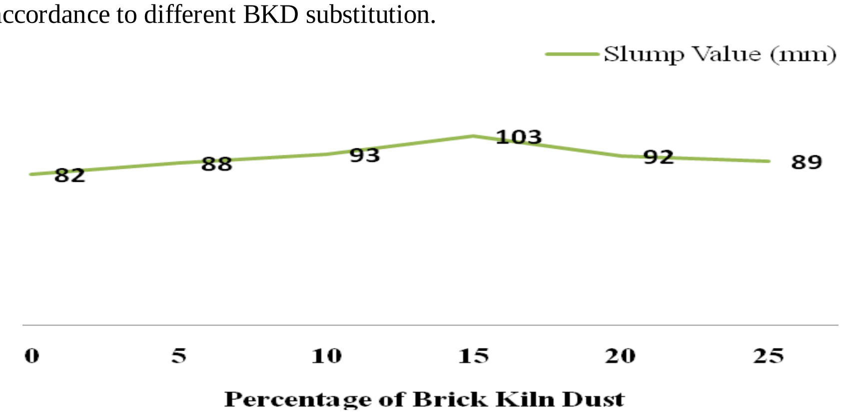

Fig. 5 Slump Value for different concrete mix.

The incorporation of Brick Kiln Dust (BKD) in varying percentages has distinct effects on the Slump values, reflecting changes in the workability of the concrete mix. Initially up-to substitution level of 15% linear increase in the slump value is noted, with maximum workability shown by mix 15BKDC this may be attributed to the finely grounded particle size of the BKD, as this fine particles inclusion may help by acting as fillers in the concrete mix to lubricate the concrete mix, reducing internal friction and facilitating better particle packing. However, at 20% BKD, a deviation occurs as the Slump value decreases, this trend continues with the higher percentage substitution of 25% as well. The reversal in the trend, with higher percentages leading to a reduction in Slump values, indicating potential changes in the material properties or behavior of the concrete mix. This reduction of slump value at higher BKD fraction may be arising due to entanglement of water in concrete by fine particles arising due to the interaction between BKD particles and water in the concrete mix. The large surface area of BKD particles results to hold more water which may be entrapped or held on the surface of the fine particles, relatively leading to greater water absorption.

B. Compressive Strength

The compressive strength test was conducted with an average of three samples of cube specimens each at the age of 7, 14 and 28 days of age. Test results obtained with different specimens at different ages have been illustrated in Figure-6.

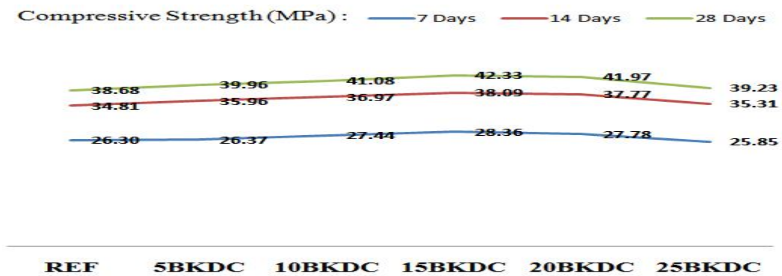

Fig. 6 Compressive Strength (N/mm2) for different concrete mix.

As illustrated in the graphical description a marginal variation can be observed with the inclusion of BKD. The maximum gain of 9% was observed in the mix 15BKDC containing 15% of Brick Kiln Dust. However when the BKD content was further enhanced the trended reversed showing a decrease in compressive strength values. The enhancement in the compressive strength may be arising due to the Pozzolanic reactions occurring between these BKD particles and calcium hydroxide produced during cement hydration. This reaction leads to the formation of additional cementations compounds, contributing to the strength of the concrete. Additionally the filling effect caused by the BKD particles within the concrete matrix enhances the packing of particles thus producing denser matrix. This overall change in the micro structure in the concrete, such as reduced porosity and improved interfacial transition zones, may contribute to enhanced compressive strength. The reduction in compressive strength with the higher percentage of BKD can be attributed to fine particle distribution of BKD, leading to increased water demand arising due to particle agglomeration. Associated reduction in workability as evident from slump values, may also result the mix to becomes too stiff or difficult to handle, resulting in poor compaction and also may be challenging during placement, resulting in reduced strength.

C. Split Tensile Strength

The strength of the three specimens was calculated using their average split-tensile strength. According to IS 5816-1999, the average splitting tensile strengths of concrete were evaluated after 7, 14, and 28 days. The results are graphically demonstrated in Figure - 7. Split Tensile Strength is also showing similar pattern in which marginal variation with the inclusion of BKD is noted.

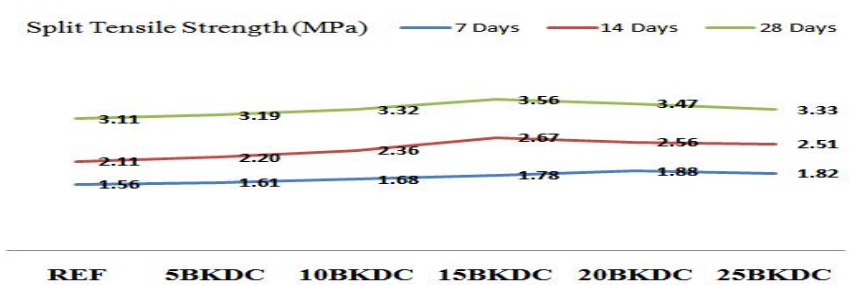

Fig. 7 Split Tensile Strength (N/mm2) for different concrete mix.

As illustrated with the addition of BKD there is variation in the split Tensile Strength with respect to reference concrete. The maximum gain of 14% was observed in the mix 15BKDC containing 15% of Brick Kiln Dust. However when the BKD content was further enhanced the trended reversed showing a decrease in Split Tensile Strength was noted. The enhancement in split tensile strength may be attributed to micro structural changes of the modified concrete. The pozzolanic reaction introduced by the addition of BKD by reacting with calcium hydroxide produced during cement hydration to form additional cementitious compounds results in the formation of denser hydration products and a more refined pore structure, which positively influences split tensile strength. Also the fine particles in Brick Kiln Dust can fill the voids in the concrete matrix, resulting in a denser and more compact structure. This filling effect also improve the resistance to cracking under tensile stresses. However when the BKD content is further increased from the optimum value, the split tensile strength starts to fall. This reduction in the split tensile strength with the higher BKD content may be attributed to incomplete hydration of cement particles arising due to the water entanglement due to the fine particle sizes and large surface area of BKD, causing increase the water demand of the concrete mix. Also the higher amounts of BKD may lead to incomplete hydration of cement particles. This can result in a less compact and weaker structure, affecting the tensile strength. All these factors may result in poor bonding between the cement matrix and BKD particles, creating weak interfaces that contribute to reduced tensile strength.

VI. CONCLUSIONS

Brick dust was mixed into concrete in this experimental research project by partially substituting cement. In light of experimental research, the following conclusions can be made:

1) An alternative to cement in a concrete mix is brick kiln dust.
2) When compared to the controlled mix, the compressive strength increases with the addition of brick kiln dust.
3) The concrete mix became less workable when brick kiln dust was added.
4) The optimum quantity of brick kiln dust is 15% of the cement's weight, and this produces more favourable results than the control mixture.
5) The compressive strength at 28 days of age at optimum dosage showed 9% gain with respect to neat concrete. Once brick kiln dust content reaches 15%, compressive strength tends to rise; however, after this point, it tends to decline.
6) The split tensile strength with 15% of brick kiln dust substitution to cement had a marginal gain of 15% to the reference concrete's split tensile strength.
7) The integration of Brick Kiln Dust into concrete not only enhances the structural integrity of the material but also elegantly addresses the imperative for sustainable waste management.
8) Brick Kiln Dust as a cement substitute not only signifies a shift towards environmental sustainability but also unveils financial prudence, gracefully reducing project costs with economic wisdom.

VII. SCOPE OF FUTURE WORK

To assess the viability of Brick Kiln Dust (BKD) in concrete, thorough research and experiments are essential. Focus on evaluating durability properties such as compressive strength, flexural strength, permeability, and resistance to environmental factors. Explore different BKD proportions, curing conditions, and durations to identify optimal blends. Collaborate across academia, industry, and regulatory bodies to establish standardized guidelines. Conduct a life cycle analysis for environmental impact. The goal is to unlock BKD's potential for creating cost-effective, durable, and sustainable concrete structures. Furthermore, the following recommendations are offered:

1) *Cost Savings:* Cost savings through the utilization of Brick Kiln Dust in concrete can be recommended through Raw Material Substitution and Local Sourcing reducing the transportation costs.
2) *Business Opportunities:* The utilization of Brick Kiln Dust in concrete opens up various business opportunities, fostering economic growth and job creation within the construction industry.
3) *Energy Efficiency:* The utilization of Brick Kiln Dust in concrete can contribute to enhanced energy efficiency in several ways viz - Energy Recovery from BKD Production, Reduced Clinker Production by Optimized Concrete Mix Design along with Sustainable Construction Practices.
4) *Green Building Certifications:* The utilization of Brick Kiln Dust in the construction industry can contribute positively to achieving various green building certifications. BKD into construction practices not only aligns with these green building certifications but also supports broader sustainability goals.

5) *Resource Conservation:* The utilization of Brick Kiln Dust in the construction industry contributes to resource conservation by waste utilization reducing the demand for natural resources.
6) *Preservation of Ecosystem:* Utilization of BKD is concrete, prevents the disposal of this byproduct in landfills. Thus the environmental impact associated with landfill usage and addressing waste management challenges, thus there is a reduction in the environmental impact associated with BKD disposal.

VIII. ACKNOWLEDGMENT

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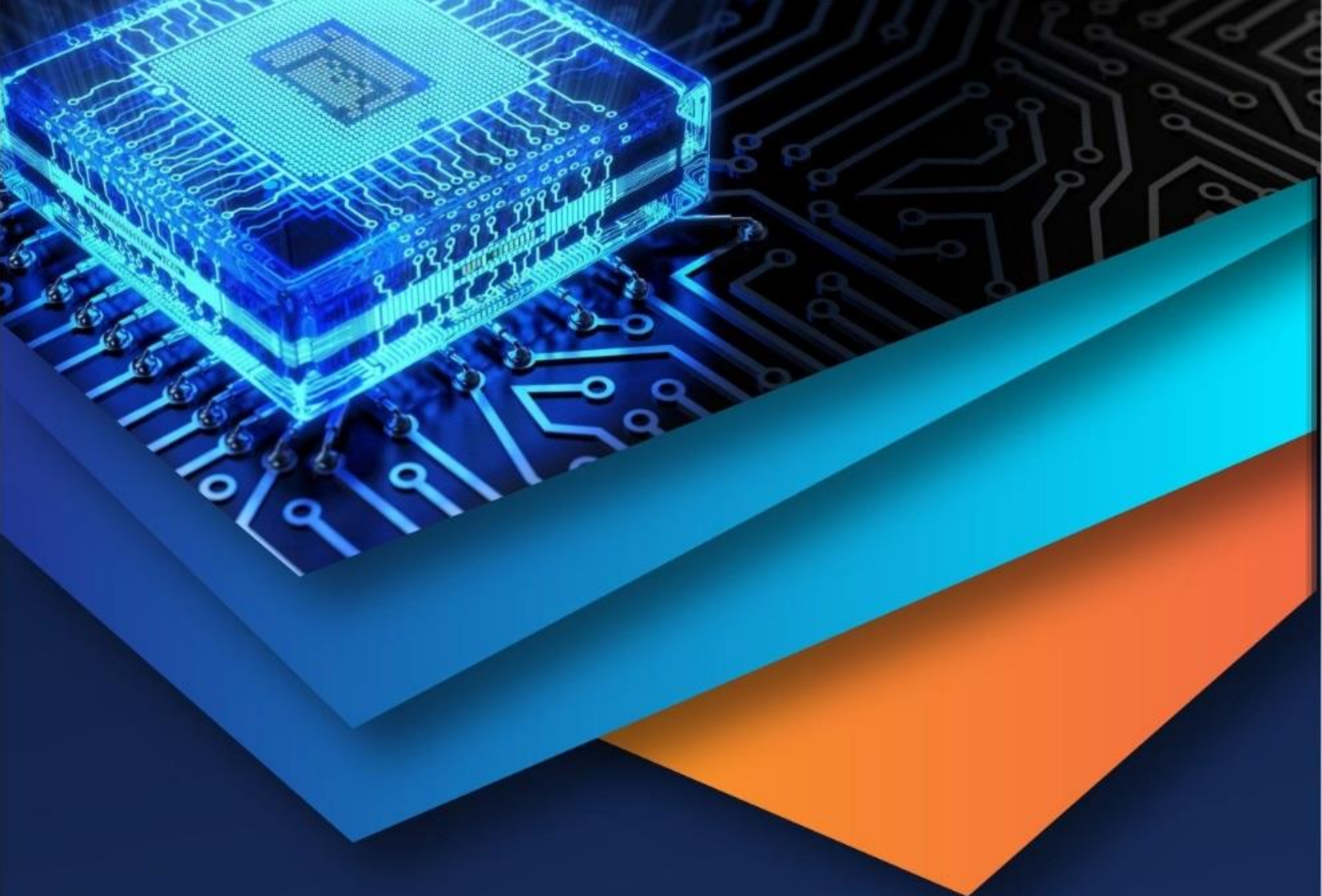

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