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Study the Properties of Cement Mortar Using Manufactured Sand as Fine Aggregate for Plastering

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Abstract: ***Rapid urbanization and extensive construction activities have led to excessive exploitation of natural river sand, causing serious environmental and ecological concerns. Manufactured sand (M-sand) has emerged as a sustainable alternative fine aggregate, particularly for mortar applications. This experimental study investigates the suitability of M-sand as a replacement for natural sand in cement mortar for plastering applications. Mortar mixes with cement–sand ratios of 1:4 and 1:6 were prepared using both natural sand and manufactured sand. The study evaluates workability, compressive strength, drying shrinkage, and adhesive (bond) strength at different curing ages. Results indicate that M-sand mortars exhibit lower workability than natural sand mortars at equivalent water–cement ratios due to angular particle shape and higher surface area; however, this limitation can be effectively mitigated by proper water control and the use of plasticizers. M-sand mortars show significantly higher compressive strength and marginally improved adhesive strength compared to river sand mortars, attributed to better particle interlocking and stronger paste–aggregate bonding. Drying shrinkage in M-sand mortars is slightly lower than that of natural sand mortars, enhancing dimensional stability. Among all mixes studied, M-sand mortar with a 1:4 cement–sand ratio demonstrates the best overall performance in terms of strength, bond characteristics, durability, and shrinkage control, making it highly suitable for plastering applications. The findings confirm that manufactured sand is a technically viable and environmentally sustainable alternative to natural river sand in cement mortar.***

Keywords: ***Manufactured sand (M-sand), Mortar rheology, Bond strength, Drying shrinkage, Sustainable construction materials.***

I. INTRODUCTION

Rapid population growth has significantly increased the consumption of natural resources and energy, with the construction industry consuming about 40% of extracted resources and generating large amounts of waste. Excessive use of materials like sand, stone, timber, and water has caused environmental degradation and ecological imbalance. To control these impacts, governments have imposed regulations on the construction sector. However, such regulations may slow economic growth since construction contributes substantially to GDP. Sand is the second most consumed natural resource after water, and rapid urbanization has greatly increased its demand. Overexploitation of river sand by the construction industry has led to scarcity and environmental concerns. This has created the need for sustainable alternatives to natural fine aggregates. Researches have been carried out to reclaim and recycled the waste and reduce the over exploitation of natural resources. Previous research shows that M-sand mortar has lower workability than natural sand mortar due to its angular shape, rough texture, and higher fines content, though it contains less clay and silt. The angular particles improve interlocking, resulting in higher compressive and bond strength, but increased surface area and gap gradation reduce flow even with admixtures. M-sand mortars generally exhibit higher porosity yet superior strength and durability compared to natural sand mortars. However, limited studies exist on flow and workability at varying M-sand replacement levels. Therefore, this study compares the flow and compressive strength of M-sand and natural sand mortars.

II. LITERATURE REVIEW

1) Praveen Kumar K & Radhakrishna (2015) The study evaluated strength and workability of 1:6 cement mortar with partial replacement of natural sand by M-sand. Workability increased up to 80% M-sand replacement and decreased at 100%. Compressive strength consistently increased with higher M-sand content.
2) Catarina Nenoa et al. (2013) This research investigated mortars using recycled concrete aggregates as partial and full replacements of natural sand. Replacement levels of 20% and 100% showed promising results, with 20% performing best overall. The 20% RCA mortar outperformed the reference mortar in most properties except dimensional stability and adhesion.

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3) B.V. Venkatarama Reddy & Ajay Gupta (2014) The influence of sand grading on mortar and masonry properties was examined. Finer sand increased water demand, drying shrinkage, and reduced compressive strength and modulus. Masonry tensile bond strength decreased with finer sand, while compressive strength was less affected.
4) D.D. Cortes et al. (2017) This study analyzed the effect of aggregate shape on mortar flow and strength. Angular sands required higher paste volume to achieve adequate flow and strength compared to rounded sands. Strength correlated positively with flow near the void–paste transition but plateaued at higher paste volumes.
5) Shivang Jayswal & Mahesh Mungule (2018) The study assessed M-sand as a replacement for natural sand in M25 and M30 concrete. M-sand concrete showed comparable workability but higher compressive and flexural strength at 28 days. The results indicate M-sand as a viable and sustainable alternative.
6) M. Westerholm et al. (2007) This research examined the effect of manufactured aggregate fines on micromortar rheology. Increased fines content raised yield stress, viscosity, and thixotropy, especially for manufactured fines. Superplasticizers mainly dispersed cement particles rather than fines.
7) Nimitha Vijayaraghavan & A.S. Wayal (2013) Durability studies showed reduced water penetration with increasing M-sand content. Angular particles improved packing density and reduced voids. The results support complete replacement of natural sand with M-sand for improved durability.
8) B.V. Venkatarama Reddy (2012) This comparative study found M-sand mortars and concretes to have better workability, strength, and bond characteristics than river sand mixes. M-sand complied with IS grading requirements and showed improved masonry performance. The study concluded M-sand as a superior alternative to river sand.
9) Rebeca Martínez-García et al. (2021) The study evaluated fine recycled concrete aggregates in mortar at varying replacement levels. A 25% replacement showed optimal compressive and flexural strength due to internal curing effects. Higher replacements reduced strength but remained within acceptable limits.
10) Haitao Zhao et al. (2014) This research analyzed pore structure and strength of mortars with manufactured and natural sand. Manufactured sand mortars showed higher porosity yet higher compressive strength. Advanced pore distribution models explained the complex relationship between pore structure and strength.

III. OBJECTIVE OF STUDY

The main objectives of this study are:

1) To determine the W/C ratio for various mix proportions to achieve pre-determined workability/consistency.
2) To determine the dry density and shrinkage of various mix sample prepared.
3) To determine the compressive strength and adhesive strength of various mix sample prepared.
4) To compare the consistency and strength of N-sand mortar and M-sand mortar for the viability of manufactured sand as construction material.

IV. MATERIAL USED

A. *Cement*

Pozzolana Portland Cement (PPC) of Ambuja Cement conforming to IS 1489 (Part 1):2015 was used in this study. The cement contained about 35% fly ash and showed a minimum 28-day compressive strength of 33 MPa. Physical properties such as consistency, fineness, setting times, and specific gravity were tested as per IS 4031. The test results are presented in the relevant table.

Table1. Properties of Cement (PPC)

S.No.	Particular	Experimental value
1.	Specific Gravity	3.15
2.	Initial Setting Time	280 Minute
3.	Final Setting Time	320 Minute
4.	Fineness of cement	360 m^2/Kg
5.	Compressive Strength	
	3 days	28 MPa
	7 days	36 MPa
	28 days	UT

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B. Natural Sand

In this study local river sand (Gajuki Nala) falling under Zone I classification, with a specific gravity of 2.19 and a fineness modulus of 2.97, was utilized as the fine aggregate. The maximum particle size considered for this sand was 4.75 mm. All testing procedures for the sand were carried out in accordance with the Indian Standard IS: 383:2016 guidelines.

C. Manufactured Sand

M- Sand was used as replacement of fine aggregate. The manufactured sand, taken from local area of Alwar region of Rajasthan, specific gravity and fineness modulus was found to be 2.51 and 2.07 respectively.

D. Water

Clean potable water confirming to IS 456:2000 and IS 3025standards was used for mixing and curing. Test results: pH 7.35, TDS 1274 mg/l, chloride 258 mg/l, all within permissible limits. The water is suitable for mortar preparation.

V. RESULTS AND DISCUSSION

A. Workability

The flow test results indicate that workability increases with an increase in water–cement ratio for both natural sand and manufactured sand mortars. At all water–cement ratios, mortars made with natural sand show higher flow compared to manufactured sand mortars due to the smoother texture and rounded particles of natural sand. The 1:6 mixes exhibit greater flow than the 1:4 mixes for both sand types, especially at lower water–cement ratios. At higher water contents, the difference in flow between natural sand and manufactured sand mortars decreases, showing that increased water compensates for the lower workability of M-sand.

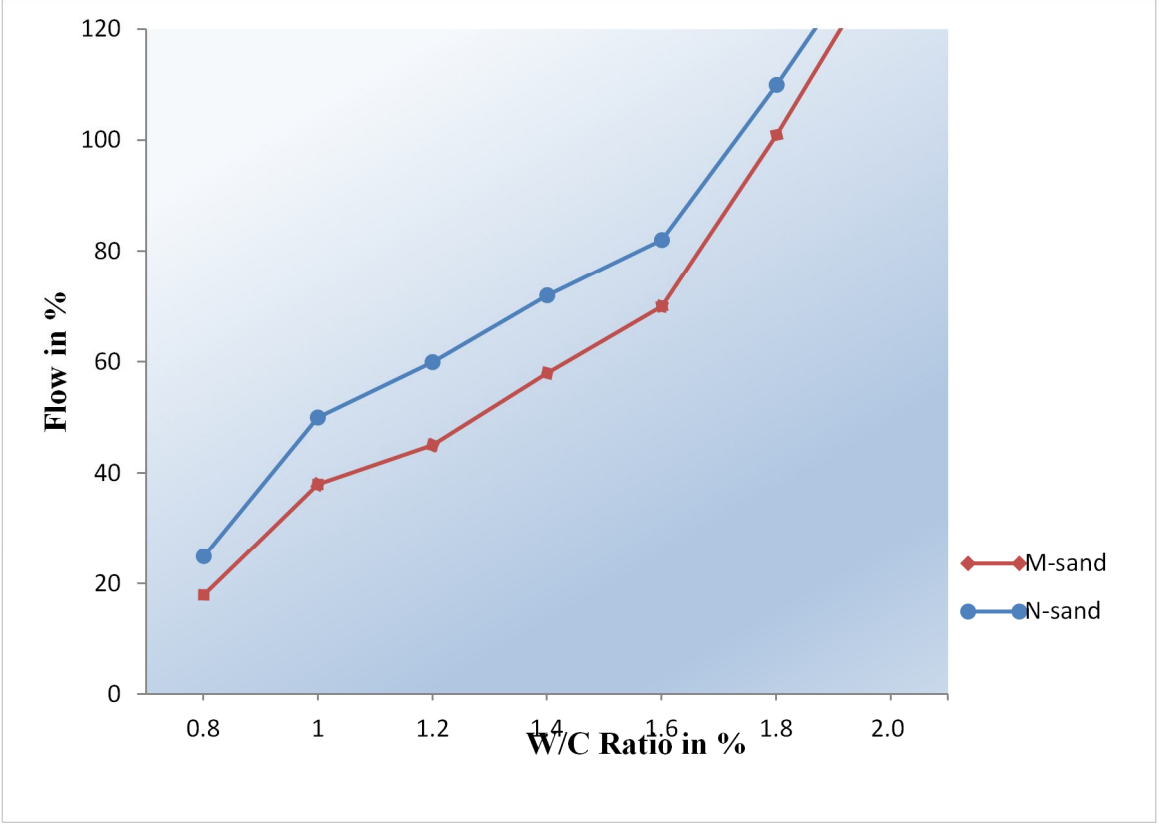

Figure 1: Flow Test on 1:6 Mortar Mix

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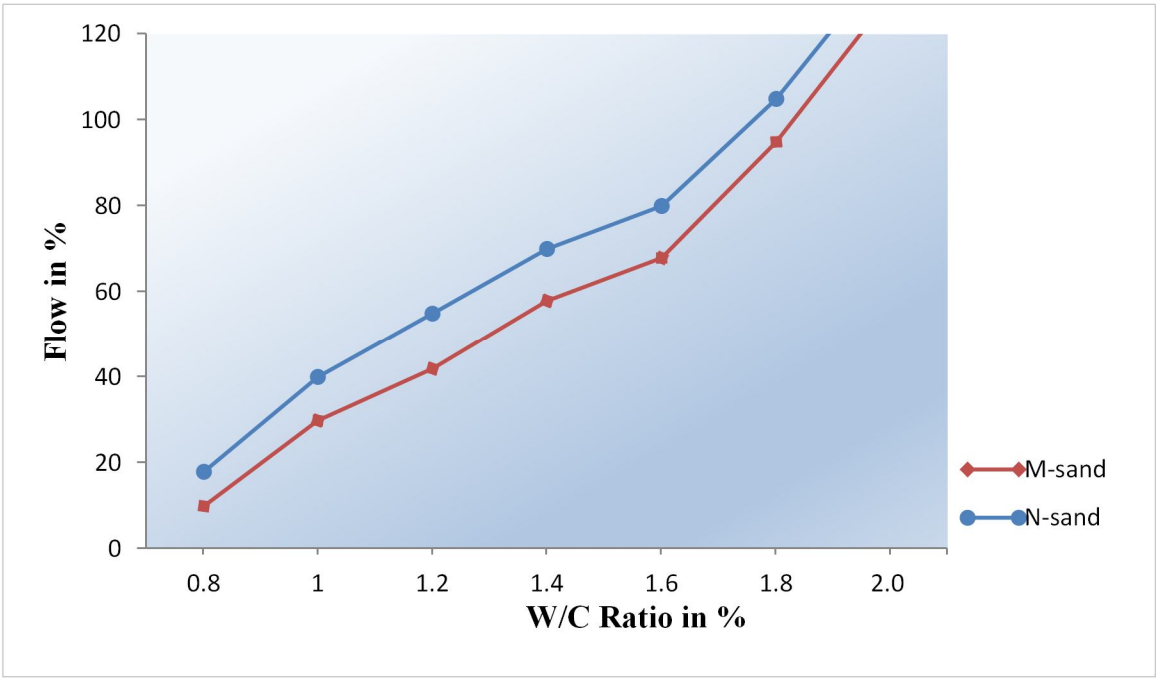

Figure 2: Flow Test on 1: 4 Mortar Mix

B. Compressive Strength

The compressive strength of all mortar mixes increases from 7 to 28 days of curing. For both 1:6 and 1:4 mixes, M-sand mortars show considerably higher compressive strength than natural sand mortars. The 1:4 mixes achieve greater strength than the 1:6 mixes due to higher cement content. The improved strength of M-sand mortars is attributed to better particle interlocking and stronger bond between cement paste and angular sand particles.

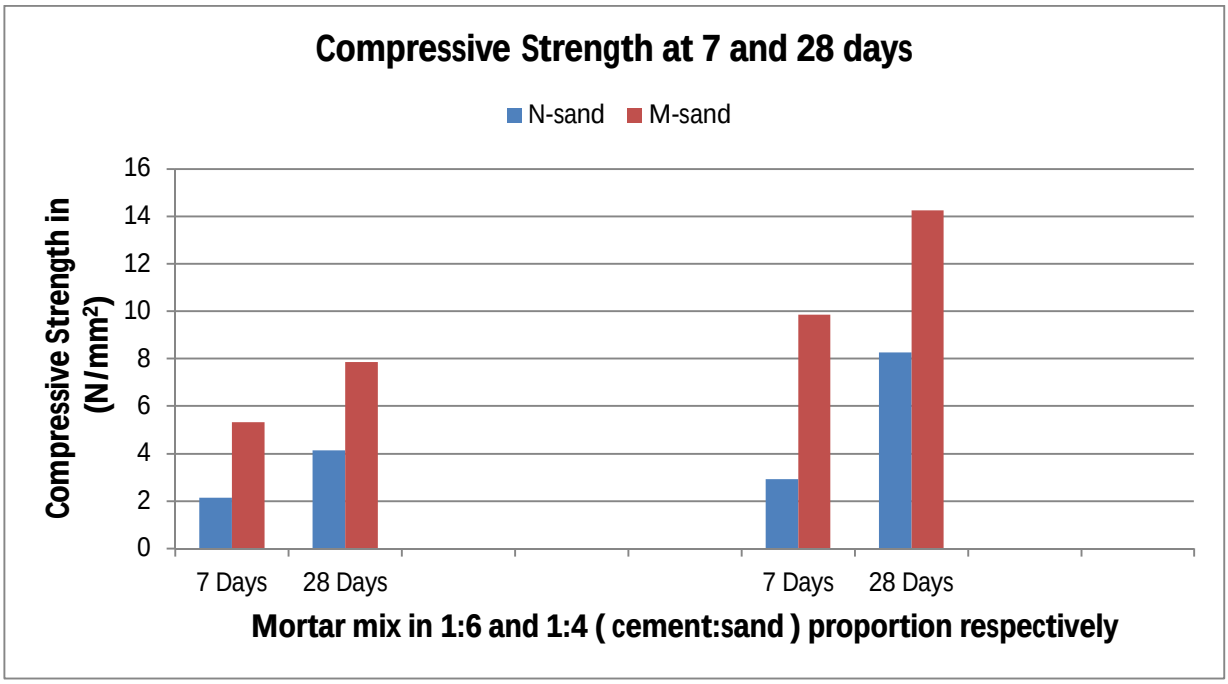

Figure 3: Compressive Strength Test on Mortar Mix

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C. Drying Shrinkage

Dry shrinkage of all mortar mixes increases with age and stabilizes after about 28–35 days. Mortars made with M-sand exhibit slightly lower dry shrinkage compared to corresponding natural sand mortars for both 1:6 and 1:4 mixes. The 1:4 mixes show marginally higher shrinkage than 1:6 mixes due to higher cement content. Reduced shrinkage in M-sand mortars may be attributed to better particle packing and reduced moisture loss.

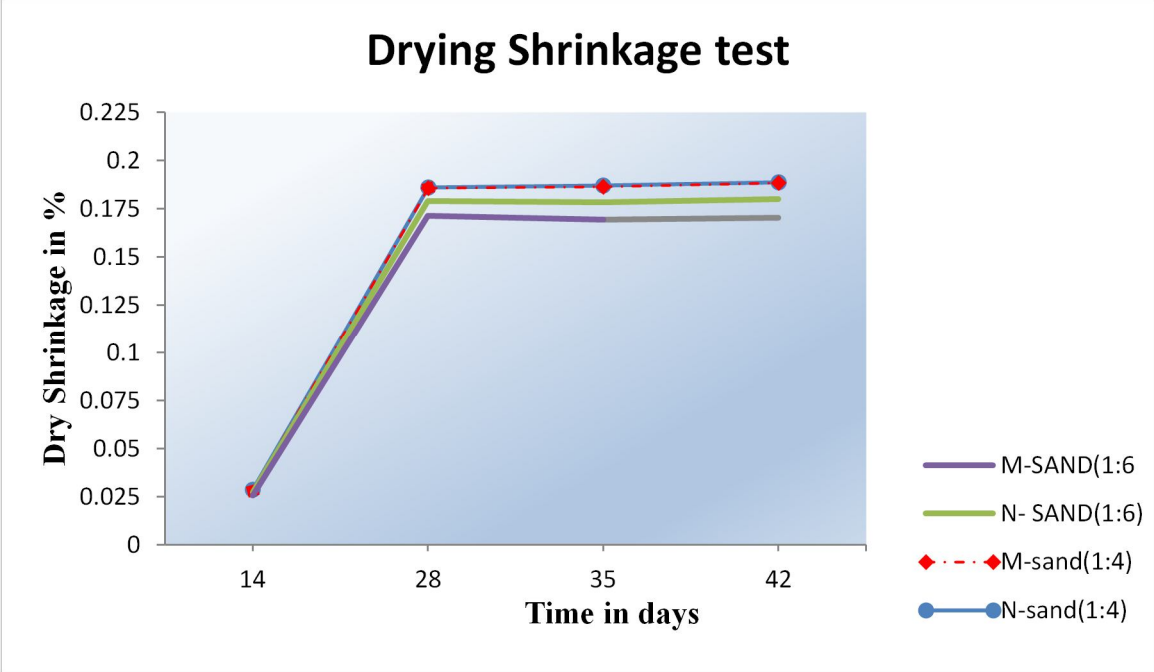

Figure 4: Drying Shrinkage Test on Mortar Mix

D. Adhesive Strength

The adhesive strength of all mortar mixes increases with curing time from 7 to 28 days. Mortars with manufactured sand show slightly higher bond strength than river sand mortars for both 1:6 and 1:4 mixes. The 1:4 mixes develop greater adhesive strength compared to 1:6 mixes due to higher cement content. Improved surface roughness and angularity of manufactured sand contribute to better bonding with the substrate.

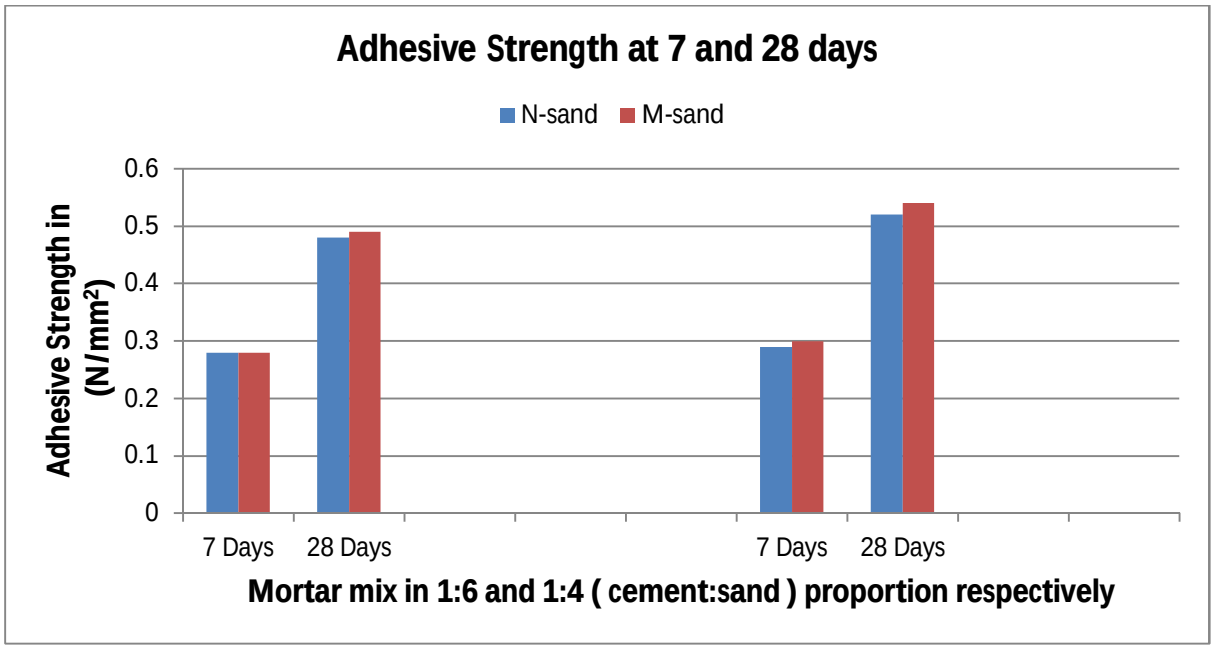

Figure 4: Adhesive Strength Test on Mortar Mix

VI. CONCLUSION

1) Workability increases with an increase in water–cement ratio for all mixes. Mortars with manufactured sand exhibit lower flow than river sand mortars due to angular particle shape and higher surface area, though the difference reduces at higher water contents.

2) Compressive strength increases with curing age for all mixes. Manufactured sand mortars show significantly higher compressive strength than river sand mortars for both 1:6 and 1:4 mixes due to improved particle interlocking and bond.

3) Dry shrinkage increases with age and stabilizes after about 28–35 days. Mortars with manufactured sand show slightly lower shrinkage compared to river sand mortars, while 1:4 mixes exhibit marginally higher shrinkage than 1:6 mixes due to higher cement content.

4) Adhesive strength improves with increased curing period. Manufactured sand mortars develop marginally higher bond strength than river sand mortars, and 1:4 mixes show better adhesion than 1:6 mixes because of higher cement paste content. Considering all performance parameters and When a plasticizer is used, the workability limitations of manufactured sand (M-sand) mortar are significantly reduced**.,** manufactured sand mortar with a cement:sand ratio of 1:4 **is** recommended as the best mortar for plastering. It provides a good balance of workability, higher bond strength, improved durability, and reduced shrinkage. Proper control of water–cement ratio and curing practices is advised to achieve optimal plastering performance.

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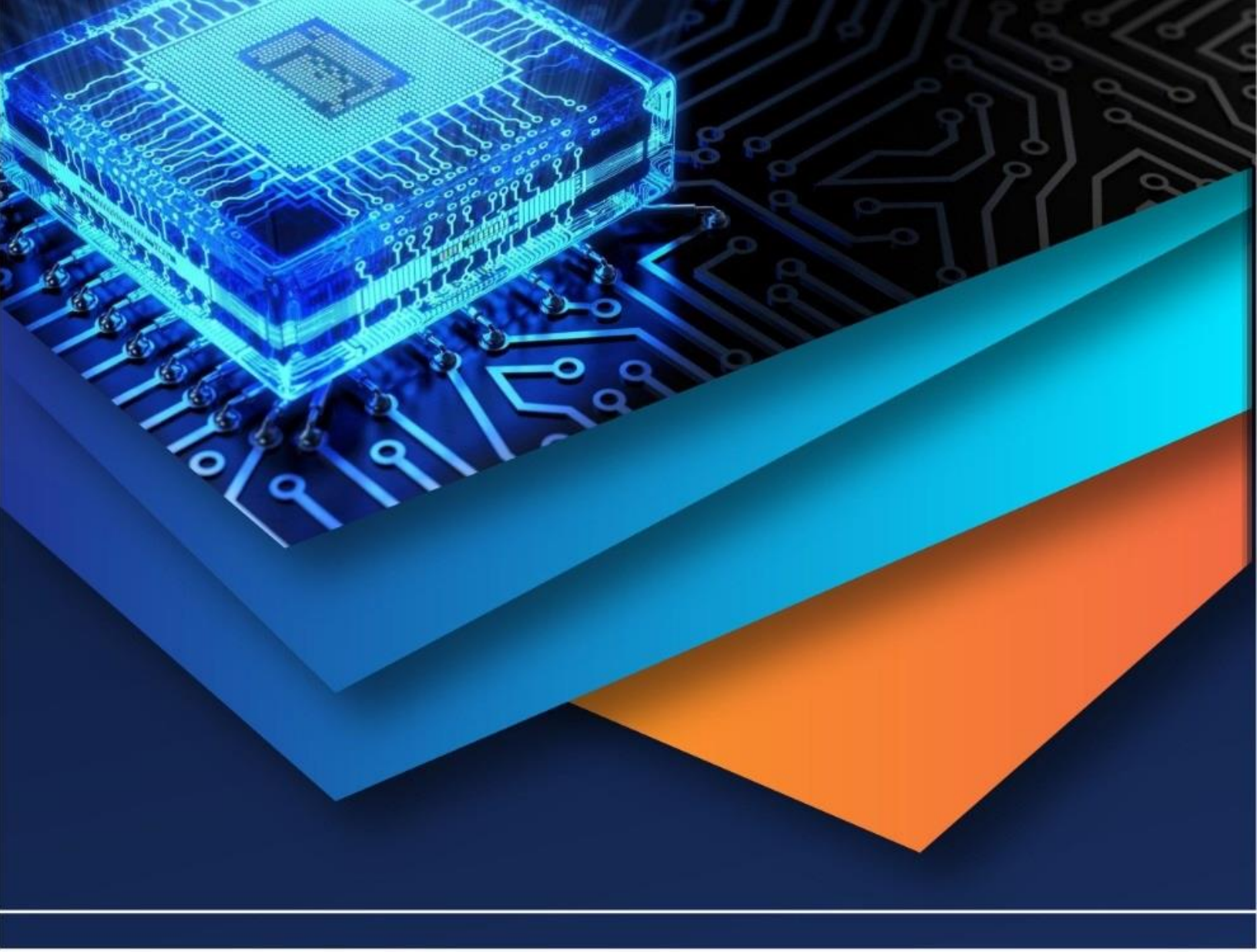

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