iJRASET
International Journal For Research in
Applied Science and Engineering Technology

# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

**Volume:** 13 **Issue:** V **Month of publication:** May 2025

**DOI:** https://doi.org/10.22214/ijraset.2025.71061

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

# Experimental Study of the Mechanical Characteristics of Evaluated Floor Panels

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***Abstract: Raised access floors are widely used in commercial and industrial buildings due to their adaptability, ease of installation, and maintenance. However, conventional materials used on these floors often exhibit poor mechanical performance and pose environmental concerns. This study investigates the strength of raised access floor panels composed of gypsum, cement, and silica fume. The aim is to enhance the physical and mechanical properties while utilizing sustainable, eco-friendly materials. Laboratory tests were conducted to evaluate the density, water absorption, compressive strength, and flexural strength of the composites. Additionally, the structural performance of floor panels was assessed under compression load test. Results revealed that adding 10% cement improved compressive strength by 26.9%, while 5% silica fume increased it further by 15.5% through enhanced compactness. The panels demonstrated potential for use in sustainable raised access flooring systems, providing an eco-friendly alternative to conventional materials.***
***Keywords: Raised access floors; Mechanical performance; Silica fume, Portland cement.***

## I. INTRODUCTION

Raised access floors gained popularity in the 1960s and 70s as a means to service IBM computers and provide distribution of services within buildings such as offices and studios. The BBC also made use of raised floors to distribute services throughout their facilities. By the 1980s, the transition from cubicles to open-plan offices led to an increased demand for flexibility, making raised access floors an essential component for bringing power and data up through the floor. This era signified a significant shift towards more open and adaptable work environments, where raised floors played a critical role in accommodating evolving office layouts and technological advancements [1]. The raised floor provides hidden space above a solid slab for purposes such as heating, cooling air circulation ventilating, air-conditioning ducting water and chemical piping, and computer and telephone cables [2]. Modifications and maintenance are easy with this system because the floor panels are easily removed or changed. Elevated floor panels offer numerous advantages in various settings. They provide a modular design facilitating easy access to electrical conduit and data cables, reducing installation and maintenance costs [3]. Wu et al. [4], developed a panel made from sheet molding compound containing 30% glass fibers, using SolidWorks software for product modeling. Life cycle assessment (LCA) and finite element analysis (FEA) were conducted, with the LCA showing significant environmental impacts in areas such as carbon emissions (84%), total energy consumption (91%), and water eutrophication (66%). The FEA indicated that the deformation under a 3000 N load was below 2.5 mm, meeting the British Standards' Class A deformation criteria for flooring products. The panels for the elevated floors can be made from a variety of materials, including wood, ceramic, rock plates, concrete, and wood [5].There is a large carbon footprint associated with the extraction and production of these materials. one of the sustainable options being researched to address this problem is gypsum. Gypsum is a widely used material in construction, particularly for interior finishes such as ceilings and walls [6]. its popularity stems from its advantages, including sustainability, thermal insulation, and acoustic properties [7]. Additionally, gypsum is often employed in firebreak systems due to the significant latent heat released during its dehydration into hemihydrate and anhydrite forms [8] . Moreover, gypsum can be recycled when processed correctly [9]. Gypsum plaster is produced by calcining the gypsum mineral, a process that involves grinding the raw material (calcium sulfate dihydrate, CaSO4.2H2O) and heating it between 125 and 180°C. This process expels water vapor and results in commercial gypsum plaster (calcium sulfate hemihydrate, Ca$SO_4$4.1/2$H_2$O) [10]. There have been a lot of published studies on composites made of gypsum and reinforced with natural fibers. A large portion of these studies aim to develop new composite materials with enhanced thermophysical and mechanical capabilities in order to lower building energy consumption. According to Álvarez et al. [11] composites that have vermiculite and super absorbent polymers added to them considerably outperform conventional materials in terms of water absorption, with improvements of up to 7.3% observed, and only a minor (13%) loss in mechanical strength compared to existing materials with similar addition. Polymer-modified gypsum-based composites with optimal mix proportions, particularly SBR modified composites, exhibited improved water resistance and strength development compared to traditional gypsum composites [12]. Gencel et al. [13] have created a new composite material by adding polypropylene fibers and diatomite in gypsum. The addition of these materials lowers the density of the toughened material by increasing the material's heat conductivity. Based on Dai and Fan [14], the best amount of reinforcement was attained by adding wood sawdust in proportions between 20% and 30%.Herrero et al. [15] investigation plaster-rubber mortars and observed that the use of recycled tires with rubber particles reduced the density from 1222 kg/m3 to 654 kg/m3. The smallest particles showed a density drop ranging from 16 to 47%. Density decreases as the proportion of rubber increases. According to Khalil et al. [16] adding various types of silica reduced the bulk density and improved the composites' setting time, normal consistency, apparent porosity, and, to some extent, compressive strength. A 10% silica composite was added to common gypsum, resulting in a 9% decrease in density (from 1150 kg/m3 to 1030 kg/m3), which may have been caused by prolonged additive usage. Hankhuntod et al. [17] found that adding water hyacinth and coconut fiber to gypsum plaster reduced the material's thermal conductivity and density. As seen in Figure 2-4, Shiroma et al. [18] demonstrate that a higher wood particle ratio decreases composite density, while Morale-Conde [19] reveals that, in general, an increase in the proportion of additives (either in the form of sawdust or wood shavings) results in a decrease in the gypsum matrix's density. Fantilli et al. [20] examined the mechanical properties of gypsum reinforced with sheep wool and hemp fibers. Their findings indicate that both the compressive and flexural strengths are 20% lower compared to natural gypsum. Pavel et al. [21] study the gypsum composites reinforced with recycled tire wires. The study revealed that the presence of large voids in the composites resulted in low compressive strength due to damage localization in the areas that were not properly compacted. By adding palm fiber, Al-Rifaie and Al-Niami [22] discovered that the gypsum's brittleness changed to a more flexible state and its compressive strength increased from 6.8 MPa to 13 MPa. Ejaz et al. [23], conducted research on sustainable gypsum false ceiling tiles using agricultural waste such as rice husk and wheat straw (2.5%-10%). The developed composites showed lower shore C hardness and density than the control mix containing 100% gypsum. While numerous studies have explored various combinations of gypsum with other materials, limited research has focused on the combined effects of gypsum, cement, and silica fumes. This study aims to evaluate the strength characteristics of raised access gypsum composite floor panels, with a particular focus on their mechanical properties and performance under load. By investigating the effects of different material compositions and additives, this research seeks to provide valuable insights into the potential of gypsum-based composites as a sustainable and resilient solution for raised flooring applications.

## II. METHODOLOGY

The methodology covers material collection, preparation of composite samples, testing procedures, and data analysis. The primary aim is to assess the physical and mechanical properties of different mixes. Raised access floor panels will be fabricated using different material ratios and subjected to compression load tests. A comprehensive literature review will be conducted before the collection of materials, followed by sample preparation, testing, and data analysis.

### *A. Materials*

#### *1) Gypsum*

The primary material used in the manufacturing of the test specimens was gypsum, often referred to as plaster of Paris ($CaSO_4 \cdot 1/2H_2O$).

#### *2) Cement*

The cement utilized in this study was ASTM Type 1. It contains 95% clinker and 5% gypsum. The specific gravity, as determined according to ASTM C187 [25], is 3.15, and its fineness, measured in accordance with ASTM C786, is 99% (passing through sieve #200).

#### *3) Silica Fume*

Silica fumes are highly reactive pozzolanic substances and are a byproduct from the production of silicone or Ferro- silicon metals. It is a very fine powder and composed of the flue gases from electric is furnace.

#### *4) Water*

Essential for the hydration and setting processes of the composite. Regular drinking water was utilized to mix all gypsum formulations in this research. Clean water is crucial in the material composition needed for this study to achieve optimal outcomes, thus utilizing the primary natural water resource available.

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Volume 13 Issue V May 2025- Available at www.ijraset.com

### B. Mix Proportions

In this study, different mix proportions were prepared, as outlined in Table 1.

**Table 1:** Mix proportions of gypsum composite

| Proportions | Gypsum | Cement | Silica fume |
|---|---|---|---|
| G | 100% | 0 | 0 |
| GC | 90% | 20% | 0 |
| G5%SF | 85% | 0% | 5% |
| G10%SF | 90% | 0% | 10% |
| G15%SF | 85% | 0% | 15% |
| GC5%SF | 85% | 10% | 5% |
| GC10%SF | 80% | 10% | 10% |
| GC15%SF | 75% | 10% | 15% |

*G = Gypsum; C = Cement; SF = Silica Fume.

### C. Mixing procedure

In a clean, dry container, thoroughly mix the weighed gypsum and cement until a uniform blend is achieved. Add the required amount of silica fume to the dry mix and blend thoroughly to ensure even distribution of the fine particles.

### D. Specimens Casting

- For every blend, a variety of test specimens were created. The material was dry mixed for the density and compressive tests, added the required amount of water, and then manually re-mixed for about 30 seconds before being poured into the steel molds as described in Figure 3. The cubic (5×5×5) cm specimens were removed from the mold after roughly thirty minutes. For every mixture, six cubes were made, as seen in Figure 4.
- For flexural samples measuring 40 mm × 40 mm × 160 mm beam are make to access their flexural strength.

### E. Samples Testing

#### 1) Water Absorption Test

The sample was submerged in water for an entire day following its dry weight measurement. It was then weighted and let too dry with a piece of cloth. To determine the percentage of absorption using equation (1).

$$\text{\% of water absorption} = \frac{\text{weight after absorbtion} - \text{weight before absorbtion}}{\text{weight before absorbtion}} \qquad (1)$$

#### 2) Density

The density of the gypsum composite mix is determined by weighing the cubes after drying and cooling.

#### 3) Compressive Strength

For compressive strength, 50.8 mm cubes were used for each gypsum composite mix. Gypsum samples were removed from the molds after the setting process took place and kept in a lab environment until the testing age.

#### 4) Flexural strength Test

In accordance with EN 13279-2:2014, 160 mm by 40 mm by 40 mm prisms were prepared for the flexural test. Three-point load tests were conducted on these prisms to measure their flexure strength as per the procedure described in EN 13279-2:2014 by using a universal testing machine as shown in Figure 1. The corresponding flexure strength was calculated using Equation (2).

$$P_F = 0.00234 \times P \qquad (2)$$

$P_F$ is the flexure strength (N/$mm^2$), and P is the average breaking load of at least three obtained values.

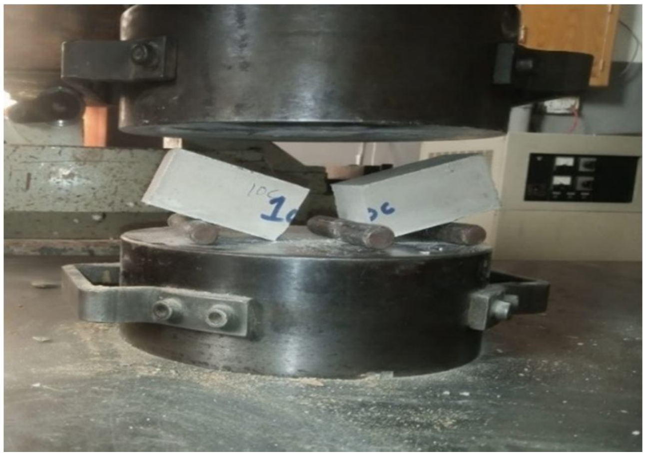

Figure 1: Sample breaking

### F. Panel Fabrications

Evaluated floor panels are make of best result mixture and compression test are performed on it.

#### 1) Compression Load test

Provide floor panels with a bottom-surface deflection under load of no more than 0.080 inches (2.03 cm) and a permanent set of no more than an average of 0.010 inches (0.25), in accordance with CISCA/AF Section 1. It should be possible for these floor panels to withstand a concentrated design load of 1,250 pounds (4448 N).

## III. RESULTS & DISCUSSIONS

### A. Water Absorption

The water absorption results show in Figure-2 a clear trend that the inclusion of silica fume and cement influences the porosity and water absorption capacity of the gypsum composites. The control mix (100% gypsum) exhibited the highest absorption value of 18.2%. The addition of 5%, 10%, and 15% silica fume gradually reduced the absorption to 15.6%, 13.9%, and 12.8%, respectively, due to the filler effect and pozzolanic reaction of silica fume which leads to pore refinement.

When 10% cement was included alongside silica fume (in GC mixes), the water absorption decreased even further. The GC10%SF mix showed the lowest absorption of 10.2%, indicating a denser matrix with reduced capillary porosity. The reduced porosity improves durability and moisture resistance of floor panels, making them more suitable for humid environments.

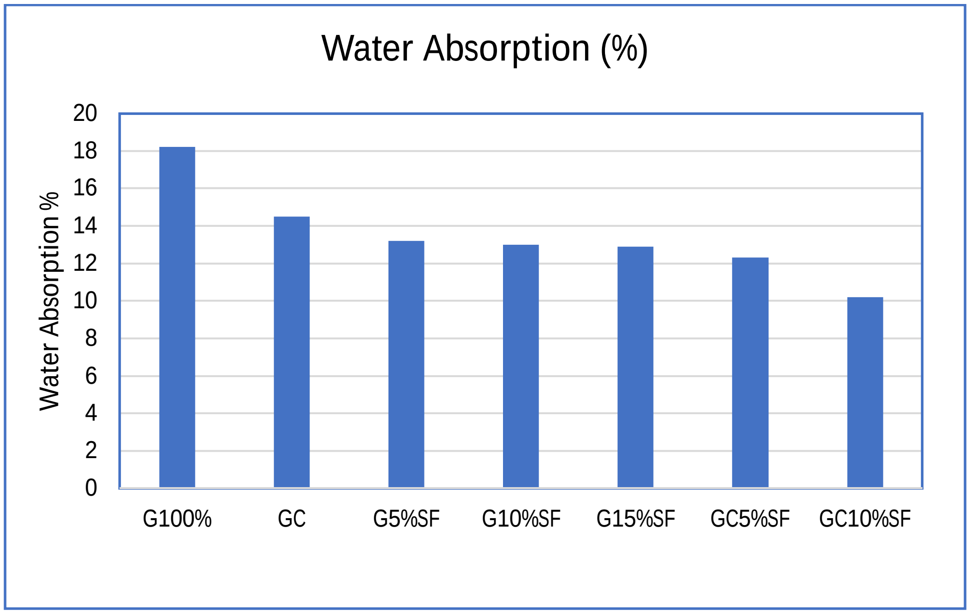


Figure 2: Water Absorption

### B. Density

The bulk density of the specimens ranged from 980 kg/m³ for the GC15%SF mix to 1155 kg/m³ for the GC10%SF mix as shown in Figure-3. Increased silica fume content slightly reduced the density due to the finer particle structure. However, when cement was added, the density increased due to the higher specific gravity of cement and better particle packing.

Higher density in the GC10%SF mix is a positive indicator for compressive performance, as well-compacted and dense composites usually show higher strength and lower permeability.

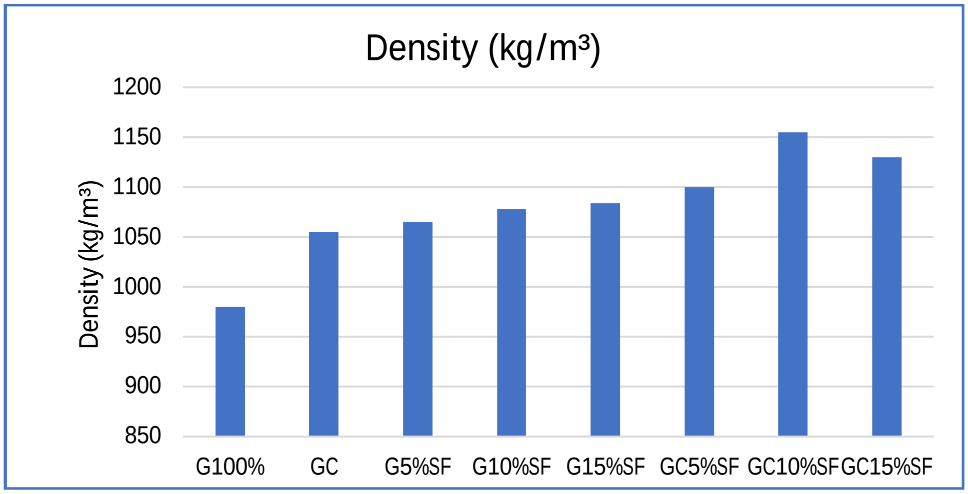


Figure 3: Density

### C. Compressive Strength

The compressive strength of the control (100% gypsum) was recorded at 6.2 MPa as shown in figure-4. The inclusion of 10% cement (GC mix) improved the compressive strength to 7.87 MPa, showing a 26.9% increase due to enhanced hydration and matrix formation.

With the addition of 5% silica fume to the GC mix (GC5%SF), the strength increased further to 9.09 MPa, while GC10%SF achieved 10.5 MPa — a total improvement of approximately 69.4% over the control. This increase is attributed to silica fume's ability to fill micro-voids and improve the interfacial transition zone. The GC15%SF mix, however, showed a slight reduction to 9.7 MPa, possibly due to excessive fines leading to poor workability and increased water demand.

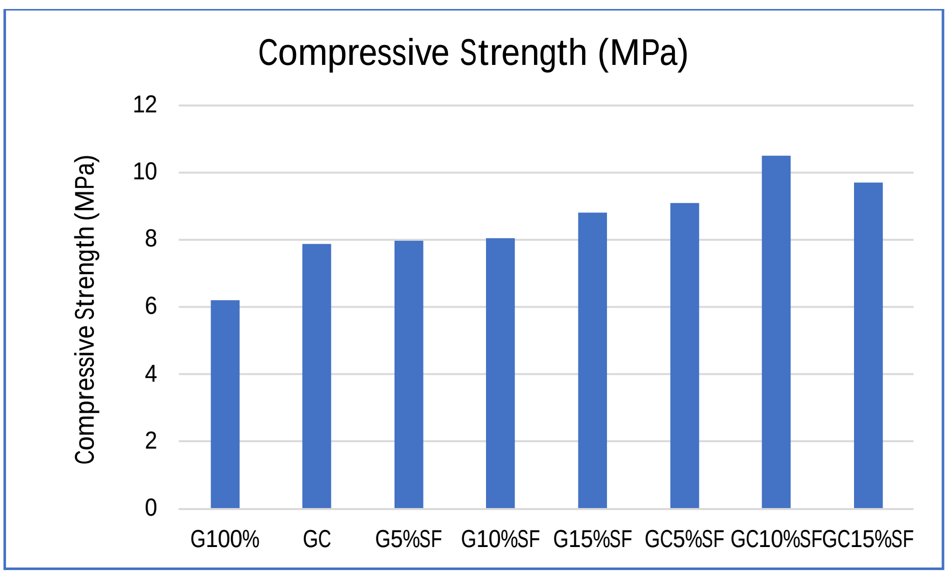


Figure 4: Compressive strength

### *D. Flexural Strength*

The control mix showed an average flexural strength of 2.1 MPa as shown in Figure-5. With cement addition, the strength improved to 2.65 MPa. Maximum flexural strength was observed for GC10%SF, reaching 3.3 MPa — over 57% higher than the control. This indicates improved crack-bridging and tensile performance due to both pozzolanic activity and better bond strength. Similar to compressive strength trends, GC15%SF showed a drop to 3.0 MPa due to potential microcrack formation or non-uniform dispersion of fines.

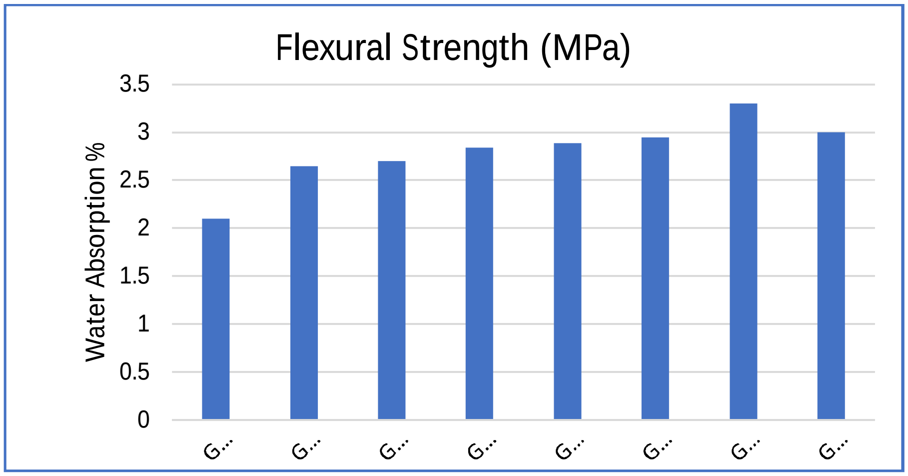


Figure 5: Flexural strength

### *E. Panel Compression Test*

Full-scale floor panels fabricated from GC10%SF composite were subjected to a concentrated load test. The panel successfully withstood the required load of 4448 N with a deflection of 1.76 cm — below the maximum allowable 2.03 cm — and permanent set was under 0.25 cm, complying with CISCA/AF standards. This demonstrates the suitability of the optimized mix design for practical flooring applications.

## IV. CONCLUSION

1) The study successfully investigated the mechanical properties of raised floor panels made from gypsum modified with cement and silica fume.
2) The incorporation of **10% cement and 10% silica fume (GC10%SF)** produced the most favorable results among all tested mixes.
3) Key improvements observed in the GC10%SF mix compared to the control (100% gypsum) include:

- Compressive strength increased by approximately 69%, enhancing the load-bearing capacity.
- Flexural strength improved by over 57%, improving the panel's resistance to bending and cracking.
- Water absorption decreased by more than 44%, indicating reduced porosity and improved moisture resistance.
- Density increased, suggesting better compaction and structural uniformity.

Full-scale panel tests confirmed that GC10%SF panels:

- Met required standards for **load capacity and deflection** according to CISCA/AF guidelines.
- Showed minimal permanent set, indicating good elastic recovery after loading.
- The research supports the use of **industrial by-products** to enhance material performance while promoting environmental sustainability in construction

## V. RECOMMENDATIONS

1) Material Optimization: Future studies could investigate the use of additional fibers (e.g., PVA, hemp, or basalt) to further enhance tensile and flexural properties of gypsum-based panels.
2) Long-term Durability: Conduct freeze-thaw resistance, sulfate attack, and thermal cycling tests to assess long-term environmental stability and degradation behavior.
3) Fire and Acoustic Performance: Since gypsum is fire-resistant, testing panels for flame spread rating and sound insulation performance can widen their functional applications.

4) Scaling and Application: Evaluate the cost-effectiveness and manufacturability of GC10%SF panels at industrial scale to assess commercialization viability.
5) Environmental Impact: Conduct a Life Cycle Assessment (LCA) to validate the environmental benefits over traditional raised floor materials.

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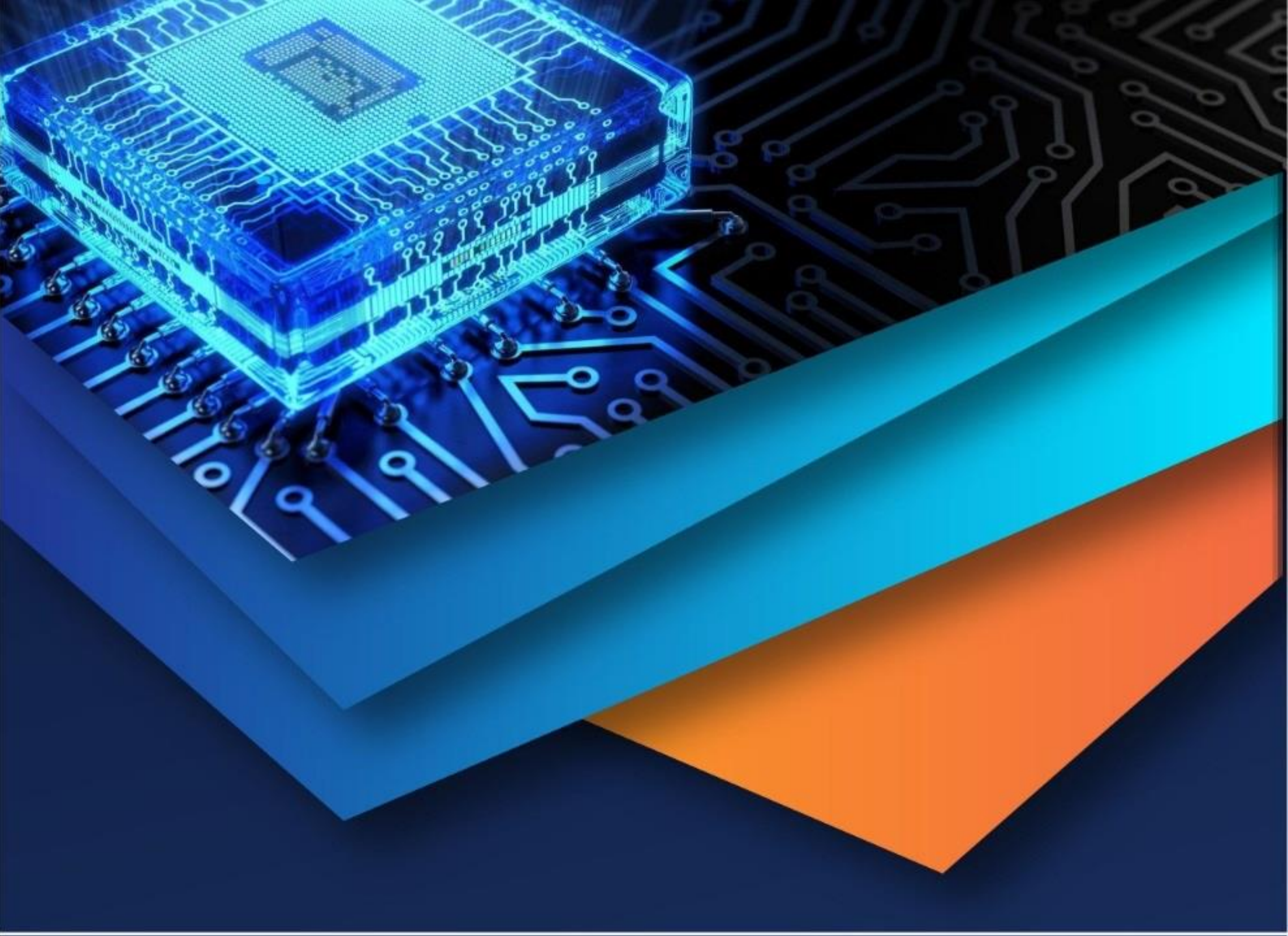


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