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Zero External Water Concrete Using Superabsorbent Polymer (SAP) as Internal Curing Agent

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Abstract— Self-curing concrete has emerged as an effective solution for minimizing water loss and improving hydration, especially in regions facing water scarcity and inadequate curing practices. This study investigates the performance of self-curing concrete incorporating Super Absorbent Polymer (SAP), MYK Arment ArmixEmmecrete PC-10, and Recron 3S fibers to enhance mechanical and durability properties without continuous external curing. The experimental program used M30 and M25 grade concrete with SAP dosage of 0.2% by weight of cement, constant PC-10 (0.5%), and Recron 3S fiber at 1.25% and 2.25% volume fractions. Fresh concrete properties were evaluated via slump and flow table tests; hardened properties through compressive strength, split tensile strength at 7, 14, and 28 days. Microstructural investigations using XRD confirmed enhanced hydration and denser C–S–H gel in SAP-modified mixes. Results indicate that the combination of SAP and PC-10 significantly improves internal moisture retention, leading to compressive strength within 3% of the conventionally cured control, while Recron 3S fibers at 1.25% improved split tensile strength by approximately 14.5% at 28 days in M30 grade.

Keywords— Self-curing concrete, Superabsorbent polymer (SAP), Internal curing, zero external water curing, PC-10 superplasticizer, Recron 3S fiber, Compressive strength, Split tensile strength, XRD.

I. INTRODUCTION

Concrete is among the most widely used construction materials globally, renowned for its high compressive strength, versatility, and durability. Its performance and longevity depend critically on proper curing, which ensures adequate hydration of cement. Conventional curing methods involve continuous external water application for 7 to 28 days; however, in many practical situations, this is difficult to implement effectively due to water scarcity, adverse environmental conditions, lack of skilled labour, and inaccessibility of structural elements.

To address these challenges, self-curing concrete — also known as zero external water curing concrete — has emerged as an innovative solution. Self-curing employs internal curing agents that supply water from within the concrete matrix, eliminating or significantly reducing the need for external water. Super Absorbent Polymers (SAP) are capable of absorbing 100–500 times their own mass of water and releasing it gradually during cement hydration, thereby controlling self-desiccation, minimising autogenous shrinkage, and preventing early-age cracking. The combined use of SAP with a polycarboxylate-based super plasticizer (PC-10) creates a synergistic effect, improving both fresh and hardened concrete properties.

This paper presents an experimental investigation on M30 and M25 grade self-curing concrete incorporating SAP, PC-10, and Recron 3S synthetic micro-fibres. The study evaluates compressive strength, split tensile strength, workability, and microstructural properties as a function of SAP dosage and fibre content.

II. LITERATURE REVIEW

Dhanya Sathyan (2025) concluded that internally cured concrete using Polyethylene Glycol (PEG), SAP, and Lightweight Aggregates (LWA) improved hydration, reduced shrinkage, and enhanced durability over 90 days. Optimum PEG dosages of 1–3% significantly increased compressive, tensile, and flexural strength, while excessive dosage reduced strength due to pore formation [1].

Zhenjun Wang (2023) demonstrated that SAP enhances slurry viscosity and improves uniformity in cement-based grouting materials. Small SAP additions below 0.3% enhanced 28-day compressive strength, especially in dry, unsealed conditions, confirming SAP as a highly effective internal curing agent [2].

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Peter C. Taylor (2024) reported that internally cured concrete using SAP, lightweight aggregates, and supplementary cementitious materials showed improved hydration, reduced shrinkage, and better durability, with enhanced microstructure at 28 and 90 days [3].
K. Vamsi Krishna (2023) studied self-curing concrete using PEG 400 and found the optimum mix achieving 43.12 N/mm² at 28 days with improved acid and sulphate resistance. SEM analysis confirmed denser microstructures in the optimum blends [4].
D. Mehra (2025) reviewed SAP as an internal curing agent, finding that optimum dosages of 0.3–0.4% by weight of cement improve long-term concrete performance through reduced shrinkage, enhanced crack resistance, and improved durability without significant compressive strength loss [5].

III. OBJECTIVES AND PROBLEM STATEMENT

A. Objectives

The objectives of this study are: (i) to develop self-curing concrete using SAP and PC-10 as internal curing agents; (ii) to eliminate or reduce conventional external water curing by maintaining internal moisture; (iii) to compare the performance of self-curing concrete with conventional concrete in terms of strength and durability; (iv) to determine the optimum dosage of SAP and PC-10; (v) to study the effect of SAP dosage on hydration and internal curing efficiency; and (vi) to conduct microstructural investigations using SEM and XRD.

B. Problem Statement

Conventional concrete requires continuous external curing that is difficult to maintain in remote locations and water-scarce regions. Inadequate curing leads to early-age shrinkage, cracking, and reduced durability. Rapid loss of internal moisture during hydration causes self-desiccation, negatively affecting strength development. High water content required for workability often reduces long-term durability.

IV. MATERIALS USED

The following materials were used in this investigation:

A. Ordinary Portland Cement (OPC 53 Grade)

OPC 53 Grade cement conforming to IS 12269 was used. Its specific gravity was determined as 3.15. It undergoes hydration when mixed with water, forming calcium silicate hydrate (C–S–H) that binds aggregates and develops strength.

B. Fine Aggregate

River sand with particles smaller than 4.75 mm was used, classified as Zone II conforming to IS 383. Specific gravity was 2.51.

C. Coarse Aggregate

Crushed granite aggregate of nominal maximum size 20 mm was used. Specific gravity was 2.57, conforming to IS 383.

D. Superabsorbent Polymer (SAP)

SAP is a hydrophilic polymer capable of absorbing 100–500 times its own mass of water and releasing it gradually during hydration. It was added at dosages of 0.1%, 0.2%, and 0.3% by weight of cement. The specific gravity is 1.02–1.2.

E. MYK Arment ArmixEmmecrete PC-10 (Super Plasticizer)

PC-10 is a high-performance polycarboxylate-based super plasticizer used at 0.5% by weight of cement. It improves cement particle dispersion, enhances workability, and reduces water demand by 20–40% without compromising strength. Specific gravity: 1.052–1.10.

F. Recron 3S Synthetic Fibres

Recron 3S is a triangular cross-section polypropylene/polyester micro-fibre used as secondary reinforcement. It arrests micro-cracks through a bridging mechanism and reduces plastic shrinkage. Used at 1.25% and 2.25% volume fractions.

V. METHODOLOGY

The methodology involved: (i) selection and preliminary testing of materials; (ii) mix design for M30 and M25 grade concrete; (iii) preparation of concrete mixes with varying SAP and PC-10 dosages; (iv) casting of standard cube (150 × 150 × 150 mm), cylinder (150 × 300 mm), and prism specimens; (v) zero external water curing (self-curing condition) except for the control mix; and (vi) testing of specimens at 7, 14, and 28 days for compressive, split tensile, and flexural strength.

VI. PRELIMINARY TEST RESULTS

TABLE I
Sieve Analysis of Fine Aggregate (Zone II)

Sieve Size	Wt. Retained (g)	% Retained	Cumulative %	% Passing
4.75 mm	86	8.60	8.6	91.4
2.36 mm	66	6.60	16.2	84.8
1.18 mm	245	24.50	39.7	60.3
600 µm	386	38.60	77.7	22.3
300 µm	190	19.00	96.7	3.3
150 µm	26	2.60	99.3	0.7
Pan	0	0	99.3	0.7

TABLE II
Sieve Analysis of Coarse Aggregate

Sieve Size	Wt. Retained (g)	% Retained	Cumulative %	% Passing
40 mm	0	0	0	100
20 mm	342	6.84	6.84	93.16
12.5 mm	3726	74.52	81.36	18.16
10.0 mm	827	17.58	98.94	1.06
4.75 mm	20	0.40	99.34	0.66
Pan	0	0	99.34	0.66

VII. FRESH CONCRETE TEST RESULTS

A. Slump Test [IS 1199 (Part-2): 2018]

The slump test was conducted to evaluate workability. Fresh concrete was filled into a standard slump cone in three layers and compacted uniformly. The cone was lifted vertically and the slump was measured. A target slump of 50–100 mm (medium workability) was maintained for normal reinforced concrete work.



Fig. 1. Slump Test

B. Flow Table Test [IS 1199 (Part 6): 2018]

The flow table test assessed spread ability of fresh concrete. Fresh concrete placed in a mould at the centre of the flow table was subjected to a specified number of drops. A flow value of 40–60% indicates medium workability.



Fig. 2. Flow Table Test

VIII. HARDENED CONCRETE TEST RESULTS

A. Compressive Strength [IS 456:2000]

Compressive strength fc = P/A, where P is the applied load (N) and A is the cross-sectional area (mm²). For a 150 mm cube: A = 22,500 mm². Specimens were tested at 7, 14, and 28 days on a compression testing machine with load applied continuously without shock.

TABLE III
Compressive Strength Results — M30 Grade (7, 14 & 28 Days)

Mix Type	SAP (%)	SP (%)	Fiber (%)	7-Day Avg (MPa)	14-Day Avg (MPa)	28-Day Avg (MPa)
Normal Concrete (Control)	0	0	0	20.14	26.66	30.66
SAP + PC-10 + Recron 3S	0.2	0.8	1.25	19.55	22.43	29.77
SAP + PC-10 + Recron 3S	0.2	0.8	2.25	18.81	16.22	23.84

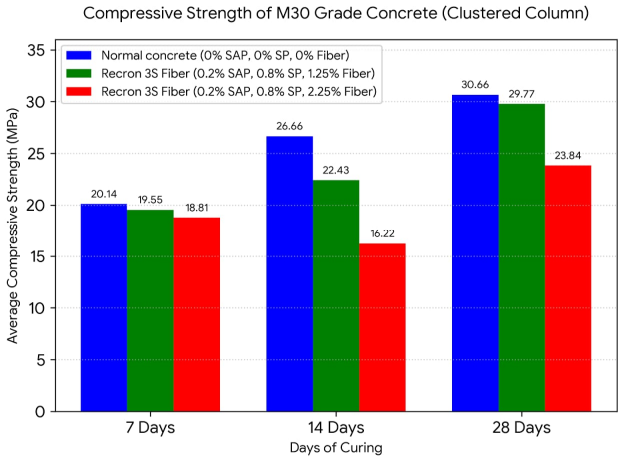


Fig. 3. Compressive Strength Results — M30 Grade (7, 14, and 28 Days)

The graph displays a clear, continuous upward trend in average compressive strength of all M30 grade mixes across the curing period. The control mix (Normal Concrete) maintains the highest compressive strength at every testing stage, beginning at 20.14 MPa at 7 days, rising to 26.66 MPa at 14 days, and peaking at 30.66 MPa at 28 days, meeting the M30 design benchmark. The 1.25% Recron 3S fibre mix closely tracks the control and reaches 29.77 MPa at 28 days.

The 2.25% fibre dosage shows significantly lower performance (23.84 MPa at 28 days), attributed to reduced workability, poor fibre distribution, and increased air void entrapment.

TABLE IV
Compressive Strength Results — M25 Grade (7, 14 & 28 Days)

Mix Type	SAP (%)	SP (%)	Fiber (%)	7-Day Avg (MPa)	14-Day Avg (MPa)	28-Day Avg (MPa)
Normal Concrete (Control)	0	0	0	17.32	23.10	25.92
SAP + PC-10 + Recron 3S	0.2	0.8	1.25	15.84	19.33	23.84
SAP + PC-10 + Recron 3S	0.2	0.8	2.25	13.32	15.33	21.80

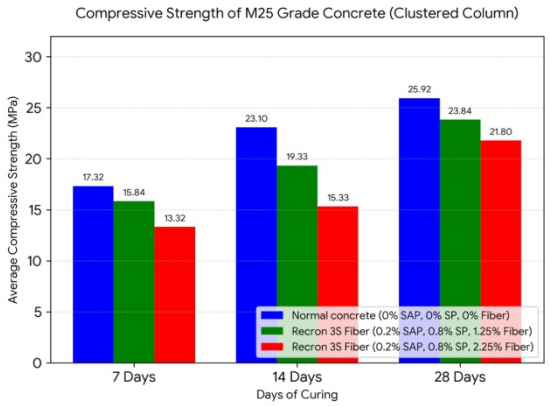


Fig.4. Compressive Strength Results — M25 Grade (7, 14, and 28 Days)

For M25 grade, the control mix achieves 25.92 MPa at 28 days. The 1.25% fibre mix recovers to 23.84 MPa at 28 days, while the 2.25% fibre dosage finishes at just 21.80 MPa, highlighting the detrimental effect of excessive fibre volume fractions on air voids and workability.

B. Split Tensile Strength [IS 5816:1999]

Split tensile strength ft = 2P/(πLD), where P is the applied load, L the length, and D the diameter of the cylinder (150 × 300 mm). Load was applied continuously along the length until the specimen split into two halves.

TABLE V
Split Tensile Strength — M30 Grade (7, 14 & 28 Days)

Mix Type	SAP (%)	SP (%)	Fiber (%)	7-Day Avg (MPa)	14-Day Avg (MPa)	28-Day Avg (MPa)
Normal Concrete (Control)	0	0	0	1.97	2.45	2.49
SAP + PC-10 + Recron 3S	0.2	0.8	1.25	1.83	2.17	2.85
SAP + PC-10 + Recron 3S	0.2	0.8	2.25	1.50	1.88	2.55

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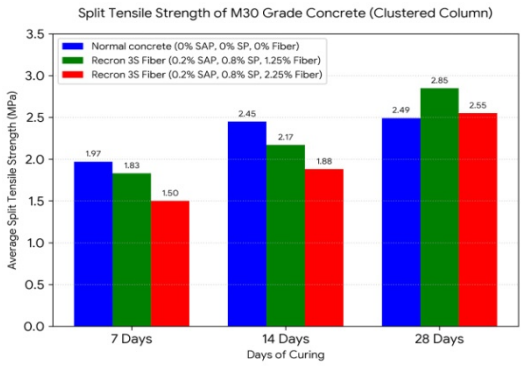


Fig.5. Split Tensile Strength — M30 Grade (7, 14, and 28 Days)

The line graph illustrates a continuous upward trend for all M30 mixes. The control mix leads at early ages (2.45 MPa at 14 days), but by 28 days both fibre-modified mixes surpass the control due to the fibre bridging effect across micro-cracks. The 1.25% fibre mix achieves the peak split tensile strength of 2.85 MPa at 28 days — a 14.5% improvement over the control (2.49 MPa).

TABLE VI
Split Tensile Strength — M25 Grade (7, 14 & 28 Days)

Mix Type	SAP (%)	SP (%)	Fiber (%)	7-Day Avg (MPa)	14-Day Avg (MPa)	28-Day Avg (MPa)
Normal Concrete (Control)	0	0	0	1.59	2.07	2.49
SAP + PC-10 + Recron 3S	0.2	0.8	1.25	1.69	1.97	2.17
SAP + PC-10 + Recron 3S	0.2	0.8	2.25	1.27	1.69	1.87

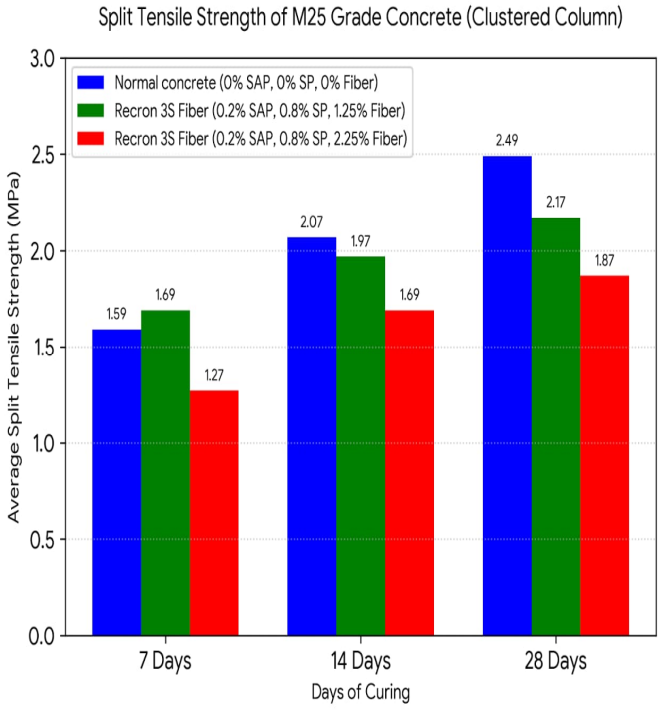


Fig. 6. Split Tensile Strength — M25 Grade (7, 14, and 28 Days)

For M25 grade, the control mix maintains dominance at 14 and 28 days (2.49 MPa). The 1.25% fibre mix achieves competitive early strength (1.69 MPa at 7 days) but finishes at 2.17 MPa at 28 days. The 2.25% fibre content consistently yields the lowest split tensile values across all curing ages.

IX. MICROSTRUCTURAL ANALYSIS

A. XRD Analysis [ASTM D3906]

X-ray Diffraction (XRD) analysis was conducted to identify the crystalline phases present in the concrete matrix. The XRD pattern of the internal-curing concrete exhibited distinct diffraction peaks at 2θ values of approximately 29°–30°, 50°–52°, and 60°–61°, indicating the presence of crystalline phases associated with lime (CaO/Ca $(OH)_2$), silica (SiO_2), and alumina-containing compounds. A broad background hump at lower diffraction angles confirmed the existence of amorphous and semi-crystalline phases contributed by the polymeric SAP component. The coexistence of crystalline and amorphous phases confirms successful incorporation of SAP within the concrete matrix and supports enhanced hydration, microstructural densification, and overall durability.

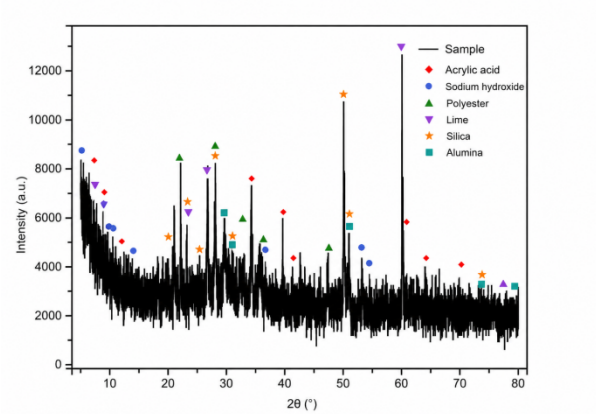


Fig.7. XRD Pattern of Self-Curing Concrete Incorporating SAP

X. CONCLUSIONS

The following conclusions are drawn from this study:

1) The SAP-based internal curing system effectively replaced external water curing by maintaining internal relative humidity and supporting continuous cement hydration throughout the 28-day period.

2) The 0.2% SAP dosage combined with 0.5% PC-10 was identified as the optimum blend, achieving compressive strengths of 29.77 MPa (M30) and 23.84 MPa (M25) at 28 days — within 3% of the conventionally cured control mix.

3) Recron 3S fibre at 1.25% volume fraction improved split tensile strength at 28 days by approximately 14.5% in M30 grade, confirming the fibre bridging effect on crack arrest and tensile toughness.

4) Increasing fibre content to 2.25% caused a measurable decline in compressive strength and workability due to fibre clustering, increased air void entrapment, and non-uniform distribution.

5) Self-curing concrete using SAP and PC-10 is a practical and effective solution for construction in water-scarce regions, precast applications, high-rise structures, and wherever continuous external curing is difficult to maintain.

XI. FUTURE SCOPE

Future research should: (i) evaluate performance at higher SAP dosages (0.4–0.5%) with compensated water to offset void-induced strength reduction; (ii) investigate combined effects of SAP with fly ash, GGBS, and silica fume for high-performance self-curing concrete; (iii) study long-term durability including carbonation depth, chloride penetration (RCPT), and freeze-thaw performance; and (iv) extend the investigation to higher-grade concretes (M40, M50) for structural applications.

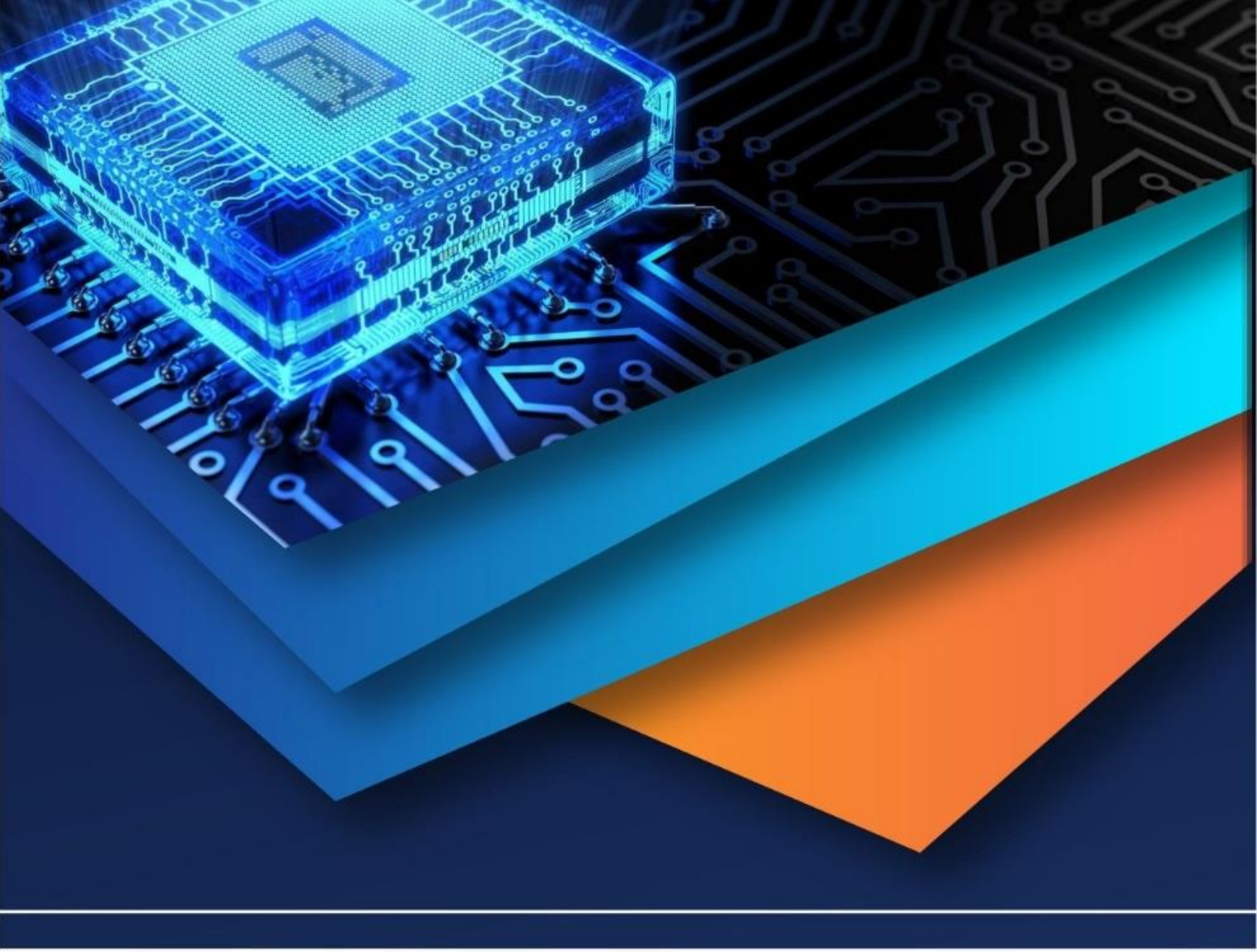
XII. ACKNOWLEDGMENT

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