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Replacement of Coarse Aggregate with Expanded Polystyrene Beads to Achieve Lightweight Concrete

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Abstract: In this study, we explore how replacing traditional coarse aggregates with Expanded polystyrene (EPS) beads can enhance the properties of concrete. Lightweight concrete is valued in construction for its reduced self-weight, which eases handling and reduces load on structures, as well as for its superior thermal insulation and soundproofing qualities. By integrating EPS beads, which are known for being light and insulating, we aim to push these benefits even further. Concrete has to be designed based on density factor to accomplish reduction of the concrete self- weight with is ranging from 2000kg/m3 to 990kg/m3 total volume of EPS 0-100% and water cement ratio 0.45 Structural self-weight is quite important it shows a maximum portion of the load details. The main aim is to design EPS lightweight concrete according to standard concrete mix proportion. This mix proportion includes replacement of the conventional coarse aggregate by Partially or complete part with EPS beads, which ensures concrete workability and density. To study the properties of concrete like workability, compressive strength, Split tensile strength and Flexural strength test with partial replacement of course aggregate with expanded polystyrene beads EPS in concrete. Various test was conducted for fresh and harden concrete to know physical and mechanical properties of concrete at age of 7, 14 and 28days. Green construction is becoming a more important global problem and a key approach to conserve biodiversity and limit the amount of waste that ends up in landfills. To ensure the success of this investigation, coarse aggregate, cement, sand, water, and EPS beads with a diameter of not more than 10mm will be employed. In addition, four trial mixes must be made. The outcome indicates that increasing the quantity of EPS beads there will be decreasing strength of concrete with reduction in density. We can also Comparision strength for both conventional and lightweight concrete, which also makes us to the differentiate in cause of use.
Keywords: Concrete, Expanded polystyrene (EPS), workability, Aggregate replacement.

I. INTRODUCTION

A. General

Incorporating lightweight aggregates like fly ash, silica fume, and fibers enhances concrete strength and durability. The addition of EPS beads creates a porous structure with excellent thermal and acoustic insulation, making it ideal for partition walls, precast panels, and roofing. This concrete also offers fire resistance, low water absorption, and energy efficiency.Despite being lightweight, it can achieve compressive strengths of 2.5 to 20 MPa, depending on mix design. Admixtures like plasticizers improve workability, while fibers enhance tensile strength and crack resistance. EPS concrete is eco-friendly, integrating recycled materials to reduce construction waste. Its low density provides seismic resistance and reduces transportation and labor costs. Common uses include insulating floor screeds, lightweight blocks, and void-filling. However, lower mechanical strength limits its use in load-bearing structures. Proper curing and mix optimization ensure long-term durability.The first major structural lightweight concrete project was the 1928–1929 expansion of the Southwestern Bell Telephone office in Kansas City, proving its viability for construction.

B. Expanded Polystyrene (EPS)

Expanded Polystyrene (EPS) is a lightweight, closed-cell foam made by expanding polystyrene beads using heat. Originally developed in Germany in 1926 and later commercialized by Dow Chemical as "Styrofoam" in 1954, EPS is water-resistant, impact-resistant, and offers stable thermal insulation. In construction, EPS concrete reduces structural weight by replacing normal aggregates with EPS beads. This lowers seismic mass, improves insulation, and allows structural modifications like adding floors to existing buildings. With densities ranging from 12–50 kg/m³, EPS concrete balances strength and weight, making it ideal for lightweight, energy-efficient structures while also reducing transportation and fuel costs.

C. Blending of EPS

Expanded Polystyrene (EPS) is processed from resin containing pentane gas, which expands with steam to 40% of its original size. The expanded pellets are molded into blocks, with density being a key factor in mechanical properties like compression, shear, and tensile strength. Manufacturing costs and insulation properties also depend on density. According to IS 4671:1984, EPS densities range from 15 to 35 kg/m³. In the USA, ASTM C 578-95 categorizes EPS types as XI (12 kg/m³)

Type	XI	I	VIII	II	IX
Density (kg/m^3)	12	15	18	22	29

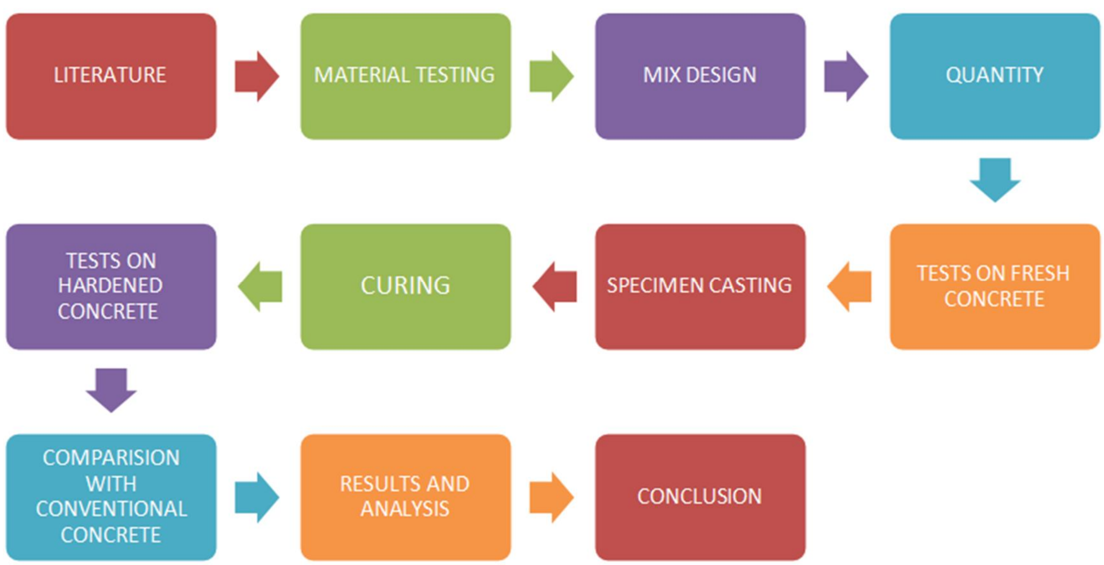
D. Scope and Objectives

This study explores replacing coarse aggregate with Expanded Polystyrene (EPS) to create lightweight concrete. Using a 0.45 water-cement ratio, concrete cubes and cylinders were tested for compressive and tensile strength at 7, 14, and 28 days.

Objectives

- Develop lightweight concrete with thermal and sound insulation.
- Assess its suitability for various building sections.
- Evaluate strength properties (compressive, tensile, flexural) with different EPS proportions.
- Analyze material properties and mix design.
- Study the impact of EPS replacement on fresh and hardened concrete.
- Examine durability and density compared to conventional concrete.

II. METHODOLOGY



Percentage of Replacement of material for various mixes to get desire density

Mix designation	Percentage of Coarse Aggregate	Percentage of Fine Aggregate	Percentage of EPS Beads	Density Achieved By Mix Design Kg/m³
M0	58%	42%	0%	2410
M1	55%	35%	10%	2261
M2	42%	30%	28%	1950
M3	31%	35%	34%	1801
M4	15%	35%	50%	1500
M5	0%	23%	77%	990

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Table Quantity of material taken for various mixes of concrete done for the present investigation

Mixes	Density Kg/m³	Cement in Kg/m³	Coarse aggregate Kg/m³	EPS beads Kg/ m³	Fine aggregates Kg/m³	Water Kg/ m³
M0	2410	320	1070	0	880	140
M1	2261	320	1006	0.78	795	140
M2	1950	320	802	1.05	687	140
M3	1801	320	639	2.5	700	140
M4	1500	320	337	3.12	700	140
M5	990	320	0	5.64	524.3	140

III. MATERIALS

1) *Cement:* The cement used was ordinary Portland cement of 53 grade in accordance with the IS 12269:2013. The cement should be fresh and uniform consistency. Where there is evidence of lumps or any foreign matter in the material, it should not be used. The cement should be stored under dry conditions and for as short duration as possible.
2) *Aggregates:* Aggregates are generally classified into two group sizes, coarse and fine aggregate. In so many cases two or more actual sizes of material has been used, because of a further subdivision by size of material either present in one or both of the groups. Generally fine aggregate is taken as, which has been passing from the 4.75mm sieve. As a results it also must have specific gravity of 2.6 . Coarse aggregate is consider as the particle which was retained on the IS sieve 4.75 mm
3) *Expanded polystyrene (EPS):* Expended polystyrene (EPS) Beads Expended polystyrene (EPS) is a plastics substantial which is contained around 98% air and 2% polystyrene. These are light in weight comprising of fine circular shaped particles. Its like closed cell arrangement cannot absorb water. It as decent thermal and sound resistance qualities and additionally impact resistance. EPS material is non-biodegradable. The waste material which is coming after packing industry.
4) *Water:* Water is a one of the important ingredient in the concrete and this will help chemical reaction with cement. In the concrete, strength is mainly depending on the binding operation of hydrated cement gel. The water is added to get required consistency for the suitable workability. Water used for the concrete preparation must be fresh and potable, Ocean water and drainage water should not be used because of sulphate reaction

IV. MATERIAL PROPERTIES

A. Cement

Generally the physical properties of cement like specific gravity, standard consistency, initial setting time and final setting time of cement will be determined by the laboratory method and by the code of IS 4031- 1988 part 5.

Properties of cement

Property	Value
Specific gravity	3.07
Fineness	98%
Initial setting time	30 minutes
Final setting time	210 minutes

B. Fine Aggregate

Fine aggregates is used an artificial material of M-Sand. The EPS Partial replacement of manufacture sand and cement. Now-a-days good sand is not readily presented. The Fine Aggregates day by day demand in construction sector. But we have used the natural river sand with is nearly available. Fine aggregates are the aggregates whose size is less than 4.75mm. Generally, sieve analysis is conducted to know the grading criteria and size of nominal fine aggregate.

Properties of fine aggregate

Property	Value
Specific gravity	2.7
Water absorption	0.84%
Fineness modulus	2.322%
Unit weight	1600kg/m³

C. Coarse Aggregate

Properties of Coarse aggregate according to I.S 383, I.S 2386 part III&IV

Property	Value
Specific gravity	2.74
Fineness modulus	6.62%
Unit weight	1650kg/m^3

D. Water

Properties of water

S.NO	Impurity	Max. limit	Results
1	p^H value	6-8	7.6
2	Suspended matter (mg/lit)	2000	220
3	Organic matter (mg/lit)	200	20
4	inorganic matter (mg/lit)	3000	150
5	Sulphates (SO_4) (mg/lit)	500	30
6	Chlorides (CL) (mg/lit)	2000 for P.C.C 1000 for R.C.C	60

V. TEST RESULTS AND DISCUSSIONS

This section discusses the results of the various tests conducted on concrete blocks at various ages of curing and with various mix proportions. Cubes of size 150mm x 150mm x 150mm, cylinders of size 150mm diameter and 300 mm of height are been casted using the design mix and are kept for curing. After the different ages of curing they are tested for compressive strength, split tensile test and the young"s modulus of concrete.

A. Test Results On Design Concrete Mix

1) Workability

The workability of concrete with EPS beads is determined by slump cone test and compaction factor test.

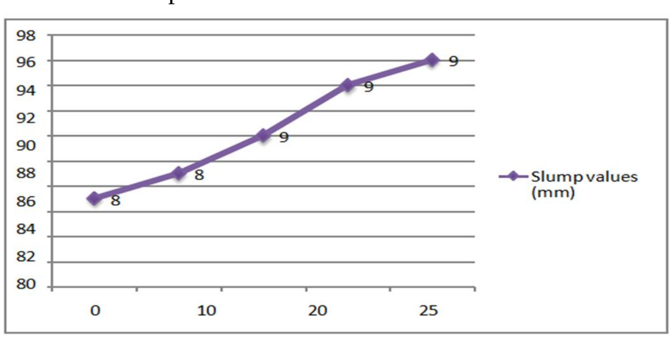
SLUMP CONE TEST

This test conducted for determining workability of the fresh concrete. Testing method principle aggregate size should not exceed 20mm as per is 456:2000 and no slump for designed concrete.

Slump values for different percentage of mix

% of EPS Beads replaced	Slump value (mm)
0	85
10	87
25	94
40	97

Slump cone values for different % of EPS



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2) Compaction Factor Test

Test results for compaction factor test

S.No	Description	Conventional concrete	Lightweight concrete
1	Weight of empty mould (w)	3.2kg	3.2 kg
2	Weight of empty mould + loose concrete (w_1)	14.18 kg	6.27kg
3	Weight of empty mould + compacted concrete (w_2)	15.27kg	7.13kg

Compaction factor for conventional concrete:
= 14.18/15.27
= 0.92 (medium workability concrete) Compaction factor for lightweight concrete:
=6.27/7.13
= 0.87 (medium workability concrete).

3) Non Destructive Test

a) Rebound Hammer Test

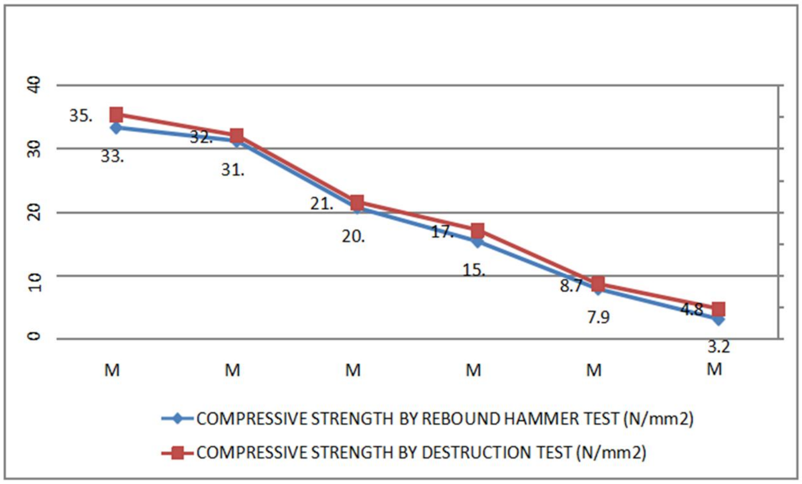
Rebound hammer consist of spring control hammer, a plunger. The plunger is pushed towards the surface of the specimen, the mass is being rebound from plunger and it withdraws against the compel of spring. The hammer impacts against the concrete and spring control mass rebounds, the rider is taken by hammer with it along guide scale the rider is kept in place by clicking the button and rebound number is observed.

Comparision in strength by Rebound hammer test and compressive strength test after 28 days of curing for designed lightweight concrete.

Mix	Rebound Values For Various Mixes	Compressive Strength From Rebound Test (N/Mm^2)	Compressive Strength by Destructive Test (N/Mm^2)
M0	32	33.3	35.4
M1	30	31.2	32.1
M2	19	20.7	21.6
M3	14	15.4	17.2
M4	7	7.9	8.7
M5	2	3.2	4.8

From the results of table , it is observed that the 150mm cube, compressive strength of designed mix concrete gives the equally good results with that of the conventional concrete upto 28 days of curing. Beyond 28 days of curing the compressive strength of designed mix concrete i.e., lightweight concrete was found to be slightly reduces.

Graph Comparison of compressive strength by rebound hammer and compressive strength test for designed lightweight concretee



b) Water Absorption Test

Table water absorption test results for designed light weighted concrete (EPS) after 28 days of curing

TRIAL MIX	Dry weight in grams (W1)	Wet weight in grams (W2)	Percentage of water absorption (%)
M0	8.030	8.224	2.415
M1	7.780	7.890	1.414
M2	7.010	7.160	2.139
M3	6.430	6.580	2.332
M4	5.20	5.550	3.730
M5	3.460	3.620	4.624

The test is done on cubes made by partial and complete substitution of coarse aggregate with EPS beads the lowest water absorption noticed for normal trial mix i.e. M0 the mix M5 with 77% of EPS beads with coarse aggregate which is having highest water absorption. By increased volume of EPS beads porosity is increases by decreasing the density of the concrete.

4) Destructive Test

a) Compressive Strength Test

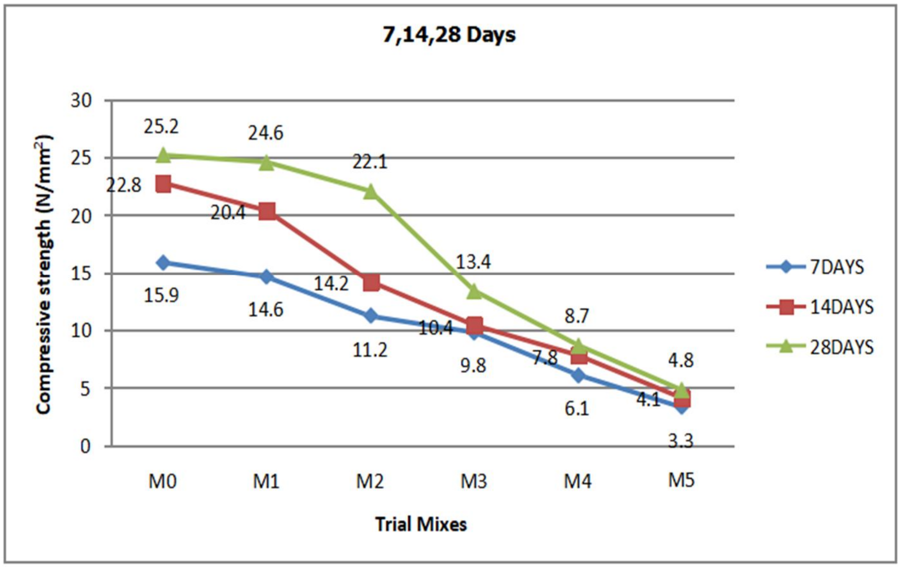
At 7 and 28 days, compressive strength is measured. The results show that as the proportion of Expanded polystyrene beads grows from 0% to 77%, the compressive strength increases, but as the percentage of EPS beads goes higher, the compressive strength decreases. As a result, we can substitute up to 10% of the time.

Figure: Results Collection from Compressive Strength

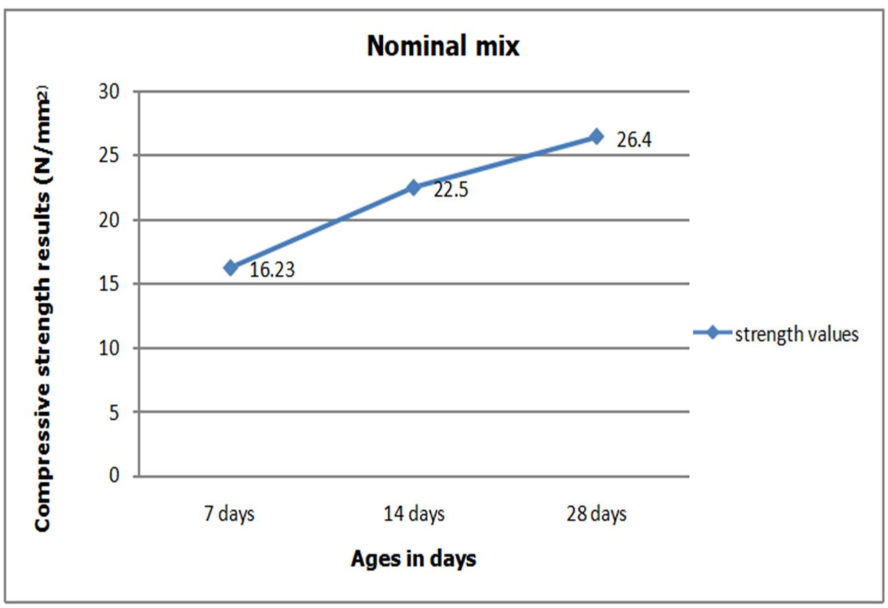
Table compressive strength test results for Nominal concrete mix design.

Mix Design	Compressive Strength At 7 Days (N/mm^2)	Compressive Strength At 14 Days (N/mm^2)	Compressive Strength At 28 Days (N/mm^2)
M0	15.9	22.8	25.2
M1	14.6	20.4	24.6
M2	11.2	14.2	22.1
M3	9.8	10.4	13.4
M4	6.1	7.8	8.7
M5	3.3	4.1	4.8

Graph representation of compressive strength values for nominal designed concrete.



Graph Representation of the Compressive strength test results for M25 conventional concrete



b) Split Tensile Strength Test

Tensile strength is the capacity of a material or structure to withstand tension. The tensile strength of concrete greatly affects the size of cracking in structures. Due to the brittle nature of concrete, it is weak in tension. So, concrete generally develops cracks when tensile forces exceed its tensile strength. Split tensile test can be done on universal testing machine. The Split tensile strength is obtained by dividing the recorded load to the bearing area of the specimen .

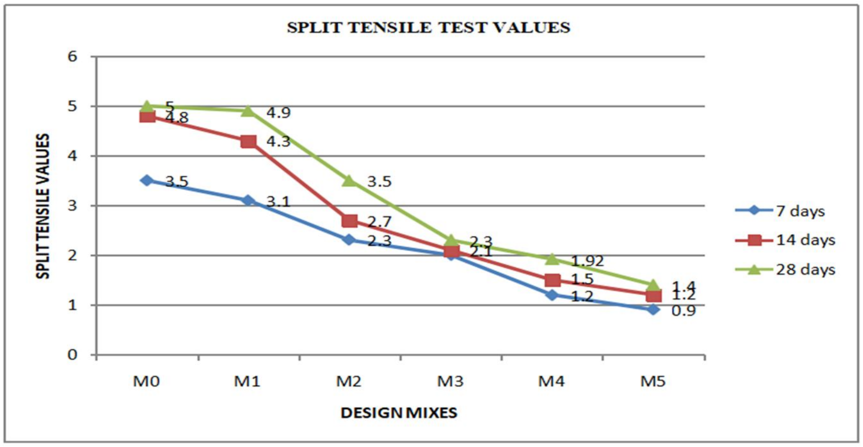
Figure: Observation from Split tensile strength

Split tensile strength = 2P/πdl in N/sq mm.
Where P is load at failure.
D is diameter of cylinder. L is length of cylinder.

Table Split tensile strength test results for designed lightweight concrete .

Mix Design	Split tensile Strength at 7 Days(N/mm^2)	Split tensile Strength at 14 Days(N/mm^2)	Split tensile Strength at 28 Days(N/mm^2)
M0	3.5	4.8	5
M1	3.1	4.3	4.9
M2	2.3	2.7	3.5
M3	2	2.1	2.3
M4	1.2	1.5	1.92
M5	0.9	1.2	1.4

Graph Representation of split tensile strength of con



VI. CONCLUSION

In the present work, an experimental investigation has been carried out on EPS LWC mixtures prepared with replacement of the conventional coarse aggregate with EPS beads. A study on the fresh concrete density as well as basic mechanical properties of the designed concrete was conducted.

Based on the experimental results following conclusions are made.

1) EPS concrete Compressive strength increases with decrease in the replacements levels of the Expanded polystyrene beads Polystyrene can replace Polystyrene up to 10% without alternating the strength of concrete considerably.
2) The polystyrene we can achieve light-weight concrete. The density of concrete decreasing, the dead weight of the structure also by replacing the polystyrene we can achieve light-weight concrete.
3) Use of expanded polystyrene (EPS) beads in concrete can be you of the waste disposal method and one of the energy-saving method where EPS beads are completely replaces the aggregate. Hence, this type of LWC can be considered environmentally sustainable material for non-structural application.
4) EPS entails no complex production techniques and processes. Though, the most critical parameters in relation to producing EPS Light weight concrete to obtain a desired concrete quality is the order of dosage of mixture constituents and mixing process as well as the casting method.
5) Density of the concrete will reduce at maximum extent is about 990Kg/m3.
6) With an increase in the percentage of polystyrene replacement strength is decrease steeply compared to normal concrete.
7) The maximum strength (compressive, split tensile and flexural) was attained at 10% of expanded polystyrene and was found to reduce for 30% of expanded polystyrene but it can be used for single floor building to make economical and to reduce the dead load.
8) The results reveal that all of the EPS Concrete, without the need of a specific bonding agent, has good workability and can be compacted and finished quickly.
9) The EPS particle size affects the flexural strength, primarily affecting the reduction of the effective cross-section flexural height.
10) The EPS beads have a closed cellular structure, increasing their volumetric proportion in the mixes decreases markedly the compressive strength.

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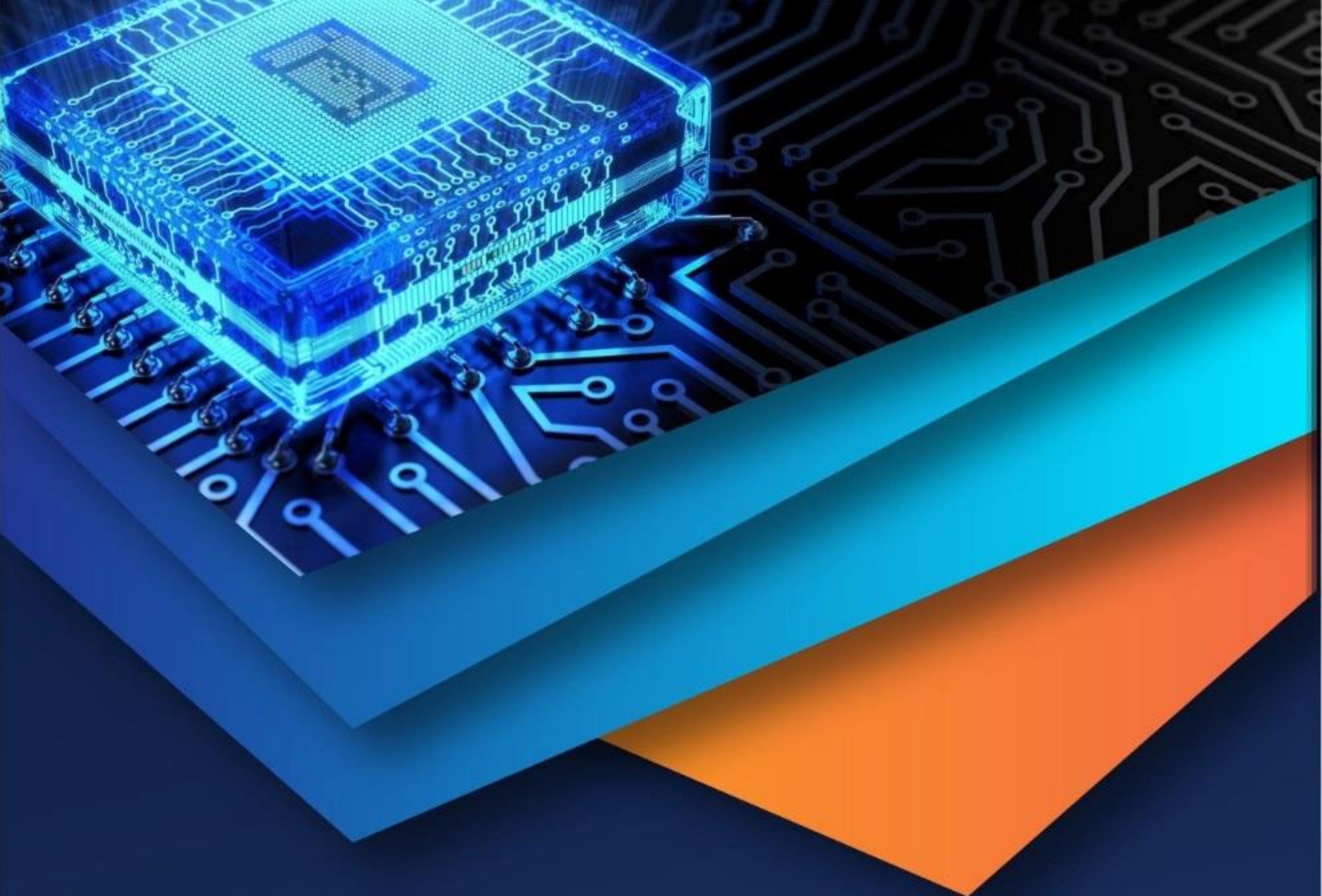

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