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An Experimental Study on Concrete by Bacterial Mineral Precipitation

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***Abstract:** A new technique in remediating cracks and fissures in concrete by utilizing microbiologically induced Calcite ($CaCo_3$) precipitation is discussed. Microbiologically induced calcite precipitation (MICP) is a technique that comes under a broader category of science called Bio Mineralization. It is a process by which living organisms form inorganic solids. Bacillus subtilis, a common soil bacterium can induce the precipitation of calcite. The objective of the present investigation is to study the potential application of bacterial species i.e. Bacillus subtilis to improve the strength of cement concrete. Here we have made an attempt to incorporate dormant but viable bacteria in the concrete matrix which will contribute to the strength of the concrete. In this project, bacterial concrete is prepared under grade of concrete M_{30}.The design mix proportioning also carried under IS code provision. Testing of specimens are carried at 7 days, 14 days and 28 days of curing by Compression Testing Machine and Universal Testing Machine for corresponding specimens.*

I. REVIEW OF LITERATURE

B. M. Mali (2012) Investigated the potential application of bacterial species i.e. B.sphaericus to improve the strength of cement concrete. Here an attempt to incorporate dormant but viable bacteria in the concrete matrix which will contribute to the strength of the concrete. Water which enters the concrete will activate the dormant bacteria which in turn will give strength to the concrete through the process of metabolically mediated calcium carbonate precipitation.

Srinivasa Reddy, (2012)A novel eco-friendly self-healing technique called Bio calcification is one such approach on which studies were carried out to investigate the crack healing mechanism in enhancing the strength and durability of concrete. Microbiologically induced calcite precipitation (MICP), a highly impermeable calcite layer formed over the surface of an already existing concrete layer, due to microbial activities of the bacteria (Bacillus subtilis JC3) seals the cracks in the concrete structure and also has excellent resistance to corrosion.

S. Sunil Pratap Reddy, (2010) Researchers with different bacteria have proposed different bacterial concrete's. Here an attempt was made by using the bacteria "Bacillus subtilis". Calcite formation by Bacillus subtilis is a model laboratory bacterium, which can produce calcite precipitates on suitable media supplemented with a calcium source. This study showed a significant increase in the compressive strength was observed due to the addition of bacteria for a cell concentration of 10^5 cells per ml of mixing water. From Scanning Electron Micrography analysis, it is noted that pores were partially filled up by material growth with the addition of the bacteria. From the durability studies, the percentage weight loss and percentage strength loss with 5% H_2SO_4 revealed that Bacterial concrete has less weight and strength losses than the conventional concrete and it also revealed that bacterial concrete is more durable in terms of "Acid Durability Factor" and "Acid Attack Factor" than conventional concrete.

De Muynck W. Et Al.,(2007)In our research groups, first the criteria for the selection of calcium precipitating Bacillus strains were established. Bacillus sphaericus strains capable of the remediation of Euville limestone, by precipitating a dense and coherent calcium carbonate layer and concomitantly inducing a reduction of capillary water absorption, were characterized by a high urease activity, abundant EPS-production, a good biofilm production and a very negative ζ-potential.

II. MATERIALS AND TESTING

A. Cement

In market various types of cements are available but our present investigation ordinary Portland cement of 53 grade is used. OPC is the most commonly produced and used cement. The properties of cement tested as per IS: 4031-1988 and found to be conforming to various specifications of IS: 12269-2009.

B. Metakaolin

Metakaoiln is a dehydroxylated form of the clay mineral kaolinite. Stone that are rich in kaolinite are known as china clay or kaolin, traditionally used in the manufacture of porcelain. The particle size of metakaolin is smaller than cement particles, but not fine as silica fume.

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C. Water

Water used for mixing and curing is fresh potable water, conforming to IS: 3025 – 1964 part 22, part 23 and IS: 456 – 2000.

D. Bacteria

Researchers with different bacteria proposed different bacterial concretes. The various bacteria used in the concrete are Bacillus pasteurii, Bacillus sphaericus, E.coli etc. In the present study an attempt was made by using the bacteria Bacillus subtilis strain no.113 (MTCC). The main advantage of embedding bacteria in the concrete is that it can constantly precipitate calcite. This phenomenon is called Microbiologically Induced Calcite Precipitation (MICP).
Nutrient Broth is used for the general cultivation of bacterial microorganisms, can be enriched with blood or other biological fluids.

Table1 Nutrient Broth

S.No	Ingredients	Gms / Litre
1	Peptic digest of animal tissue	5.000
2	Sodium chloride	5.000
3	Beef extract	1.500
4	Yeast extract	1.500
5	Final pH (at 25°C)	7.4±0.2

Figure 1 Nutrient Broth

Table2. Mix proportioning for a M30 grade concrete

WATER	CEMENT	FINE AGGREGATE	COARSE AGGREGATE
197.16	492.9	610.25	1126.29

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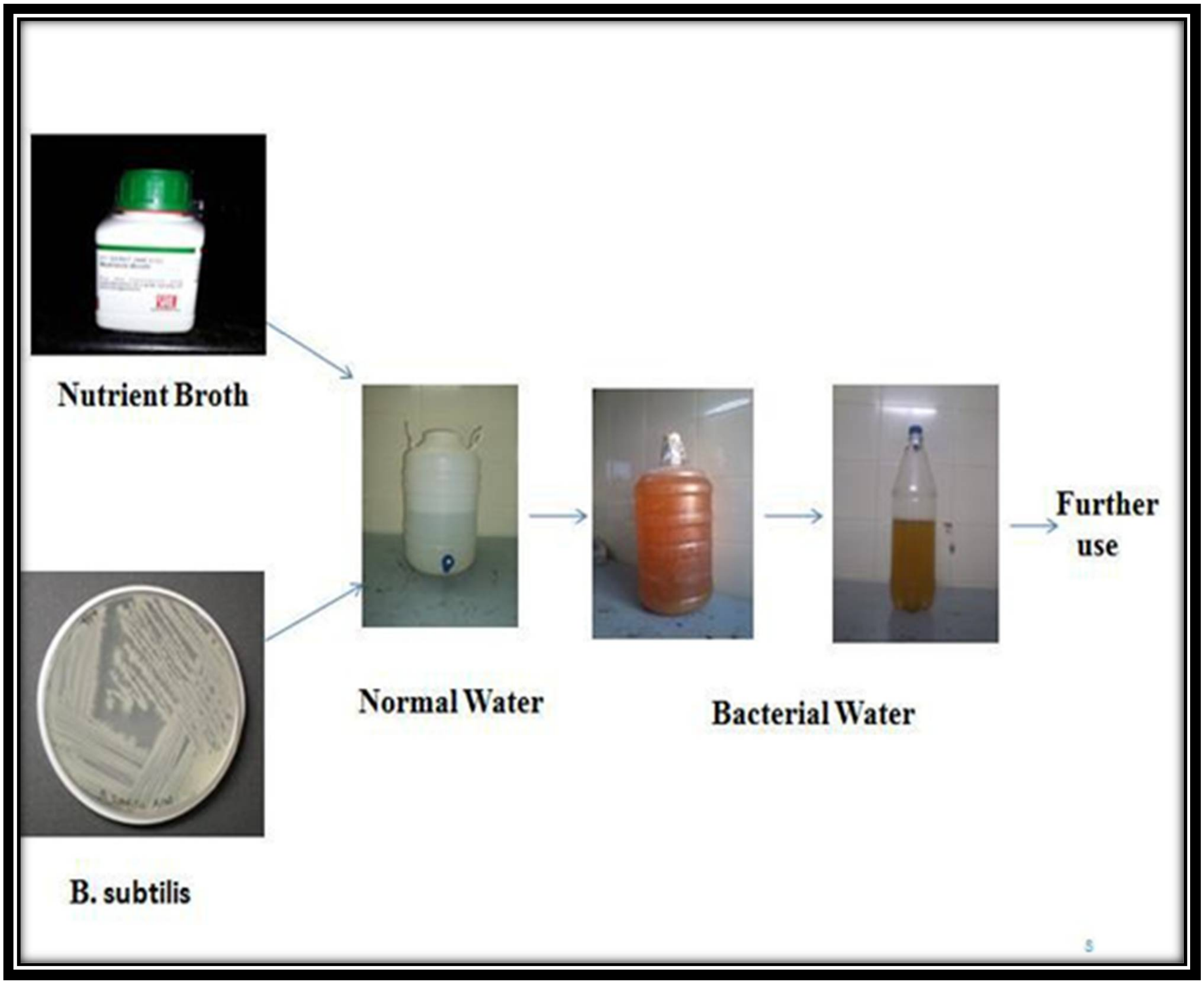
III. EXPERIMENTAL INVESTIGATION

A. Production of Bacterial Water

The nutrient broth and other chemicals are mixed with required water. After that the mixed water is boiled for autoclaving process. The boiled water should have the reddish color due to nutrient broth and other chemicals. After the atmospheric cooling the required bacterial cell is transferred from nutrient agar plate to that prepared liquid media. Then the liquid media should be covered with aluminum foil and shake periodically.

The reddish color should be changed into light yellow color after 36 – 48 hours which shows the presence of bacillus subtilis in the liquid media. Before mixing into the concrete, concentration of bacterial cell is tested.



IV. EXPERIMENTAL STUDY ON COMPRESSIVE STRENGTH OF CONCRETE

A. Compressive Strength of Concrete

The investigation is carried out to study the compressive strength concrete. The results of the compressive strength of controlled, bacterial concrete and bacterial metakaolin concrete at 7 days, 14 days and 28 days for M30 grade concrete are tabulated in Table 4.1In M30 grade of concrete the compressive strength at 7 days, 14 days and 28 days are given in Table 4.1. It is observed that with the addition of bacteria and metakaolin increases the compressive strength of concrete showed significant by adding bacteria 26.52%, 28 % and 30.90 % at 7 days, 14 days and 28 days and with replacement of cement with metakaolin increase the compressive strength 29.73%, 30.20 % and 35.78 % at 7 days, 14 days and 28 days respectively.

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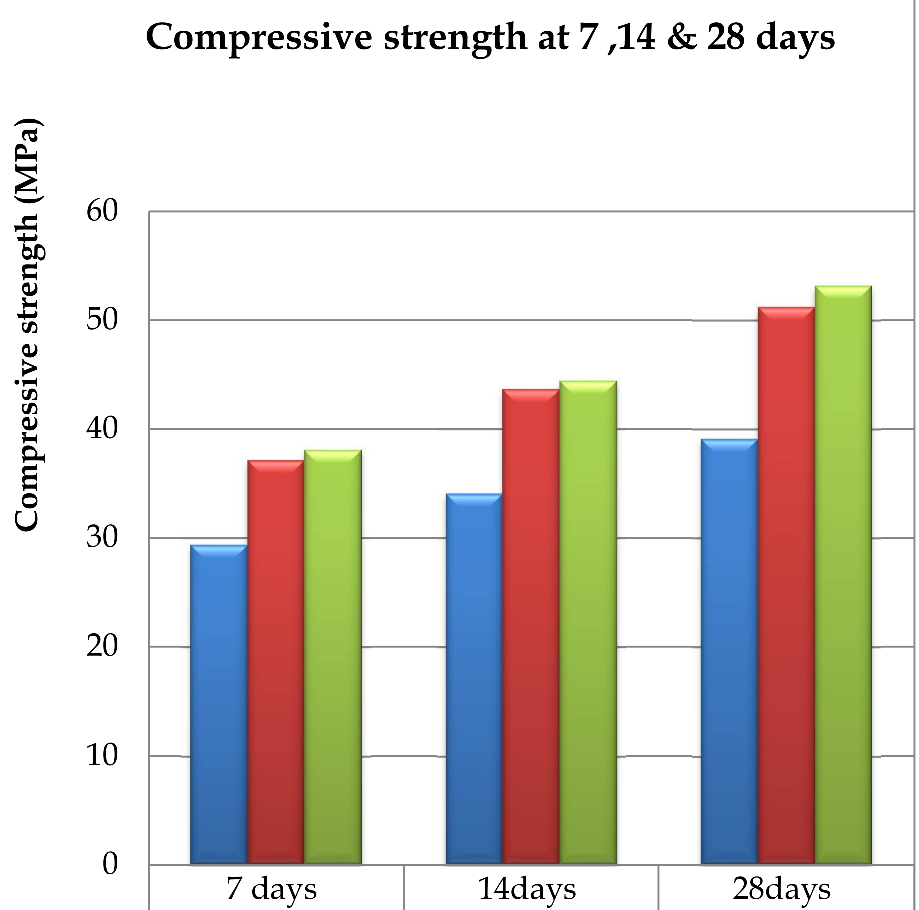

	7 days	14days	28days
Compressive strength for Conventional concrete cube N/mm2	29.33	34.07	39.12
Compressive strength for Bacterial Concrete cube N/mm2	37.11	43.61	51.21
Compressive strength for Bacterial Concrete cube with 10% Replacement of Metakaolin N/mm2	38.05	44.36	53.12

Figure 4.1 Comparison of Compressive Strength between Controlled and Bacterial Concrete with Age

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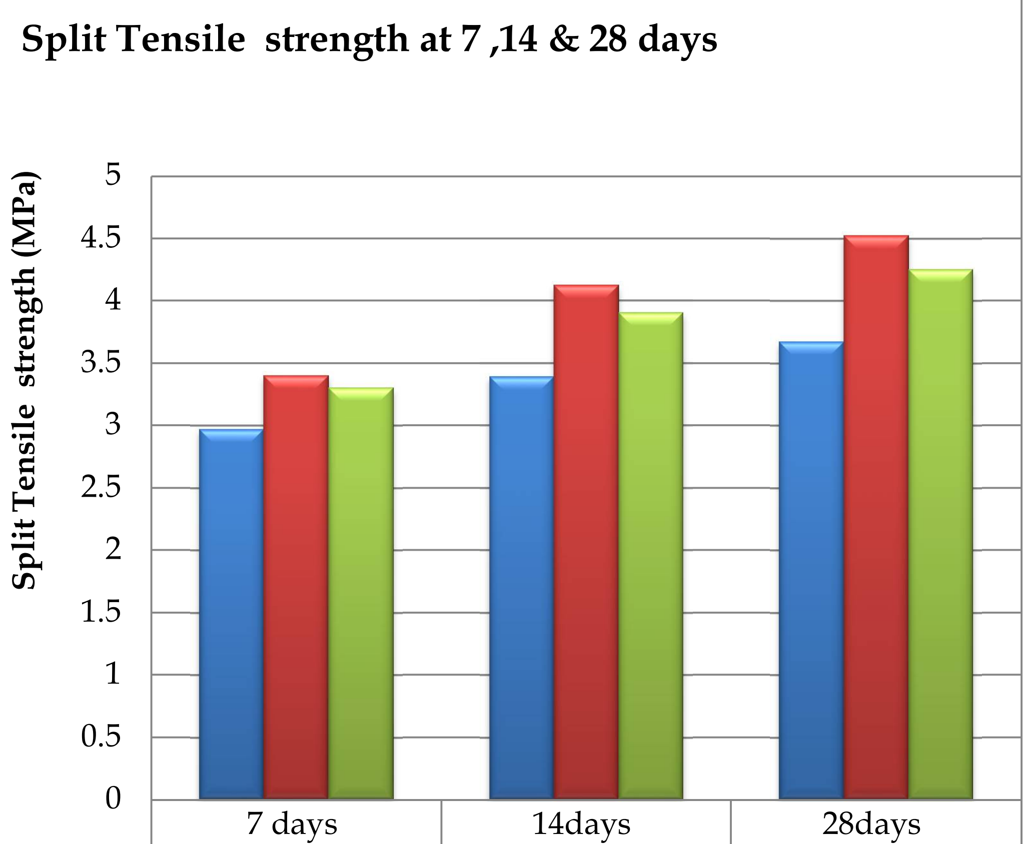
B. Split Tensile Strength of Concrete

In M30 grade concrete the Split Tensile Strength on standard cylindrical specimens at 7 days, 14 days and 28 days are given in Table 7.2. It is observed that with the addition of bacteria there is a significant increase in the spilt tensile strength by 14.47%, 21.53 % and 23.16% at 7 days, 14 days and 28 days and with replacement of cement with metakaolin decrease the split tensile strength 11.11%, 14.70 % and 15.80 % at 7 days, 14 days and 28 days respectively.



	7 days	14days	28days
Split Tensile strength for Conventional concrete cube N/mm2	2.97	3.39	3.67
Split Tensile strength for Bacterial Concrete cube N/mm2	3.4	4.12	4.52
Split Tensile strength for Bacterial Concrete cube with 10% Replacement of Metakaolin N/mm2	3.3	3.9	4.25

Figure 6.2 Comparison of Split Tensile Strength between Controlled and Bacterial Concrete with Age

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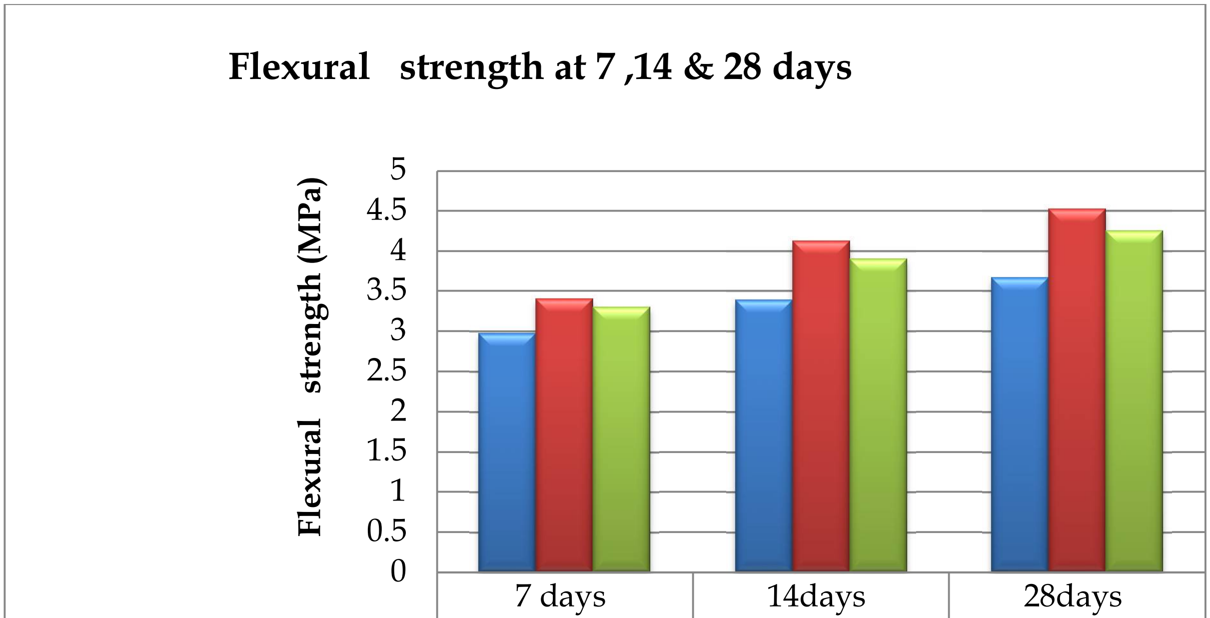
C. Flexural Strength of Concrete

The investigation is carried to study the flexural behavior of concrete. 27 simply supported beams consisting of balanced section are cast and tested. The cross section of the beam specimen is 100mm x 100mm x 500mm. The beams are cast using with bacteria and without bacteria in M30 grade concrete. The flexural strength of both controlled and bacterial concrete is calculated and the result is tabulated in Table 6.3



	7 days	14days	28days
Flexural strength for Conventional concrete cube (MPa)	2.97	3.39	3.67
Flexural strength for Bacterial Concrete cube (MPa)	3.4	4.12	4.52
Flexural strength for Bacterial Concrete cube with 10% Replacement of Metakaolin (MPa)	3.3	3.9	4.25

Figure 4.3 Comparison of Flexural Strength between Controlled and Bacterial Concrete with Age

V. CONCLUSIONS

A. Bacillus subtilis can be produced in the laboratory which is proved to be safe and cost effective.

B. In M30 grade concrete, with the addition of bacteria and metakaolin the percentage of improvement in the compressive strength is in the order of by 26.52% to 30.90 % and 29.73% to 35.78%at different ages. [2]

C. In M30 grade concrete, with the addition of bacteria the percentage of improvement in the spilt tensile strength is in the order of 14.47% to 23.16% at different ages and the percentage is reduced by replacement of metakaolin in bacterial concrete.

D. In M30 grade concrete, with the addition of bacteria the percentage of improvement in the flexural strength is in the order of 13.05% to 30.09% at different ages the percentage is reduced by replacement of metakaolin in bacterial concrete.

E. Cost of the bacterial concrete is increased to that of conventional concrete. But compare to other type of special concrete it should be very economical.

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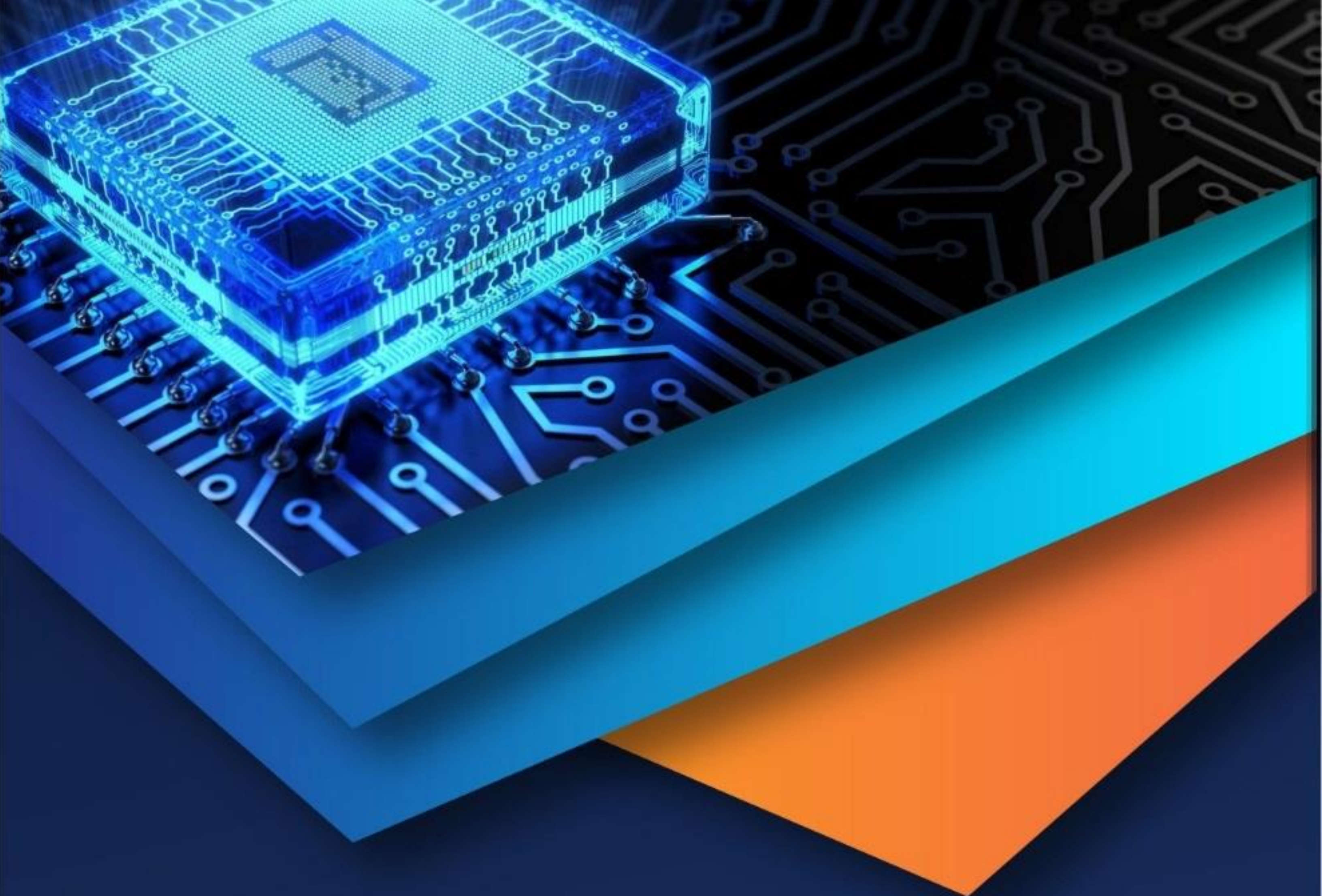

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