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State of Art Review on Bacterial Concrete

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Abstract: ***Micro - cracks are the main cause to structural failure. One way to circumvent costly manual maintenance and repair is to incorporate an autonomous self - healing mechanism in concrete. There are distinctive methods accessible in advertise however they are expensive and not cordial.Along these lines a novel strategy has been produced by utilizing a specific microbial stopping process, in which microbial metabolic exercises advance calcium carbonate precipitation; this procedure is eluded as Microbiologically Enhanced crack remediation (MECR) [1].Recently, it is discovered that microbial mineral precipitation coming about because of metabolic exercises of ideal microorganisms in concrete enhanced the overall behavior of Concrete [2].Bacterial concrete is a material, which can successfully remediate cracks in concrete. This technique is highly desirable because the mineral precipitation ($CaCO_3$) induced as a result of microbial activities is pollution free and natural[10].Consequently in this paper,topics likedefinitionof Bacterial Concrete, Formation of carbonate ions, Advantages and Disadvantages, Working of Bacterial Concrete and Literature review are discussed.***

Key words: Bacterial Concrete,Formation of carbonate ions, Working Process of Bacterial Concrete

I. INTRODUCTION

Concrete is imperative building material that is totally more vital of public infrastructure and most buildings. It is most effective when reinforced by steel bar embedded, because its tensile strength without reinforcement is considerably low relative to its compressive strength. It is brittle material so it create crack with time.High tensile stresses can result from external loads, imposed deformations, plastic shrinkage, plastic settlement, and expansive reactions (e.g. due to reinforcement corrosion, alkali silica reaction, sulphate attack).Without quick and appropriate treatment, breaks have a tendency to grow further and in the long run require exorbitant repair. Durability of concrete are additionally diminish in view of break and they gave a simple way to transport of fluids and gasses. Micro crack not only affect the concrete but it also affect the reinforcement of concrete. Water and oxygen connect through the crack and they corrode the steel. Micro-cracks are therefore precursors to structural failure. For crack repair, a variety of techniques is available but traditional repair systems have a number of disadvantageous aspects such as different thermal expansion coefficient compared to concrete and environmental and health hazards. Therefore a novel technique has been developed by using a selective microbial plugging process is known as Bacterial concrete. The "Bacterial Concrete" is a concrete which can be made by embedding bacteria in the concrete that are able to constantly precipitate calcite. This phenomenon is called Microbiologically Induced Calcite Precipitation (MICP), in which calcite precipitation induced microbial activities are involved [5]. With the use of bacteria in concrete improves compressive strength, tensile strength, Durability Aspect, reduces freeze thaw attack, crack remediation, pollution free and cost effective.

II. HISTORY OF MICROBIOLOGY

Microorganisms (Bacteria) are Microscopic Organism and they are distinctive in sizes and shapes. Microorganisms are accessible on Earth, developing in soil, radioactive waste, water additionally in Organic issue and live collections of Animals and also plants. There are 40 millions Bacterial cells in a single gram of soil, and an a huge number of microorganisms in 1 ml of new water. There are roughly five nonillion (5×10^3) Bacteria on Earth. Microorganisms were first seen by Antoine van Leeuwenhoek in 1676, utilizing a solitary focal point magnifying lens of his own outline. He called them "animalcules" and distributed his perceptions in a progression of letters to the Royal Society. The name bacterium was presented considerably later, by Christian Gottfried Ehrenberg in 1838.

In the research facility, Bacteria are normally grown with the assistance of Solid media or Liquid media. In Solid media, for example, Agar plate are utilized to confine unadulterated culture of bacterial strain. In Liquid media Luria broth utilized when expansive volumes of bacterial cell are required. Development of Bacteria takes after three stages. Microorganisms initially enter in High supplement condition that permits development.The primary period of development is the lag phase, a time of moderate development when the cells are adapting to the high-supplement condition and getting ready for quick development. The second phase of development is the logarithmic stage (log stage), also known as the exponential phaseduring log phase, nutrients are

metabolized at maximum speed until one of the nutrients is depleted and starts limiting growth. The final phase of growth is the stationary phaseand is caused by depleted nutrients. The cells reduce their metabolic activity and consume non-essential cellular proteins.

III.PREPARATION OF BACTERIAL SOLUTION

Primarily, 4 gm of Nutrient broth (media) is added to a 200ml conical flask containing distilled water. It is then covered with a thick cotton plug and is made air tight with paper and rubber band. It is then sterilized using a oven for about 10-20 minutes. Now the solution is free from any contaminants. Now bacteria added and the solution is clear orange in colour before the addition of the bacteria. Later the flasks are opened up and an exactly 1ml of the bacterium is added with the help of nichrome wire to the sterilized flask and is kept in a shaker at a speed of 150-200 rpm overnight. After 24 hours the bacterial solution was found to be whitish yellow turbid solution [15].

IV.FORMATION OF CARBONATE IONS

The bacteria produces unease which catalyzes the hydrolysis of urea (CO $(NH_2)_2$) into ammonium (NH^{4+}) and carbonate ($CO3^{2-}$). First, 1 mol of urea is hydrolyzed intracellular to 1mol of carbamate and 1mol of ammonia (eq. (1)). Carbamate spontaneously hydrolyses to form additionally 1mol of ammonia and carbonic acid (eq. (2)). These products subsequently form 1mol of bicarbonate and 2mol of ammonium and hydroxide ions (eq. (3) and (4)). The last 2 reactions give rise to a pH increase, which in turn shifts the bicarbonate equilibrium, resulting in the formation of carbonate ions (eq. (5))

$CO(NH_2)_2 + H_2O \rightarrow NH_2COOH + NH_3$ (1)

$NH_2COOH + H_2O \rightarrow NH_3 + H_2CO_3$(2)

$H_2CO_3 \longleftrightarrow HCO_3^- + H^+$ (3)

$2NH_3 + 2H_2O \longleftrightarrow 2NH_4 + 2OH^-$(4)

$HCO_3^- + H^+ + 2NH_4 + 2OH^- \longleftrightarrow CO_3^{2-} + 2NH_4^+ + 2H_2O$ (5)

Since the cell wall of the bacteria is negatively charged, the bacteria draw cations from the environment, including Ca^{2+}, to deposit on their cell surface. The Ca^{2+} -ions subsequently react with the CO_3^{2-}-ions, leading to the precipitation of $CaCO_3$ at the cell surface that serves as a nucleation site (eqs. (6) and (7))

$Ca^{2+} + Cell \longrightarrow Cell-$ (6)

$Cell\text{-}Ca^{2+} + CO_3^{2-} \longrightarrow Cell\text{-}CaCO_3\downarrow$ (7)

In equation (6) the negative charged Bacterial Cell wall attracts the positively charged Ca^{2+} to deposit on the cell wall. In equation (7) the Ca^{2+} ion then react with the CO_3^{2-} ion and finally it leads to the precipitation of $CaCO_3$ at the cell surface.

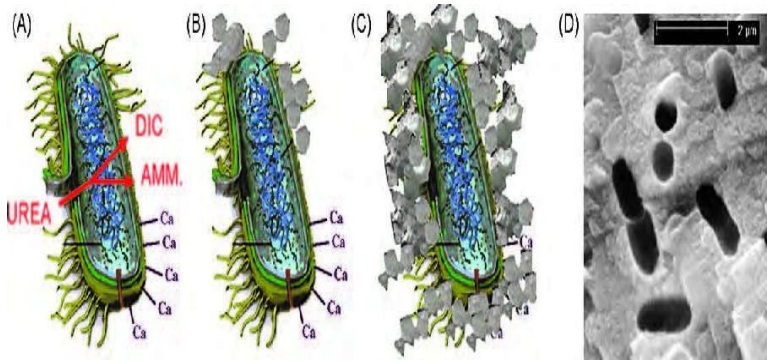

Fig. 1 Events occurring in MICP

For better calcinations conbimbined mechanisms are reported to play a crucial role. Events during the MICP are represented in simplified manner in Figure 1. Calcium ions which are positively charged in the solution are attracted to the bacterial cell wall which is negatively charged. Presence of urea to the bacteria vicinity, due to microbial activity dissolved inorganic carbon (DIC) and ammonium (AMM) are released in the microenvironment of the bacteria (A). Due to local supper saturation of ion along with calcium ions, result in heterogeneous precipitation of calcium carbonate on the bacterial cell wall (B). as process forwards, the whole cell becomes encapsulated by calcium precipitation (C), resulted in limiting nutrient transfer leads to cell death. Image (D) shows the imprints of bacterial cells left after carbonate precipitation

V. BACTERIAL CONCRETE

The concept of bacterial concrete was first introduced by V. Ramakrishnan*et al*. A novel technique is adopted in remediating cracks and fissures in concrete by utilizing microbiologically induced calcite (CaCO3) precipitation. Microbiologically induced calcite precipitation (MICP) is a technique that comes under a broader category of science called biomineralization. Microbiologically induced calcite precipitation is highly desirable because the calcite precipitation induced as a result of microbial activities, is pollution free and natural. The technique can be used to improve the compressive strength and stiffness of cracked concrete specimens. In Bacterial concrete, bacteria induced calcite precipitation is carried out. This phenomenon is called microbiologically induced calcite precipitation (MICP). The pioneering work of bacterial concrete with use of MICP technique is reported by the Research group of Ramakrishnan V and others at the South Dakota School of Mines &Technology,USA.The MICP is a technique that comes under the broader category of Microbiology. Common soil bacterium can induce the precipitation of calcite. Under favourable conditions bacteria, when used in concrete, can continuously precipitate a new highly impermeable calcite layer over the surface of the already existing concrete layer. Due to its inherent ability to precipitate calcite continuously, bacterial concrete can be called a Smart Bio Material for repairing concrete. In bacterial concrete, bacteria improve the compressive strength, flexural strength, split tensile strength and reduced permeability as well as Freeze – Thaw Attack.

VI.REV IEW OF LITERATURE

Kadapureet.al (2014) carried out an experimental investigation on the strength properties of bacterial concrete with fly ash. The percentage of use of fly ash was10%, 20% and 30% was replaced by weight of cement. B. pasteurii should be added in different cell concentration (0,103, 105, 107 cell/ml of mixing water). B. pasteurii increasing the compressive strength of concrete by up to 20.46 % and in fly ash concrete up to 17.46% ,15%,and 10.38% for 10%,20%,30% fly ash as replacement of cement at a 105 cell/ml. B . pasteurii increasing the split tensile strength of concrete by up to 18.27 % and in fly ash concrete up to 15.80% ,13.06%,and 11.30% for10%,20%,30% fly ash as replacement of cement at a 105 cell/ml.

Ravindranatha et.al(2014) had attemptedproposedcement is replaced by Fly ash, G.G.B.S.and *B. pasteurii*should be embedded in concrete. They concluded that process can reduce the seepage permanently to a considerable level. Texture becomes more compact and the compressive strength is also considerably increased. The analysis of the compressive strength test result for 14 and 28 days as shown in below[8].

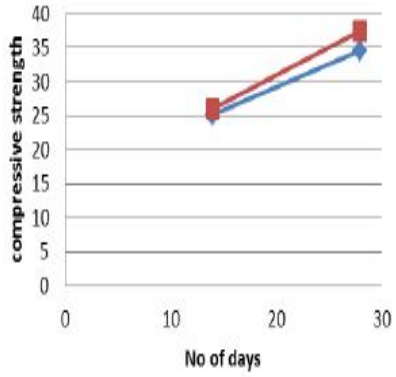

Fig. 2 Compressive strength

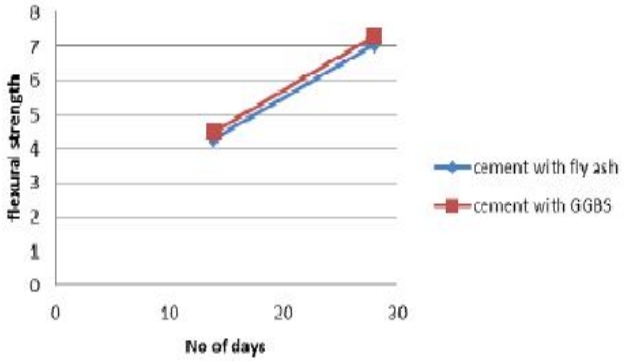

Fig. 3 Flexural strength

Chahaland Siddique (2013) studied Sporosarcinapasteurii embedded in concrete with Silica fume and fly ash. The bacterial were taken in 10^3, 10^5 and 10^7 cells/ml concentration. Cement was replaced with fly ash, and silica fume in concrete mix. The percentage use of fly ash was 0%, 10%, 20% and 30%, and that silica fume were 0%,5% and 10% was replaced by weight of cement. Maximum compressive strength after91 days was observed for a mixture with 10% fly ash and 10% silica fume which had10^5 cells/ml bacterial concentrations. it was 11% more than that in 10^3 cells/ml and13.5% more than that in 10^7 cells/ml. Electron microscopy scanned deposition of calcite on the bacteria cell surfaces and calcium carbonate precipitation was confirmed by XRD. The minimum water porosity after 91 days was observed for a mixture with 30% fly ash and 10% silica fume which had 10^5 cells/ml bacterial concentrations. The porosity for 10^5 cells/ml concentration bacteria reduced by 50% than that in same mixture without bacteria.

Muhammad I et al(2012) Bacillus subtilis, Thermusthermophilus and OPC cement are used. They observed that after 3days B.subtilis gives more compressive strength compared to Thermusthermophilus at 10^6 cell / ml. After 60 days Thermusthermophilus gives more compressive strength compared to B.subtilis.The optimum cell concentration of Bacillus subtilis and Thermusthermophilus bacteria in givin the most enhanced effect was found to be 10^6 cells/ml[5].

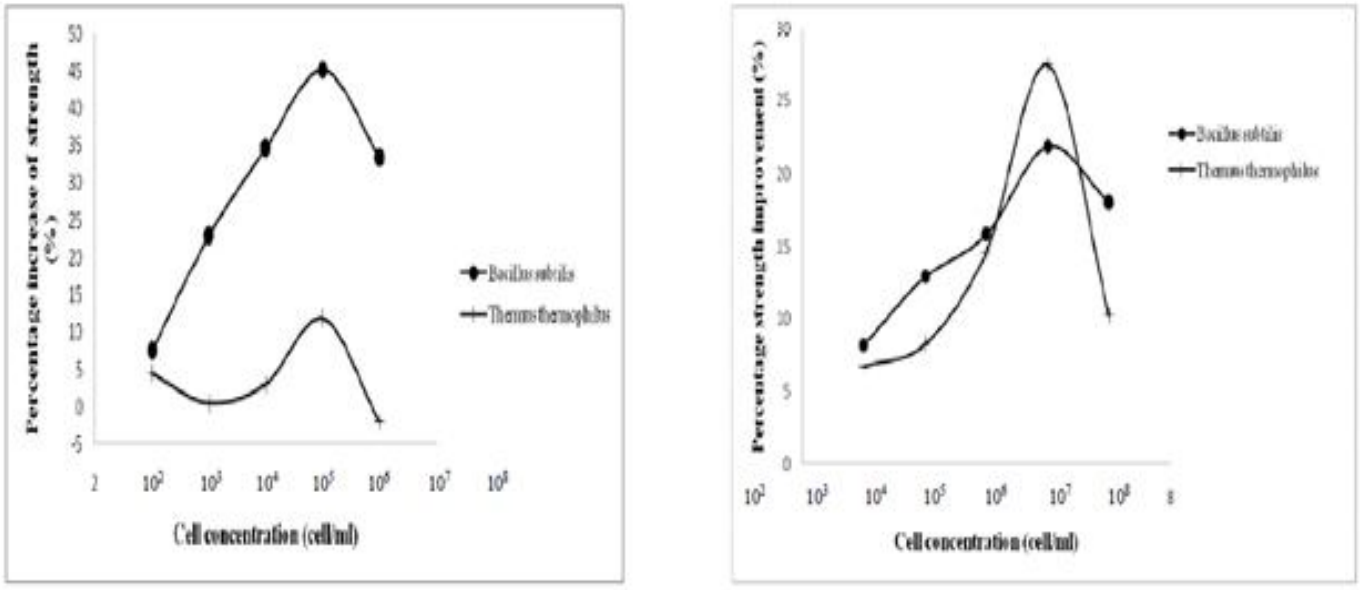

Fig. 4 Flexural strength

Willem et al(2008)highlighted the gaps between conventional surface Treatments and bacterial carbonate precipitation (bio-deposition).It was reported that the effect of bio-deposition improves the durability of cement mortar/concrete specimens. It was also observed that deposition of CaCO3 crystals decreased the water absorption of the sample depending on the inherent porosity of the specimen leading to a decrease in the carbonation rate by about 25– 30%.[3]

VII. LITERATURE SUMMARY

A. Bacillus sphaericus improve the compressive strength compare to conventional concrete.
B. MICP technique is good, economic and environment friendly compared to other healing techniques.
C. Thermusthermophilus bacteria give good strength after long period compare to Bacillus subtilis
D. Bacteria can be embedded in combination of fly-ash + Cement or G.G.B.S + Cement and it improves the strength of concrete.
E. Combinations of 30% fly ash + 10% silica fume reduction in porosity.
F. Microbial calcite precipitation was quantified by X-ray diffraction (XRD) analysis and visualized by SEM.
G. SEM confirms the presence of calcite precipitation inside cracks, rod shaped bacterial impressions and a new calcite layer on the surface of concrete

VIII. WORKING OF BACTERIAL CONCRETE

At the point when broken segment blended in microscopic organisms interacts with fresh concrete, cracked surfaces are enacted within the sight of water, and after that starts to multiply and precipitate minerals. These minerals, including calcium carbonate close the crack. A schematically introduction of bacterial based mending is displayed in figure number. The microscopic organisms should act to a great extent as an impetus and change an antecedent compound, for example, calcium carbonate-based mineral accelerates, in to an appropriate filler material.. To ensure efficient self healing for the whole service life of a structure, both bacteria and a bio cement precursor compound should be integrated in the material matrix Concrete-immobilized bacteria (dark blue) on the crack surface becomes activated due to water ingression and start to multiply and precipitate minerals (yellow) which eventually seal the crack and protect the steel reinforcement from further chemical attacks.

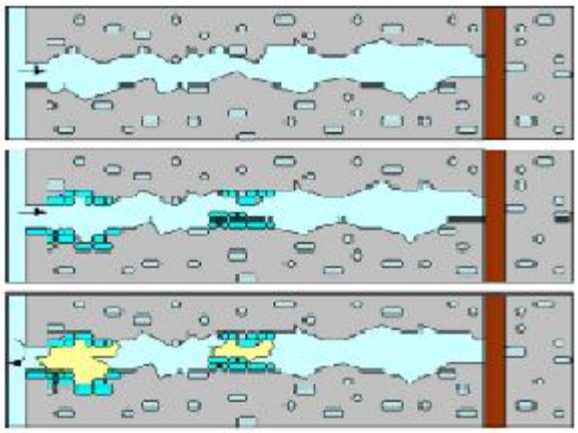

Fig. 5Bacterialbased healing process

A. Advantages

1) Remedying of cracks can be done efficiently.
2) The chances of corrosion in reinforcement are reduce.
3) The use of Bacterial Concrete significantly influences the strength of concrete.
4) Better Resistance towards Freeze – Thaw Attack reduction.
5) Reduction in Permeability of concrete.

B. Disadvantages

1) There is no available IS Code or other code for the design of Bacterial concrete.
2) The investigations involved in calcite precipitation are costly.

IX. CONCLUDING REMARK

We infer that concrete immobilized spores of such bacteria might have the capacity to seal cracks by biomineral formation afterbeingrevivedby water and growth nutrients entering freshly formed cracks, thus the utilization of Bacteria will enhance the strengthanddurabilityof cement concrete therefore it appears promising field in nearfuture.Microbio;ogy induced calcite precipitation technique proved that bacteril concrete overcame problem corrosion of concrete.

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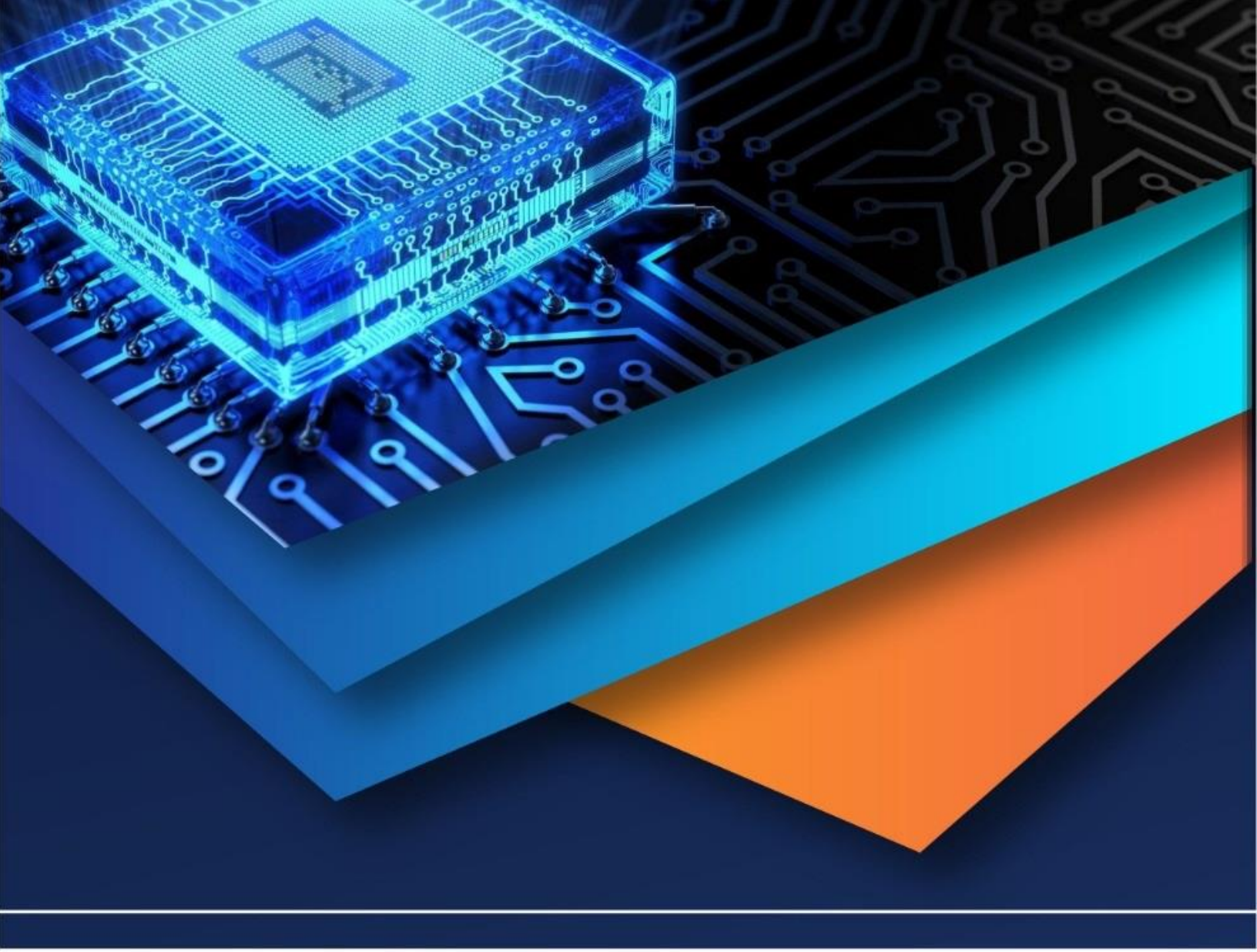

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