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Self-Healing Concrete: A Sustainable Concrete Solution

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Abstract : Concrete is one of the ancient and mostly used building materials. It is widely used throughout the world because of its versatility, it is plastic and flexible when recently mixed, and get strong and hard when solidified. It is easy in casting and has a high compressive strength. Having so many advantages although it has some major drawbacks also as it starts cracking and after sometime it gets deteriorate. This is the major drawback of concrete as it results in loss of strength and a heavy maintenance is required for curing the cracks which also takes a lot of time, care and money. This all can be saved by using self healing concrete. Self-Healing concrete (SHC) is a progressive building material that has the answer for every one of these issues and is unquestionably the building material of the not so distant future. Accordingly, we have to comprehend its properties and component and predict how it impacts the engineering plans of an opportunity to come, which standers are expected to make useful and aesthetic structures and constructions.

Keywords: Cracks, Bacteria; Chemical Methods; Physical Methods; Capsule Formation, Calcium Carbonate, self-healing, Self healing.

I. INTRODUCTION

Concrete is been used since the time of Roman's, but has never been so extensively used than today. Concrete is made of cement, usually Portland cement, water and other filling materials, like sand and grit. The concrete hardens after mixing with water, which will take about one month, because the cement hydrates with water. The major issue with ordinary concrete is its low level of sustainability. It is basically due to the formation of cracks which is an unavoidable feature of ordinary concrete. This formation of cracks leads concrete to the short life span, it is because after formation of cracks water leaking starts and as the water comes in contact with air corrosion starts. This corrosion effects the durability of concrete which leads to the weakness of structure and it can collapse too if not taken care properly.

Under some special circumstances, micro cracks in ordinary concrete can also able to heal themselves. When the mixture get harden, sometimes not every cement molecule reacts with water. This non-reacting cement molecules can react with flowing water, which occurs to flow after the formation of cracks. After the reaction, limestone will be produced, which fills the cracks. Ordinary concrete is only able to heal the micro cracks of a width of circa 0.20 mm[4], if the cracks size is larger than this, no healing will be done.

The formation of cracks occurs when the tensile stresses exceeds the tensile strength of concrete. Tensile stresses of concrete show a great increase when temperature contrasts. This formation of cracks leads concrete to the short life span. This problem can be rectify to a great extent either by using natural way to seal cracks by hydration process or by using artificial man made interventions which leaves impact on the environment and requires lot of time, care and money .

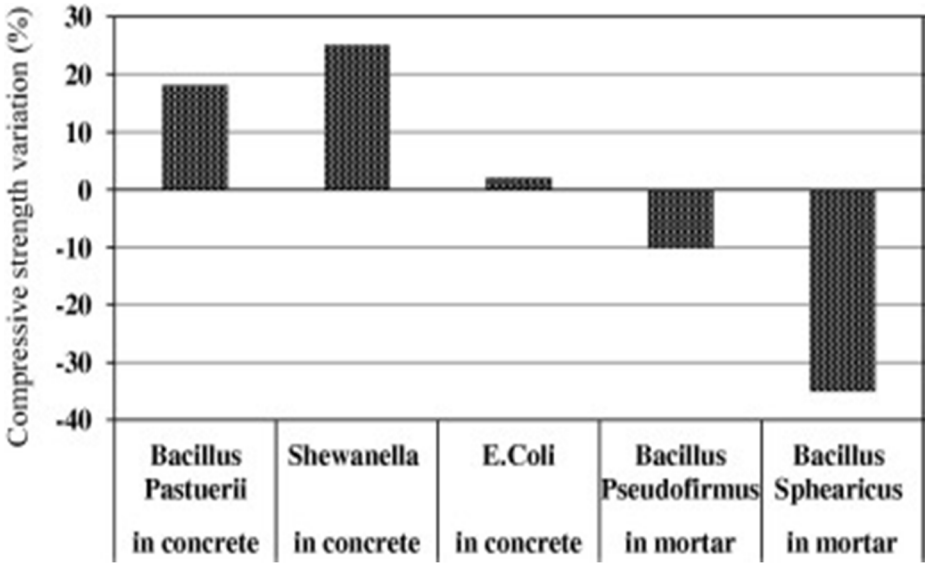
II. THE TECHNIQUE OF SELF-HEALING CONCRETE:

Self healing material is the material which is capable of repairing itself and can regain itself to original state. Self healing concrete is also like an ordinary concrete mixture but in addition with bacteria and its nutrients, which can heal cracks by its own. It also helps in enhancing the sustainability of concrete. This technique is also very much helpful for more than 80 years from the date of implementation. This is termed as Bio concrete. Apart from this, there is also an alternative method for making self healing concrete i.e. Chemical method. In this method, the healing chemicals are inserted in the capsule and capsules are embedded within the concrete at the time of casting. When the crack occurs, the capsule breaks itself and the healing agent inside the capsule consequently rejoins the crack. This technique is quite suitable for the submerged structures like canal, dams, roads in highlands etc.

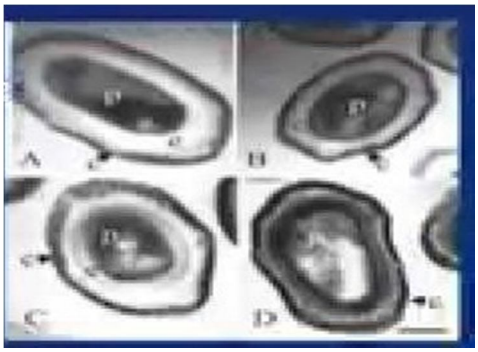
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III. MECHANISM OF BACTERIA BASED HEALING PROCESS:

It is also known as Bacterial concrete, it is a simple method to heal the concrete cracks. The microscopic organisms and calcium lactate are both implanted in capsules, to prevent interaction before cracks show up. The addition of capsule will change the composition of the mixture, since part of the mixture must be supplanted by the healing agent. For the per cubic meter concrete, 15 kg healing agent must be included, which implies that 15 kg cubic meter concrete material must be evacuated. This will diminish the quality of the concrete. There are a few useable bacteria which can be added to the concrete. More often than not, the Bacillus alkalinitrulicus, an alkali- safe soil bacteria, is included. Alkali-resistant microscopic organisms live in outrageous alkaline conditions. The ph-values run from 9 to 11. Their temperature extend comes to from 10 till 40 degrees Celsius. There is another favorable bacteria which can be included. This is a psychrophilic bacterium. This bacterium likewise lives in outrageous conditions with a similar pH run yet an ideal temperature near the point of solidification. The bacteria are added to the concrete as spores. Spores are inactive cells having a very high survival rate. They are proof against troublesome conditions like temperature change and dampness.



In these mechanism alkaliphilic bacteria is added to the concrete matrix. The spore forming alkaliphilic bacteria e.g. Genus Bacillus with calcium based nutrients i.e. calcium lactate $Ca(C_3H_5O_2)_2$ is mixed in the concrete mixture. As the crack generates in the concrete, and water reaches to the bacteria, it turns the bacteria from passive to active stage. As the bacteria germinates, it produce limestone $CaCO_3$ by multiplying itself.

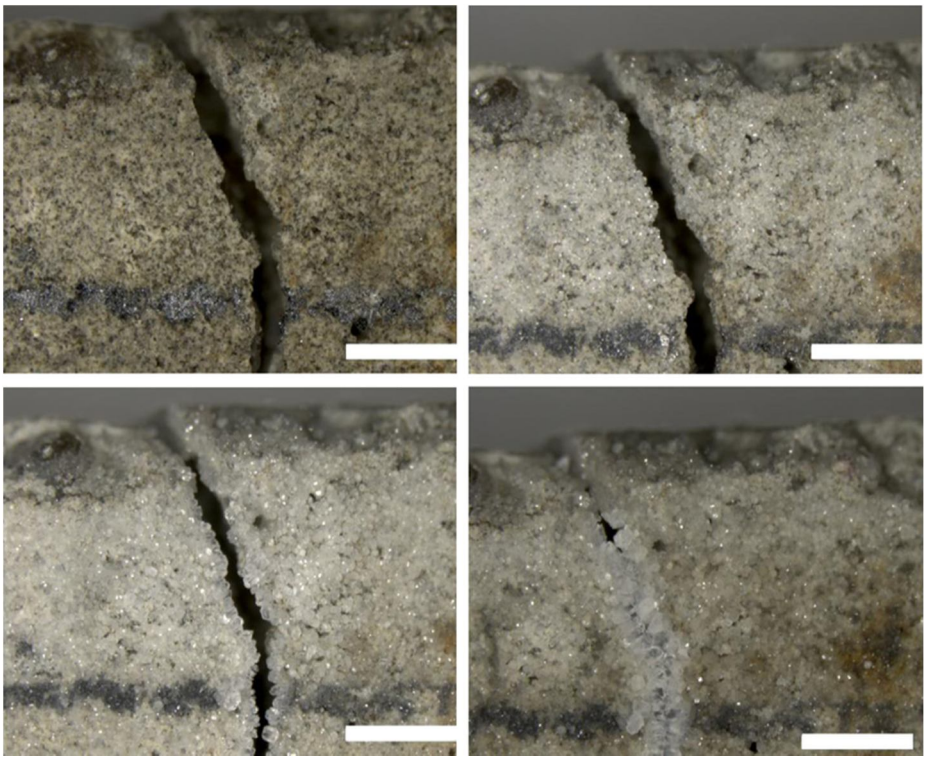


A. *Calcium Lactate*

Limestone will fill the cracks and there is no probability left for water to spill into the concrete any longer. These microscopic organisms can heal the cracks of a width of 0.80 mm inside around 100 days . After healing the cracks , the conditions will turn horrible again for the bacteria so they come again to the passive stage and form the shape of spores again.

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The bacteria used in this mechanism is spore forming and alkali resistant. These bacteria are most suitable as they can live for more than 200 years in dry conditions. Use of bacteria as a healing agent is one of the best mechanism because of its sustainable organic properties.

$5CO_2 + 5Ca(OH)_2 \rightarrow 5CaCO_3 + 5H_2O$

Carbon Dioxide + Calcium Hydroxide → Limestone + Water

Ca(C3H5O2)2 + 7O2 → CaCO3 + 5CO2 + 5H2O

Calcium Lactate + Oxygen → Limestone + Carbon Dioxide + Water

IV. SHAPE MEMORY POLYMERS

This mechanism utilizes both the autogenic and autonomic standards. It utilizes a man-made framework to expand the normal autogenic healing and seal cracks in concrete. This sort of polymers is semi-crystalline polymers that have a predefined shape remembered in their structure that later encourages the polymers to go back to their initial state.Exactly when a crack occurs, the component will be activated, in this way, the shape memory polymer inside the crack gets active through warming which can be as direct warmth, or an electrical current. At the point when it's initiated, the shape memory effect or shrinkage happens, and due to the restrained nature of tendons, a tensile force is delivered , subsequently the crack closes on itself. Starting there ahead, the autogenous healing starts.

V. FACTORS THAT AFFECTS THE USE OF SELF HEALING CONCRETE:

There are numbers of factor that are associated with the use of this special type of concrete. As it is seen; it isn't yet utilized as a part of every single new construction as it is as yet being a work in progress. The actual working cost of using this concrete is yet not decided as it is difficult to foresee a full cost. The cost efficiency is a standout amongst the most essential factors and will decide if the material will have constrained use confined to important constructions such as bridges dams and highways.

The long term efficiency will also play an vital role among the factors alongside the size of the micro cracks with a constraint size up to 150 millimeters of depth to form an ideal result. With everything taken into account , a few more factors that will decide if SHC will be utilized as a substitution of ordinary concrete seem to be are ; the economical factor, long haul efficiency , prospect providers and safety factors.

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VI. APPLICATION IN SMALL-SIZE AND MEDIUM-SIZED BUILDINGS (RESIDENTIAL AND PUBLIC)

Size and capacity of a building normally decide the approximate life-span wanted for this specific construction. Small size structures are generally residential and found either in towns or villages. In most of the structures, concrete is one of the primary building materials used, particularly for the foundation such as slabs or columns, as small residential structures rarely change function, so for expanding their life expectancy SHC can be use. Mid size structures that involves more concrete than other size of structures, except high rise structures which use more steel and small size structures which utilize more stone or wood. SHC can be used in place of ordinary concrete for the construction of medium size building and public building also. The life span of public building should be more in comparison of other structures, in this case SHC will play a vital role in enhancing the life span of buildings and level of sustainability.

VII. WHEN IS SELF-HEALING CONCRETE LUCRATIVE:

This area contains a numerical correlation, with which one can figure whether the utilization of self-healing concrete or the utilization of conventional cement is most beneficial as far as expenses and benefits. By analyzing the all cost per m^3 concrete every year (m^3 /year) of ordinary cement concrete and self-healing concrete, The cost of self-healing concrete is higher on account of the addition and transport of the self-healing agent. Be that as it may, the lifetime of the self-healing concrete will increment. By looking at the expenses per m^3 every time of the two kinds of concrete, we can figure at which costs per m^3 concrete or at which lifetime increment the expenses of the two sorts are precisely the same. Depreciation cost is neglected here.

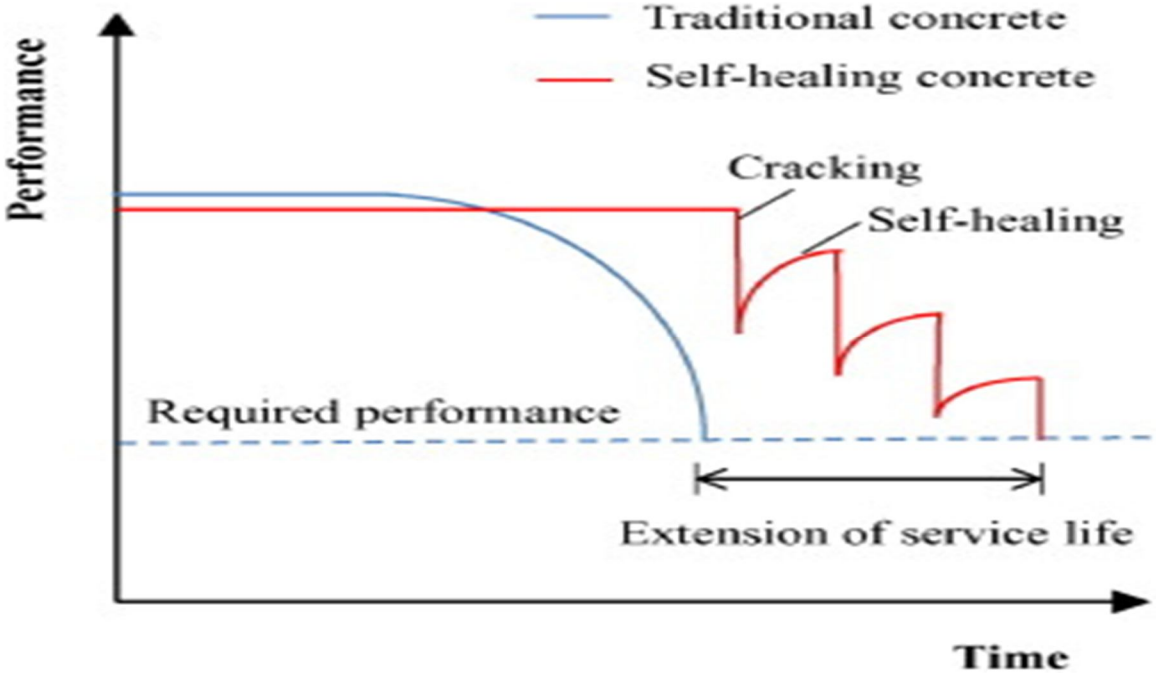
C= All cost, including material and labor, of ordinary concrete

Y = lifetime ordinary concrete in years

T = Price of self-healing concrete

Q = The increase of lifetime by using self-healing concrete.

The total cost per year of ordinary concrete can be calculated as C/Y, And the overall cost per year of self-healing concrete can be calculated as (C+T)/(QY)



VIII. APPLICATION IN LARGE-SIZE BUILDINGS AND ROADS (RESIDENTIAL AND PUBLIC)

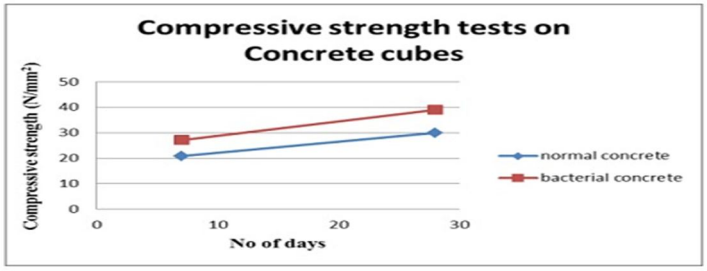
SHC is specially a good option in place of ordinary concrete particularly for the construction of bridges, dams and road construction as these structures experiences dynamic and heavy loads which results in the formation of cracks. By the use of SHC, the cost of maintenance can be decrease significantly and safety as well as efficiency of the structure enhances. The operational cost of all the heavy and large structures can be significantly decrease by the use of SHC as it results in the increase of durability, safety and efficiency.

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IX. ADVANTAGES AND DISADVANTAGES OF SHC:

A. *Advantages*

Use of SHC shows a significant increase In compressive strength and stiffness value when compared with ordinary concrete.



The Freeze-Thaw cycle can be resisted to a great extent. The cracks which is an unavoidable feature of concrete can be self heal which results in the reduction of corrosion of reinforced concrete. SHC also reduces the permeability of concrete.

B. *Disadvantages*

1) As the researches are being done on SHC, this special kind of concrete is available on a very limited scale.
2) Cost is also a very major disadvantage of this special kind of concrete.
3) Bacteria only can germinate in favorable atmosphere and medium.

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X. CONCLUSION

As a conclusion, SHC gives off an impression of being significantly more effective than normal cement. It will reshape how engineers think and plan. By examination, we see that it has more advantages than impediments and It will change concrete from an Eco-harming to an Eco-friendly material, as it lessens the CO_2 emanations essentially. There are at present numerous researches to produce SHC, but still S the most encouraging methodology is the bio-concrete which is bacteria based because it is quite simple in comparison with other mechanism. A spate study stills needed to examine the factors like cost of construction, long term efficiency, life of bacteria and atmosphere suitability for bacteria growth.

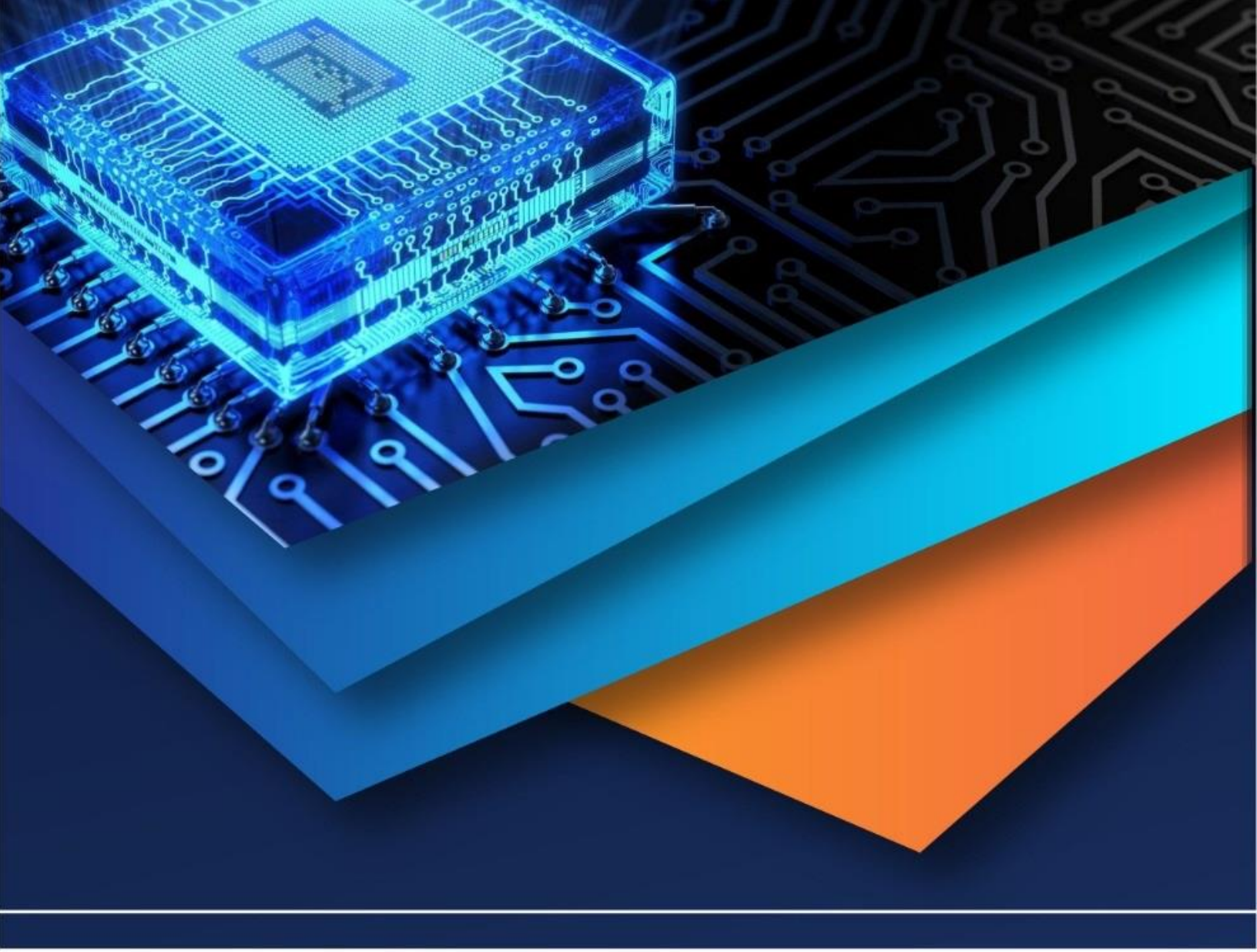
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