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SELF HEALING CONCRETE IN UNDER WATER CONSTRUCTION

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Abstract—**Self-healing concrete is a groundbreaking material that has the potential to revolutionize the construction industry by autonomously repairing cracks and damage. This research paper provides a comprehensive overview of self-healing concrete, including its innovations, mechanisms, and applications. Through a review of existing literature and case studies, the paper explores the various methods of self-healing employed in concrete, such as bacterial-induced mineral precipitation, encapsulated healing agents, and intrinsic healing mechanisms. It also examines the factors influencing the effectiveness of self-healing, including environmental conditions, crack width, and healing agent distribution. Furthermore, the paper discusses the potential applications of self-healing concrete in infrastructure projects, including bridges, highways, and buildings, and evaluates its impact on construction sustainability, durability, and lifecycle costs. By synthesizing current knowledge and identifying areas for future research, this paper aims to contribute to the advancement of self-healing concrete technology and its widespread adoption in construction practice.**

Keywords— self healing concrete, durability, sustainability, biological healing, chemical healing, optimization, effectivenesss, infrastructure.

I. INTRODUCTION

Self-healing concrete is a transformative innovation in construction materials, promising structures capable of autonomously repairing cracks and damage. Traditional concrete's susceptibility to environmental factors, mechanical loading, and chemical reactions leads to cracks compromising structural integrity. In response, researchers have developed self-healing concrete, leveraging biological, chemical, and physical processes to enhance resilience. This paper reviews recent advancements, mechanisms, and applications, aiming to explore its potential impact on construction sustainability and lifecycle costs. By synthesizing current knowledge, it seeks to propel the widespread adoption of self-healing concrete in construction practice.

Self-healing concrete presents a novel solution for enhancing the durability of underwater construction projects, where structures are exposed to harsh environmental conditions. By embedding corrosion-inhibiting agents, self-healing concrete proactively defends against corrosion, forming a protective layer around reinforcing steel to prevent further damage. Additionally, it automatically seals hairline cracks through autogenous healing mechanisms, maintaining watertight integrity and preventing moisture intrusion. This capability extends to repairing impact-induced cracks promptly, minimizing the risk of structural failure. Overall, self-healing concrete's continuous self-repair capabilities contribute to enhanced long-term performance and sustainability, reducing the need for frequent repairs and minimizing environmental impact in marine environments.

II. BACETRIAS USED IN SELF HEALING CONCRETE

Bacillus spp.: Various species of Bacillus bacteria, such as Bacillus subtilis and Bacillus sphaericus, have been investigated for their ability to induce mineral precipitation in concrete cracks. These bacteria produce urease enzymes that catalyze the hydrolysis of urea, leading to the formation of calcium carbonate ($CaCO_3$) or calcium hydroxide ($Ca(OH)_2$) in the presence of calcium ions.

Sporosarcina pasteurii: Formerly known as Bacillus pasteurii, Sporosarcina pasteurii is another commonly studied bacterium used for biomineralization in concrete. This bacterium has been shown to precipitate calcium carbonate in cracks and voids within concrete structures, effectively sealing them and enhancing durability.

Bacillus cohnii: Bacillus cohnii is known for its ability to produce extracellular polymeric substances (EPS) that facilitate mineral precipitation in concrete cracks. These EPS act as binding agents, aggregating calcium ions and promoting the formation of calcium carbonate crystals.

Bacillus megaterium: Bacillus megaterium is a spore-forming bacterium capable of surviving harsh environmental conditions, making it suitable for applications in concrete. This bacterium produces urease enzymes that catalyze the conversion of urea into carbonate ions and ammonia, leading to the formation of calcium carbonate in cracks.

Pseudomonas aeruginosa: While primarily known for its role in bioremediation and environmental processes, Pseudomonas aeruginosa has also been investigated for its potential use in self-healing concrete. This bacterium produces enzymes and metabolites that can facilitate mineral precipitation and crack repair in concrete structures.

These bacteria strains are typically incorporated into self-healing concrete either by direct addition to the concrete mix or by encapsulation within microcapsules for controlled release. Through their metabolic activities and enzymatic processes, these bacteria induce mineral precipitation and facilitate the repair of cracks, contributing to the self-healing properties of concrete.

III. MECHNISM

Self-healing concrete is a revolutionary material designed to autonomously repair cracks that develop over time. When used underwater, self-healing concrete offers unique challenges and opportunities due to the presence of water and the harsh conditions of aquatic environments. Here's a general overview of the mechanism of self-healing concrete and its potential adaptation for underwater applications:

Self-healing agent: Self-healing concrete typically contains capsules or vascular networks filled with healing agents such as calcium carbonate (CaCO3), bacteria, or other materials. When cracks form in the concrete due to various factors such as shrinkage, mechanical loading, or chemical attack, these capsules rupture or the vascular network is breached, releasing the healing agents into the crack.

Reaction with water and carbon dioxide: In underwater environments, the healing agent must react with water and carbon dioxide (CO2) to form calcium carbonate, which fills the crack and restores the integrity of the concrete. This reaction is similar to the natural process of calcification in marine organisms like corals.

Adaption for under water conditions: Adapting self-healing concrete for underwater conditions involves ensuring that the healing agents remain stable and effective in a submerged environment. Additionally, the design of the capsules or vascular networks must account for the presence of water pressure and potential leaching of the healing agents.

Protection against healing agents: To prevent premature activation of the healing process, the healing agents may be encapsulated in materials that are water-impermeable but can rupture when cracks occur. Alternatively, the vascular network can be designed to release the healing agents only when specific conditions, such as crack width or pH levels, are met.

Testing and validation: Before self-healing concrete can be deployed in underwater applications, it undergoes rigorous testing to ensure its effectiveness and durability in marine environments. This includes testing for resistance to corrosion, adhesion to substrates, and long-term performance under varying conditions of water temperature, pressure, and chemical composition.

a. According to studies, self-healing concrete has better workability and strength.
   i. Workability in cone test:
   ii. Compressive strength test
   iii. Tensile strength test

IV. FACTORS INFLUENCING SELF HEALING CONCRETE UNDER WATER

Self-healing concrete is a revolutionary material designed to repair its own cracks, enhancing its durability and lifespan. While it can exhibit self-healing properties underwater, several factors influence its effectiveness in such environments:

Water permeability: The ability of water to penetrate the concrete matrix affects the self-healing process. If the concrete has low permeability, it can better retain the healing agents within the matrix, allowing them to react with cracks and promote healing even underwater.

Healing agent selection: The choice of healing agents embedded within the concrete plays a crucial role. Some common agents include bacteria, polymers, and expansive minerals. The compatibility of these agents with underwater conditions, including temperature and pH levels, determines their effectiveness.

Crack width and depth: The size and nature of cracks influence the ability of healing agents to penetrate and fill them. Underwater, cracks may be subject to higher water pressure, which could affect the ingress of healing agents and subsequently hinder the healing process.

Curing conditions: Proper curing conditions are essential for activating the self-healing mechanisms. Underwater curing methods should be optimized to facilitate the interaction between healing agents and cracks, ensuring effective sealing and restoration of structural integrity.

Concrete composition: The composition of the concrete mixture, including the type and proportion of aggregates, cement, and additives, can impact its response to underwater self-healing. Optimizing the composition for underwater applications can enhance its performance and longevity.

Environmental factors: External factors such as water temperature, pressure, and chemical composition can influence the behavior of self-healing concrete underwater. Understanding and mitigating these environmental variables are essential for maximizing its effectiveness.

Testing and validation: Rigorous testing under simulated underwater conditions is crucial for evaluating the performance and reliability of self-healing concrete. Real-world validation through field trials in marine environments provides valuable insights into its long-term durability and effectiveness.

By considering these factors and implementing appropriate design strategies and construction practices, self-healing concrete can effectively repair cracks and improve the resilience of underwater structures, ultimately extending their service life.

V. COMPARING SELF HEALING CONCRETE WITH NORMAL CONCRETE

Comparing normal concrete with self-healing concrete under water reveals significant differences in their performance, durability, and maintenance requirements:

1. Crack repair mechanism:

Normal concrete: Cracks in traditional concrete structures typically require manual intervention for repair. Water penetration into the cracks can exacerbate deterioration over time, leading to structural weaknesses.
Self-healing concrete: Self-healing concrete contains embedded healing agents that react with water and other substances to autonomously repair cracks. This self-repair mechanism can mitigate the effects of water ingress and maintain the structural integrity of the concrete underwater.

2. Effectiveness underwater

Normal concrete: Underwater conditions pose challenges for the durability of traditional concrete, as water can accelerate the deterioration process by promoting corrosion and chemical reactions.
Self-healing concrete: Self-healing concrete can exhibit effective crack repair capabilities underwater, provided that the healing agents remain active and accessible within the concrete matrix. While water ingress may still occur, the self-healing process can mitigate the adverse effects of underwater exposure on the structural integrity of the concrete.

3. Durability:

Normal concrete: The durability of traditional concrete structures underwater is often compromised due to the ingress of water, which can lead to corrosion of reinforcement and degradation of the concrete matrix over time.
Self-healing concrete: Self-healing concrete offers improved durability by autonomously repairing cracks and preventing the propagation of damage caused by water ingress. This can extend the service life of underwater structures and reduce the need for frequent maintenance and repair interventions.

4. Maintenance requirements:

Normal concrete: Traditional concrete structures underwater require regular inspection and maintenance to identify and repair cracks, corrosion, and other forms of deterioration. This can be costly and time-consuming, especially for large-scale infrastructure projects.
Self-healing concrete: Self-healing concrete reduces the need for frequent maintenance and repair interventions, as it can autonomously repair cracks and maintain structural integrity underwater. While periodic inspections may still be necessary to assess the condition of the concrete, the frequency and extent of maintenance activities are typically reduced compared to normal concrete structures.

5. Resistance to chemical attack:

Normal concrete: Traditional concrete structures underwater are susceptible to chemical attack from substances such as saltwater, sulfates, and other corrosive agents. This can accelerate deterioration and compromise the structural integrity of the concrete over time.
Self-healing concrete: Self-healing concrete can offer improved resistance to chemical attack by autonomously repairing cracks and sealing pathways for corrosive agents to penetrate. The self-repair mechanism helps maintain the integrity of the concrete matrix, reducing the risk of chemical-induced degradation underwater.

6. Long-term cost savings:

Normal concrete: While the initial cost of using traditional concrete may be lower compared to self-healing concrete, the long-term costs associated with maintenance, repair, and replacement of deteriorated structures can be substantial, especially in underwater environments.
Self-healing concrete: Despite potentially higher initial costs, self-healing concrete can offer significant long-term cost savings by reducing the frequency and extent of maintenance and repair activities underwater. The enhanced durability and extended service life of self-healing concrete structures can outweigh the initial investment over time.

7. Sustainability and environmental impact:

Normal concrete: The production of traditional concrete involves the emission of greenhouse gases and consumption of natural resources, contributing to environmental degradation. Additionally, the frequent maintenance and repair of deteriorated concrete structures can further increase the environmental footprint.
Self-healing concrete: Self-healing concrete has the potential to improve the sustainability of underwater infrastructure by reducing the need for frequent repairs and replacements. The autonomous repair mechanism can help minimize material waste and energy consumption associated with maintenance activities, making it a more environmentally friendly option in the long run.

8. Construction complexity:

Normal concrete: The construction of traditional concrete structures underwater may require specialized equipment and techniques to address challenges such as water pressure, placement, and curing. Repairing cracks and maintaining the integrity of the concrete can also be complex and labor-intensive.
Self-healing concrete: While the use of self-healing concrete introduces additional considerations related to the selection and incorporation of healing agents, the construction process itself may not differ significantly from that of traditional

concrete. The self-repair mechanism simplifies maintenance and repair procedures underwater, potentially reducing construction complexity and associated costs.

CONCLUSION

In conclusion, the integration of self-healing concrete underwater offers a transformative approach to addressing the durability and maintenance challenges of marine infrastructure. By imbuing concrete with autonomous repair capabilities, such as crack sealing and corrosion resistance, self-healing properties enhance the longevity and resilience of underwater structures. This innovation reduces the frequency of maintenance interventions, minimizing costs and disruptions while promoting environmental sustainability through decreased material waste and energy consumption. Moreover, the heightened durability and resistance to environmental factors ensure reliable performance during extreme conditions, safeguarding coastal regions and critical infrastructure. While initial investment costs may be higher, the long-term savings in maintenance expenses and extended service life underscore the economic viability of self-healing concrete for underwater applications, marking a significant advancement in marine engineering practices.

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