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### **Application of Self-Healing Concrete in Retrofitting**

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**ABSTRACT:** Cracks in concrete structures can be efficiently repaired and maintained through advanced self-healing technology. Recent innovations have introduced microbial mechanisms that significantly enhance the durability and strength of concrete. Certain bacteria, including Bacillussubtilis, Bacilluspasteurii, and Bacillussphaericus, can autonomously generate calcium carbonate to fill cracks up to 1 mm within a span of 3 to 14 weeks, depending on the strain. This self-healing capability not only fortifies the concrete but also extends the lifespan of aging infrastructures. Complementing these self-healing properties, smart aggregates tiny piezoelectric sensors can be embedded in concrete to monitor its health in real-time. These sensors measure stress and strain, detecting crack formation and providing essential data for proactive maintenance. A novel system utilizes sound wave technology to detect damage, as cracks disrupt sound waves, facilitating early identification of issues. Retrofitting existing structures with self-healing grout presents a sustainable solution for improving durability and safety. allowing for continuous monitoring and repair, ultimately extending the service life of concrete, reducing repair costs, and enhancing overall safe

KEYWORDS: Retrofitting, Self-Healing Bacteria, Smart Aggregate, Grouting, Structural Monitoring.

#### **I.INTRODUCTION**

Retrofitting is one of the most important methods of construction and civil engineering to enhance performance, safety, and longevity of structures. This adaptation is highly crucial for the improvement of currently underperforming older buildings and infrastructure to meet the contemporary standards and codes with the help of changing environmental and regulatory challenges. Retrofitting refers to any change made on a building, from the structural strengthening, wherein major components such as beams, columns, and foundations are strengthened in order to add load-bearing and seismic resistance capacity to the building. There is also seismic upgrading that can be undertaken to make the buildings more resistant to earthquakes or quakes, especially in seismically active areas.

One of the most promising advancements in retrofitting technology is the use of self-healing concrete grout. This innovative material harnesses the natural abilities of specific bacteria, such as Bacillussubtilis, Bacilluspasteurii, and Bacillussphaericus, to autonomously repair cracks that may develop over time. When cracks form in concrete, these bacteria can produce calcium carbonate, filling voids up to 1 mm within a timeframe of 3 to 14 weeks, depending on the strain utilized. This remarkable self-healing capability not only strengthens the concrete but also minimizes the need for frequent repairs, thus reducing maintenance costs and improving the sustainability of infrastructure management.





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Fig. Cracks Heal By Self Healing Concrete Grout.

Self-healing grout represents a significant shift in maintaining concrete structures, moving away from traditional repair methods that are often time-consuming and labour-intensive. In contrast, self-healing grout offers a proactive solution by allowing the material to autonomously respond to damage. This innovative technology is particularly beneficial in areas prone to environmental stressors, where rapid repair is essential for maintaining structural integrity. Complementing this approach, grout injection is a critical component of the retrofitting process, providing additional reinforcement to aging concrete. This method involves injecting grout into cracks or voids to restore the concrete's structural capacity. By effectively filling these gaps, grout injection enhances the load-bearing capacity of the structure and prevents further deterioration. This technique is especially useful for addressing issues such as water infiltration, which can lead to corrosion and other long-term damage. Together, self-healing grout and grout injection represent a comprehensive strategy for enhancing the durability and longevity of concrete infrastructures.

While the primary focus of this discussion is on self-healing grout and grout injection, it is important to acknowledge the role of smart aggregates in the overall retrofitting strategy. Smart aggregates are small piezoelectric sensors embedded within concrete that monitor the health of the structure in real time. These sensors assess stress, strain, and crack formation, providing valuable data for proactive maintenance. While they serve as an effective tool for structural monitoring, their importance is secondary to the transformative potential of self-healing grout and grout injection techniques.

#### **I.10BJECTIVES:**

- 1. Improve the longevity of existing structures by addressing and repairing cracks autonomously, reducing the need for frequent maintenance.
- 2. Lower repair and maintenance costs by minimizing manual intervention and extending the lifespan of retrofitted structures.

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- 3. Ensure structural integrity by preventing the propagation of cracks that could compromise safety, especially in critical infrastructure.
- 4. Enable quick recovery from minor damages through the automatic healing of cracks, ensuring that structures remain operational with minimal downtime.
- 5. Maintain the visual appearance of retrofitted structures by preventing visible damage from cracking.
- 6. Facilitate the retrofitting of various structures, including bridges, buildings, and roads, with tailored self-healing solutions that meet specific environmental and structural demands.

#### **II. LITERATURE REVIEW**

#### **II.1 Self-Healing Concrete.**

**Priya S Nair, Rajesh Gupta, Vinay Agrawal (2017):**In a case study, researchers investigated the maintenance and repair of cracks in concrete structures using self-healing technology. Recently, bacteria have been utilized to enhance the durability and strength of concrete through a self-healing mechanism. This process allows microbial transformations to occur, resulting in stronger concrete. Spalling in concrete can heal cracks up to 1 mm within 3 to 14 weeks, depending on the bacterial strain used. The introduction of bacteria into the concrete mix facilitates this healing process, effectively restoring its integrity. Additionally, the self-healing properties help prevent corrosion while sealing cracks, with the effectiveness influenced by the pH of the water. Calcium carbonate is a key mineral used for filling cracks. Bacteria spread throughout the cracks, promoting healing through various mechanisms, including the formation of calcium carbonate. Incorporating supplementary materials like silica and alumina, as well as blast furnace slag and fly ash, enhances the self-healing process. The study employed high-strength concrete, demonstrating improvements in compressive strength and permeability through these microbial interventions.

**Diane Gardner, Robert Lark, Tony Jefferson, Robert Davies (2018):** In a case study, research shows that the concrete suffers from cracking. Current methods focus on using additional cementious material, which could be a more effective alternative. This shift could reduce maintenance costs and have a positive impact on the economy, environment, and society. The developed countries allocate 35-50% of their infrastructure budgets to repair, maintenance, and replacement due to design flaws. The cement and concrete industry's high energy demands and CO2 emissions call for more durable materials to meet climate change targets. Research by the M4L project aims to address concrete cracking issues. To be experienced at all stages throughout the life of a concrete structure, the contractor particular highlighted problems with early cracking (<3 days) and misperceived problems with long-term cracking (> 5 years). The research community is exploring biomimetic, self-healing cementitious materials that could revolutionize concrete structures. This material is natural or manmade engineering technology, like lime precipitating bacteria's microcapsules, etc. application includes highways, water-retaining structures, and marine structures, to the most likely. The current approaches to enhancing longevity involve using supplementary cementious material. Resulting in a reduced whole-life cost of the structure and fewer repair and maintenance works.

**Ravindranatha Rao, Udaya Kumar, Suhas Vokunnaya, Priyodip Paul, Ioannou Orestis(2015):** The study investigated the use of Bacillus flexus for repairing cracks in concrete through bio-cementation, leading to significant improvements in compressive, flexural, and split tensile strengths, as confirmed by X-ray diffraction (XRD). Bacillus flexus addresses concrete durability issues, particularly cracking, by precipitating minerals that help heal these cracks, thereby enhancing the material's strength and resilience even under adverse conditions. The process known as microbiologically induced calcite precipitation (MICP) involves bacteria converting urea to ammonium, which raises the pH and promotes calciumcarbonate precipitation for crack repair. The research focused on M30 concrete mixtures, incorporating Bacillus flexus with ordinary Portland cement (OPC), river sand, and crushed granite. Various strength tests were performed on standard shapes: compression tests used 150 mm cubes, split tensile tests utilized 150 mm diameter by 300 mm cylinders, and flexural tests involved 100 mm x 100 mm x 500 mm prisms, adhering to IS specifications. The findings revealed that concrete with Bacillus flexus exhibited over 40% higher compressive strength, over 30% greater flexural strength, and over 10% increased tensile strength compared to conventional mixes, while also enhancing durability and workability.

#### **II.2 Smart Aggregate.**

Gangbing Song, Haichang Gu and Yi-Lung Mo(2008): Concrete structures such as bridges, buildings, and roads are susceptible to damage from aging, fatigue, corrosion, and natural disasters, posing safety risks. To tackle this issue, researchers are exploring health monitoring technologies. One method involves using piezoceramic transducers for





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damage detection, categorized into two types: active monitoring, which transmits and receives sound waves, and passive monitoring, which assesses changes in electrical impedance. Recently, the development of smart aggregates small concrete blocks embedded with sensors—has enhanced monitoring capabilities. These aggregates utilize wireless sensor networks to improve efficiency and reduce costs. This paper introduces a wireless smart aggregate system designed for crack detection in concrete, validated through experiments and showing potential for real-world applications. Smart aggregates can effectively identify cracks and monitor stress using sound waves or electrical signals. Additionally, the mechanical impedance method allows for local damage assessment by comparing the impedance of damaged and undamaged structures. The new wireless system eliminates the need for cumbersome cables, making it suitable for complex environments. Overall, this technology aims to enhance the safety and maintenance of large structures.

**Suraj N. Khante, Shruti R. Gedam (2016):**Reinforced concrete structures, such as buildings and bridges, can deteriorate over time, necessitating ongoing condition monitoring for safety, known as structural health monitoring. Researchers are investigating innovative methods using smart materials, including embedding tiny sensors called PZT transducers during construction. These sensors can identify changes in structural condition and alert us to potential issues. The proposed method employs electro-mechanical impedance (EMI) as a diagnostic tool, functioning like a health check-up for structures to detect damage early. This technique is sensitive, cost-effective, and applicable in real-world scenarios, enabling timely maintenance and accident prevention.PZT transducers act like miniature watchdogs, monitoring the health of structures. By sending electric signals to these embedded sensors, they vibrate in response to structural conditions, allowing for localized assessments of health over distances of 0.4 to 2 meters. The experiment tests a concrete beam with an embedded PZT patch to measure its conductance, comparing results from healthy and damaged states. The findings indicate that the sensor effectively detects damage, showing a significant change in conductance and validating the potential of embedded sensors for ongoing structural monitoring.

**Gangbing Song,Haichang Gu and Yi-Lung(2018):** The smart aggregate is a compact sensor designed for embedding in concrete structures. It plays a vital role in early-age strength monitoring, assessing the concrete's strength as it sets to help builders determine when it can safely bear weight. Additionally, the smart aggregate detects impacts, measuring their force to identify potential damage. For ongoing structural health monitoring, it continuously evaluates the condition of the concrete, utilizing wavelet packet analysis to interpret sensor signals and detect deterioration.Researchers have confirmed the effectiveness of the smart aggregate across these applications and developed a comprehensive monitoring system for large structures like bridges and buildings.A primary smart aggregate sensor emits sound waves into the concrete, while other sensors detect these waves. When cracks or damage occur, the sound waves weaken, allowing the system to measure this reduction and assess the extent of the damage. The technology generates a "damage index" to identify severity and location. Benefits include enhanced safety, early problem detection to reduce costly repairs, and increased efficiency, ultimately transforming how concrete structures are built and maintained.

#### II.3 Grout Injection.

**Sanjay R. Kumawata, Goutam Mondal, Suresh R (2021):**This study looks at how to fix buildings like schools and hospitals that get damaged during earthquakes. These buildings are made with reinforced concrete (RC) and partial brick walls, which can cause a problem known as the "captive column effect" during earthquakes. This effect makes the buildings weaker, especially if they are made with non-ductile concrete, which doesn't bend or flex easily. In India, many buildings use fly-ash bricks, which are made from waste produced by power plants. When these buildings get damaged in an earthquake, it's hard to repair them. In this study, researchers tested two models: one bare concrete frame and one frame filled halfway with fly-ash bricks. They first damaged these models to simulate an earthquake, then repaired them using a special method. The repair method combined two techniques: injecting epoxy to fill cracks in the concrete and using steel jackets to add extra strength. After repairing the models, the researchers tested them again and found that the method worked well. The repaired frames became stronger and more resistant to earthquake forces. This shows that using steel jacketing with epoxy can effectively fix buildings damaged by earthquakes.

Hamidul Ahasan, Shajal Khan, AhmedulHassan (2017):In April 2013, a tragic collapse of a garment factory building in Bangladesh led to the deaths of 1,134 people and injuries to over 2,500. This event highlighted the ongoing challenges of ensuring workplace safety for millions of garment workers in the country. After assessing the safety of 3,500 existing garment factory buildings, about 700 were found to need urgent repairs. This paper focuses on how a 4-story garment factory building in Chittagong was strengthened. The building's foundation was weak, so jet grouting and bored piles were used to improve it. The paper explains the process of jet grouting in detail, including the design,





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construction, and performance. It also covers how the soil was loaded, how the building's foundation settled under load, and the testing of the jet grouted columns. The benefits of jet grouting as a method for improving soil and foundation stability are discussed, along with the types of treatment and the procedures followed during the process.

Michael P. Schuller, Richard H. Atkinson, and Jeffrey T. BorgsrniJler (1994):Existing masonry buildings can have cracks, gaps, and weaknesses that might compromise their strength and safety. To fix these issues, grout can be injected into the cracks to repair the building and restore its original strength Repairing and strengthening old masonry buildings using grout injection is an effective way to make them stronger and safer without changing their appearance. We are currently studying how grout injection affects the strength of old, unreinforced masonry. Various types of cement-based grouts have been found to work well for this purpose. These grouts can fill cracks and voids in damaged masonry to improve its strength. The paper outlines the process for injecting grout, including how to prepare the wall, where to place the injection ports, how to mix the grout, and how to inject it. The technique helps repair damaged masonry and can restore its strength to about 80% of what it originally was. It includes a case study that shows how grout injection improves the strength of a masonry pier.

#### **III. PROPOSED METHODOLOGY**



#### **IV. DESIRED OUTCOMES**

- Prolonged lifespan of retrofitted structures by effectively managing and repairing cracks before they lead to significant damage.
- Improved safety for users by maintaining the structural integrity of aging infrastructure, reducing the risk of failures or accidents.
- Reduced maintenance and repair costs over time by minimizing the need for manual inspections and interventions.
- Lower environmental impact through reduced material waste and energy consumption, promoting sustainable construction practices.

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- Quicker recovery from damage, allowing structures to remain in use without extensive downtime for repairs.
- Maintenance of the visual appeal of retrofitted structures by preventing visible cracking and surface deterioration.

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