



Experimental Investigation On Self-Healing Bio Concrete Utilizing Bacteria And Fly Ash For Enhanced Strength

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Abstract: Self-healing concrete has established its effectiveness in repairing cracks, ultimately leading to improved durability. Additionally, there is a need to ensure that other crucial mechanical properties, particularly the strength of the intact (uncracked) material, remain uncompromised. When microorganisms are used, calcium carbonate precipitates in concrete. This precipitation will occur naturally as a consequence of biological activity and will be pollution-free. Despite CaCO_3 precipitation being the primary component of the bacterial reaction product responsible for healing cracks and enhancing concrete strength, leveraging the effect of bacteria on concrete's mechanical properties could be subjective. This project reviews the impact of bacteria on mechanical properties, with a focus on the control (intact) strength of concrete and mortar under various conditions, with cementitious material replacement. In this project Bactaheal-PR is used as the bacteria in the concrete which helps in healing of the cracks in the concrete. In addition to the bacteria the cement is partially replaced with the fly ash which gives strength to the concrete. First the concrete is mixed without bacteria with the partial replacement of the cement with fly ash at various percentages of 6%, 8%, 10%, 12%, 30% and 40% and after curing takes place for 7, 28 days, the specimens are tested for compressive strength. Then the bacteria is added to the concrete of 0.25%, 0.5% with the partial replacement of cement with fly ash for the percentages of 12%, 30%, 40% and again the compressive strength test is carried out. The results show that comparing to the normal concrete the highest compressive strength is attained at 12% partial replacement of cement with fly ash without addition of bacteria. The optimum compressive strength is achieved at 12% partial replacement of cement with fly ash and with addition of 0.5% Bactaheal-PR bacteria. While comparing the concrete without bacteria the compressive strength is higher for the concrete with the addition of the bacteria. Comparing to the strength of the uncracked cubes the highest strength is attained by the crack healed cubes.

Index Terms - Cement, FineAggregate, CoarseAggregate, FlyAsh, Water, Bacterial species (Bactaheal -

PR).

I. INTRODUCTION

Self-healing concrete represents a remarkable innovation in construction materials, offering the potential to revolutionize the durability and sustainability of infrastructure worldwide. Traditional concrete is susceptible to various forms of damage, such as cracks caused by factors like loading, shrinkage, and environmental conditions. These cracks not only compromise structural integrity but also create avenues for the ingress of water, chemicals, and other harmful substances, leading to further deterioration over time. Self-healing concrete, however, is engineered to autonomously repair such damage, mimicking the healing process found in living organisms. Typically, this innovative material incorporates various healing mechanisms, with the most common being the use of microorganisms, encapsulated healing agents, or vascular systems embedded within the concrete matrix. Microorganism-based self-healing concrete utilizes bacteria such as *Bacillus* spp. or *Sporosarcina pasteurii*, which remain dormant within the concrete until cracks form, triggering their activation. These bacteria produce calcium carbonate when exposed to water and calcium ions, effectively sealing the cracks and restoring the material's integrity. Alternatively, encapsulated healing agents, such as polymeric capsules filled with adhesive or healing compounds, are dispersed throughout the concrete mix. When cracks occur, these capsules rupture, releasing the healing agents into the damaged areas, where they react to form a durable seal, preventing further degradation. Types of Self Healing Concrete: Bacteria-Based Self-Healing Concrete, Encapsulated Healing Agent Concrete, Vascular Network-Based Self-Healing Concrete, Mineral Precipitation-Based Self-Healing Concrete, Polymeric-Based Self-Healing Concrete.

Importance Of Self Healing Concrete



Fig1.1 Bio concrete

Durability: Self-healing concrete has the ability to repair micro-cracks autonomously, thereby enhancing its durability and extending its lifespan. This property is particularly crucial in infrastructure exposed to harsh environmental conditions or heavy loads, such as bridges and highways. **Safety:** Cracks in concrete structures can compromise their structural integrity, posing safety risks to people and property. Self-healing concrete helps mitigate these risks by preventing the propagation of cracks and maintaining the structural stability of the infrastructure. **Sustainability:** Self-healing concrete can contribute to sustainability efforts by reducing the consumption of resources required for maintenance and repair activities. It can also help minimize the environmental impact associated with the production and disposal of traditional construction materials. **Long-Term Performance:** Traditional concrete structures may experience deterioration over time due to factors such as freeze-thaw cycles, chemical exposure, and mechanical loading. Self-healing

concrete addresses these issues by continuously repairing damage, thus maintaining the performance of the structure over its lifetime.

OBJECTIVE OF THE STUDY

- To analyze the engineering properties of materials.
- Analyze mix proportions and learn to optimize concrete compositions and examine the workability of concrete mixtures.
- Evaluate the impact of partial cement replacement with fly ash and bacteria.
- To check whether the Bactaheal PR (bacteria) can heal the crack.
- To increase durability of concrete and to Improve strength of concrete by using fly ash and bacteria.
- Comparison between the characteristics of the nominal mix and the fly ash mix with the Bacterial mix of concrete.

II. LITERATURE STUDY

[1] **J.Y. Wang et al (2014)** studied Microcapsules have been put on to encapsulate bacterial spores for self-healing concrete. The viability of the influence and encapsulated spores of microcapsules on mortar specimens have been studied first. Breakage of the microcapsules upon cracking was verified by Scanning Electron Microscopy. Self-healing capacity was examined by crack healing ratio as well as the water permeability. The results suggested that the healing ratio within the examples with bio microcapsules was much higher (48%-80 %) than in those with no bacteria (18%-50 %). The maximum crack width healed in the examples on the bacteria series was 970 μm , approximately four times that of the non-bacteria series (max 250 μm). The general water permeability within the bacteria series was approximately ten times less than that in non-bacteria series. Wet-dry cycles have been found to activate self-healing in mortar specimens with encapsulated bacteria. No self-healing was noticed in most specimens stored at 95%RH, indicating that the presence of liquid water is a crucial part for self-healing.

[2] **Wei Zhang et al (2020)** author research the Cement concrete is a weak material with lower tensile strength and also is uncomplicated to crack because of shrinkage, creep, harsh service environment and load. Asphalt concrete pavement is apt to crack and wear because of the temperature instability and very poor aging resistance of asphalt concrete. Crack boosts moisture, corrosive medium transports and oxygen internally, decreasing the durability and safety of infrastructures. In comparison with traditional repair method, self-healing technology is able to heal fractures which are invisible to the naked eye and also, it's anticipated to lengthen the service life of infrastructures. It's considerable benefits for repairing marine infrastructures, concrete infrastructures and underground concrete storing hazardous materials.

[3] **E. Tziviloglou et al (2016)** studied the revolutionary engineering of self-healing concrete lets the components to restore the open micro-cracks which can endanger the durability of the framework, because of ingress of intense gasses and also liquids. Different ideas of self-healing concrete were produced, with goal on the recuperation of water tightness after cracking.

III. MATERIALS USED:

- Cement
- Fine Aggregate,
- Coarse Aggregate
- Fly Ash,
- Water
- Bacterial species (Bactaheal - PR)



Fig3.1Bactaheal-PR

These are the species involved in the Bactaheal- PR are as follows

1. Sporosarcina pasteurii.
2. Bacillus spahaericus.
3. E-Coli.
4. Bacillus subtilis.
5. Bacillus cohnii.
6. Bacillus balodurans.
7. Bacillus pseudofirmus.

MODE OF ACTION:

Calcium carbonate precipitation at cell wall. (a) Illustrates consumption of the CO_3^{2-} source by the bacterium, and secretion of dissolved inorganic carbon and ammonia into the extracellular space; (b) Ca^{2+} ions in the microenvironment of the bacterium; (c) Ca^{2+} ions react with CO_3^{2-} ions to form calcium carbonate crystals. Concrete has an autogenous healing capacity as unhydrated cement is present in the matrix. When water contacts the unhydrated cement, further hydration occurs. Furthermore, dissolved CO_2 reacts with Ca^{2+} to form CaCO_3 crystals.

IV. METHODOLOGY

1. Collection of Materials
2. Preliminary Tests on Materials
3. Calculation of Mix Design
4. Mixing of Concrete & Tests on Blended Concrete
5. Casting & Demoulding of Specimens
6. Curing for 7,28 days
7. Tests on Hardened Concrete

4.1 Tests on materials:

Percentage of fineness (%)	Normal Consistency of cement (%)	Fineness modulus of coarse aggregate	Fineness of fly ash (%)	Specific gravity of coarse aggregate
6	31	2.74	10	2.81

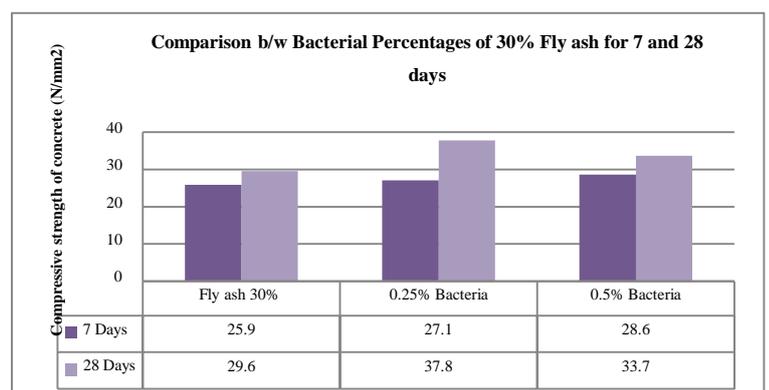
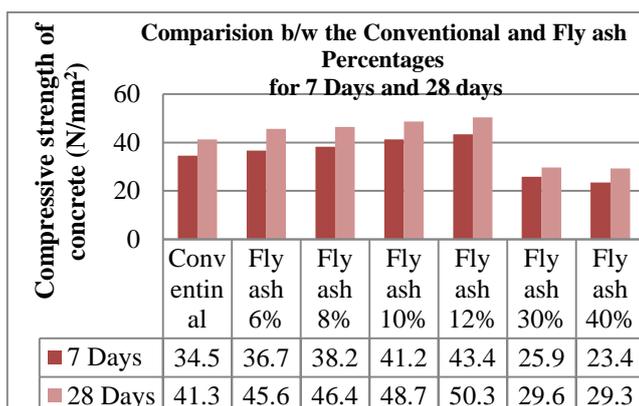
Initial setting of cement	Final setting time of cement	Specific gravity of cement	Specific gravity of Fly ash	Bulking of sand (%)	Bulk density of Fine Aggregate	Specific gravity of fine aggregate
35 min	600 min	3.55	2.11	6	1.67	2.64

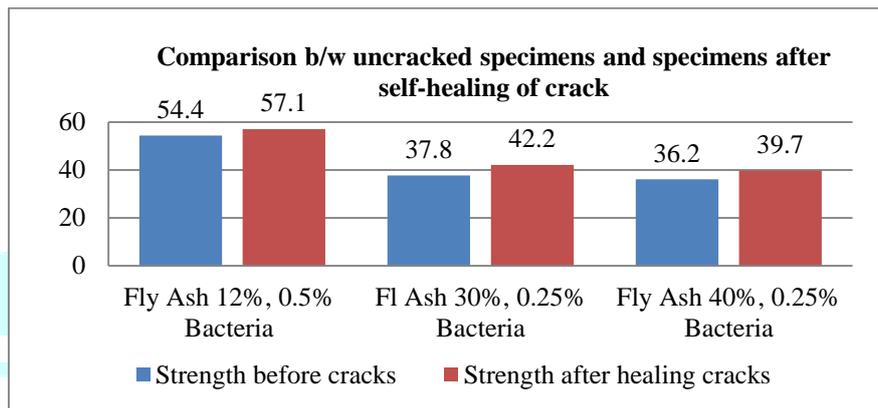
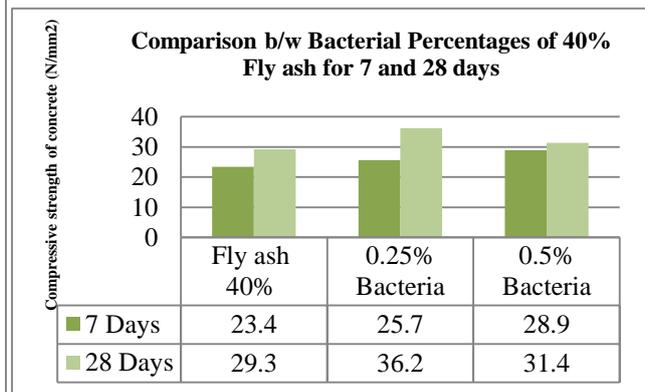
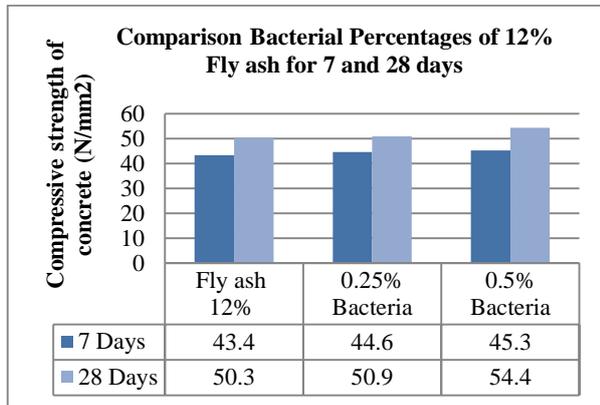
Table 4.1

4.2 Mix proportion:

Mix Proportion	C.A	F.A	Cement
	1	1.720	3.255

V. RESULTS AND DISCUSSIONS:





Optimum compressive strengths of specimens after self-healing cracks for 28 days

VI CONCLUSIONS:

- The compressive strength of concrete with 6%,8%,10%,12%,30% and 40% replacement of fly ash is 45.6,46.4,48.7,50.3,29.6 and 29.3.
- The mix of 12% Fly ash as bacterial immobilizers showed the most effective repair of cracks up to 1mm wide and allowed to recover the compression strength up to 6.9% to 7.6%.
- The majority of the bacillus bacteria have a positive effect on the compressive strength of concrete.
- The compressive strength was found to increase with bacterial addition and this increase is mainly due to deposition of microbial induced calcium carbonate precipitation on the microorganism cell surfaces and within the pores of the concrete.
- It was noticed that in normal concrete the compressive strength was increased with the bacterial mix of 0.5%.
- Maximum increase in compressive strengths was achieved at 12% fly ash with 0.5% bacteria
- The percentage increase in compressive strength of fly ash for 30% and 40% with bacterial concrete for 28 days is higher than the conventional concrete.
- The greater the amount of CaCO₃ Precipitation, the higher the self-healing effect. The 28 days curing cube shows the biggest improvement with a strength gain of 21.6 to 24 % in 40% fly ash bacterial cubes.
- There is increase in strength by 9.1% in 12% fly ash bacterial cubes
- There is increase in strength by 24 to 26.1% in 30% fly ash bacterial cubes

- It is observed that strengths after healing of cracks increased by 5 to 10% when compared to the uncracked cubes.
- Cracks width of 2mm and more do not repair of their own, as a result of the above, it may be concluded that the self-healing bacterial concrete can perform better than ordinary concrete.

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