Self-healing 2.0: Self-Healing Roads using Bacillus Subtilus Bacteria and Bio-Resin Capsules

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INTRODUCTION:

The research area revolves around using microbes in environment welfare. The research comes under environmental science and sustainable construction. Roads often develop cracks due to heavy traffic load, natural calamities like floods, High temperature etc. These cracks lead to frequent needs of repairing, which costs high and uses more of non-renewable resources and cause more environmental pollution.

This project aims to develop self-healing roads using a hybrid solution of bacillus subtilus bacteria and bio-resin capsules. The bacteria produce minerals like calcium carbonate to fill in cracks over time and the bio resin capsule produce glue like substances which help in sealing.
Expected Outcome: To create a long lasting road material which has self-healing properties thus reducing repairs and environmental damages.

SELECTION OF PROBLEM AND BACKGROUND INFORMATION:

Last year, while working on my project: ”Self-healing bricks” , I explored the use of Bacillus subtilis bacteria in making self-healing bricks that could automatically repair small cracks. This gave me the idea that the same principle could be applied to other areas where cracks cause major problems. I started looking for where else this concept could be used effectively.

In recent news, there have been many reports related to road failures. Potholes formed during monsoons have caused accidents, injuries, and even deaths. For example, several news reports highlighted how heavy rains in Mumbai and Bengaluru created thousands of potholes, leading to dangerous driving conditions and frequent accidents. In some cases, poorly maintained roads have even led to vehicles overturning.

Self-healing 2.0: Self-Healing Roads using Bacillus Subtilus Bacteria and Bio-Resin Capsules

Seeing these incidents, I realized that roads, which face constant heavy loads and harsh weather, also show frequent cracking. These cracks grow into potholes, cause accidents, and require repeated repairs that generate waste and pollution. Therefore, I wanted to continue my research as a "Self-Healing 2.0" project by applying Bacillus subtilis bacteria to road materials, but with an improvement: combining microbial healing with bio-resin capsules. **The bacteria will provide long-term mineral healing, while the capsules will give immediate sealing.** This hybrid approach could make roads safer, reduce repair frequency, and contribute to environmental sustainability.

OBJECTIVE OF RESEARCH:

Problem Statement: Roads are highly prone to cracking due to heavy traffic, rain, and temperature changes. These cracks often develop into potholes, leading to accidents, costly repairs, and environmental damage from repeated construction work. This research explores a hybrid self-healing approach by combining *Bacillus subtilis* bacteria (for long-term mineral sealing) with bio-resin capsules (for quick sealing).

Variables:

Independent Variable:

Type of healing method used in the road material

- Control
- Microbial only
- Polymer capsule only
- Hybrid of both

Dependent Variable:

- Reduction in crack width over time.
- Water leakage resistance (time to first drip).
- Water absorption height (capillary test).

Controlled Variables:

- Type and ratio of cement, sand, and additives.
- Water-cement ratio.
- Mixing and curing procedure.
- Crack width created initially.
- Volume of water added daily.

Self-healing 2.0: Self-Healing Roads using Bacillus Subtilus Bacteria and Bio-Resin Capsules

Cause and Effect Study:

The study will test how different healing methods affect the ability of road samples to self-heal cracks. By changing the healing method (independent variable), the effect on crack closure, leakage resistance, and durability (dependent variables) will be measured. All other factors such as material proportions, curing time, and water addition will be kept constant. Four types of samples will be prepared:

1. Control (no healing)
2. Microbial only (*Bacillus subtilis*)
3. Polymer capsule only (bio-resin)
4. Hybrid (both bacteria and capsules)

Controlled cracks will be created in each sample, and healing will be observed over several days. The performance of the hybrid sample will be compared with the others to determine if combining bacteria and capsules gives the best results.

HYPOTHESIS:

The hybrid road material using Bacillus subtilis and bio-resin capsules will heal cracks faster and more durably than either method alone. Capsules will give quick sealing, while bacteria will provide long-term mineral healing, making the hybrid sample the most effective.

EXPERIMENTAL PROCEDURES:

Materials Needed

- Samples / Healing Agents
- Bacillus subtilis (safe strain – available in garden probiotics or lab kits)
- Calcium lactate (nutrient for bacteria)
- Sodium alginate and calcium chloride (to make bacterial beads)
- PVA glue or natural latex (for resin)
- Gelatin capsules / short drinking straws (to prepare resin capsules)
- Road Material

Steps

1. Prepare Healing Agents

- **Bacteria beads:** Mix sodium alginate with Bacillus subtilis suspension, drop into calcium chloride solution to form beads.
- **Resin capsules:** Fill gelatin capsules or straw pieces with PVA glue, then seal ends.

Self-healing 2.0: Self-Healing Roads using Bacillus Subtilus Bacteria and Bio-Resin Capsules

2. Make Four Types of Road Slabs

- Control (C): Mortar only.
- Microbial (M): Mortar + bacteria beads + calcium lactate.
- Polymer (P): Mortar + resin capsules.
- Hybrid (H): Mortar + both bacteria beads and resin capsules.

3. Casting and Curing

- Mix cement, sand, and charcoal powder (cement:sand = 1:2).
- Add water (partly replaced with calcium lactate solution in M and H).
- Gently fold in beads/capsules without crushing them.
- Pour into molds and cure slabs for 2 days (covered and kept moist).

4. Crack Formation

- After curing, use a hammer to make small cracks.
- Record initial crack width.

5. Healing Activation

- Add equal drops of water daily along cracks for 5 days.
- This activates capsule release and bacterial mineral growth.

6. Testing

- Crack width: Measure on Day 0, Day 2, and Day 5.
- Water leakage: Place water over the crack and record time to first drip.
- Capillary absorption: Place slab in shallow water, record wetting height after 10 minutes.

7. Observation and Comparison

- Compare healing performance of C, M, P, and H samples.
- Record data in tables and take daily photos for visual proof.

Safety Precautions

- Wear gloves, lab coat, and safety goggles.
- Use sterile techniques to avoid contamination.
- Properly dispose of biological waste.

Self-healing 2.0: Self-Healing Roads using Bacillus Subtilus Bacteria and Bio-Resin Capsules

Data Analysis

In this study, we will compare four types of road samples:

1. Control (no healing agent)
2. Microbial (with *Bacillus subtilis*)
3. Polymer (with bio-resin capsules)
4. Hybrid (with both bacteria and capsules)

The goal is to analyze how each type heals cracks over time. Data will be collected over 5 days.

- **Crack width reduction:** Crack size will be measured on Day 0, Day 2, and Day 5 using a ruler. Percentage reduction will be calculated.
- **Water leakage test:** A small amount of water will be placed over the crack, and the time taken for the first drip to appear below will be recorded. Longer times mean better healing.
- **Capillary absorption test:** Each slab will be placed upright in shallow water for 10 minutes. The height of water absorbed will be measured. Lower height means better crack sealing.

Graphs will be made to compare performance. The hybrid sample is expected to show **fast initial sealing (due to resin capsules)** and **strong long-term healing (due to bacteria)**.

Table 1: Crack Width Measurements (mm):

Sample	Day 0	Day 2	Day 5	% Reduction
Control (C)				
Microbial (M)				
Polymer (P)				
Hybrid (H)				

Self-healing 2.0: Self-Healing Roads using Bacillus Subtilus Bacteria and Bio-Resin Capsules

Table 2: Water Leakage Time (seconds):

Sample	Day 0	Day 2	Day 5
Control (C)			
Microbial (M)			
Polymer (P)			
Hybrid (H)			

Table 3: Capillary Absorption Height (cm):

Sample	Day 0	Day 2	Day 5
Control (C)			
Microbial (M)			
Polymer (P)			
Hybrid (H)			

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