Study and Improvement of Structure by using Self Healing Concrete

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Abstract - *Self Healing Concrete is a very new concept in the construction industry and not many people are familiar with it. Due to the low tensile strength of concrete, cracks are a regular occurrence in concrete. These fissures reduce the durability of concrete by providing a convenient conduit for the passage of liquids and gases that may potentially contain harmful compounds. If micro-cracks become large enough to reach the reinforcement, not only will the concrete be harmed, but the reinforcement will also be corroded. As a result, it's critical to keep the crack width under control and to cure the cracks as quickly as feasible. Since the expenses involved in maintaining and repairing concrete structures are typically expensive, this research study focuses on developing low-cost self-healing concrete. Self-healing of cracks in concrete will indeed enhance the service life of concrete structures, making the material not only more sustainable but also more durable.*

***Key Words*: Self healing concrete 1, fly ash 2, cracks 3, comprehensive strength 4, cost effective 5.**

1.INTRODUCTION

Concrete is one of the most widely utilized construction mat erial. Because of raw material availability, compressive strength, durability, and cost affordability. Crack occurrence in reinforced concrete should be avoided as much as possible for both longevity of structure and cost considerations, as crack repair is expensive. Concrete autogenous repair, or self-healing, would save a significant amount of money by reducing the need for manual inspection and crack repair. As a result, not only would a dependable self-healing mechanism for concrete result in more durable structures, but it would also benefit the global economy. This research looked into the possibility of using calcite-precipitating bacteria as a crack-healing agent.

Numerous factors, such as shrinkage, freeze-thaw reactions, and mechanical compressive-and tensile stresses, can cause cracks in concrete structures. Although microcracks may not always result in considerable concrete strength loss, the intrusion of water and other reactive chemicals such as chloride and water may represent a threat to steel reinforcement since these chemicals substances strongly intensify its corrosion rate.

Most concrete structures, on the other hand, will undoubtedl y deteriorate and degrade over time. This really is due to water penetration into the concrete, which has a negative impact on the concrete's efficiency. One of these sources of deterioration is the establishment of macro and micro cracks, which provide a pathway for water ingress, dissolved particles in liquids, and undesirable acidic gases. As a result, undesirable contaminants and other things seep into the concrete, compromising its strength and longevity. Few cracks will emerge at the tiny scale, making them undetectable and difficult to approach. The size and number of cracks grow as a result of material ex pansion, contraction, and penetration. Infrastructure maintenance and inspection approaches must be given top priority in this regard. Continuous inspection and maintenance of large-scale infrastructures, however, is challenging due to financial constraints. Other considerations, such as the location of the damage within the afflicted building, may make the restoration difficult.

A unique mending technology based on microorganisms is b eing developed to tackle the aforementioned challenges. Self-healing concrete has the potential to tackle the problem of concrete constructions deteriorating much before their service lives are over.

As a result, the bacterial method appears to be a very promis ing mechanism for facilitating self-healing in concrete structures.

1.1 Problem Statement

Cracks are becoming one of major problem in Construction industry which can decrease the strength of structure resulting in failure of structure. Cement possess self healing property but it cannot heal cracks larger than 0.02mm. In that case Self Healing Concrete becomes useful in which certain bacteria performs chemical reaction which can heal cracks larger than 0.02mm and increases the life of structure. But it becomes much expensive for construction firms to use this technique in construction projects. Hence in this research waste materials are used to replace the quantity of cement which reduces the initial cost of construction.

1.2 Materials

Cement –A construction material that hardens, sets, and attaches to other materials to tie them together. Concrete is made with ordinary Portland cement with a grade of 53. The cement used was tested in accordance with IS 4031-1988.

Fine aggregate – It is used to fill gaps between aggregates. By shaping the bulk, it reduces the cost of mortar or concrete.

It avoids shrinkage and breaking of the material. It's easily accessible. The sand used was river sand that has been sieved with a 4.75mm IS sieve.

Coarse aggregates – Crushed stones up to 20mm in size are retained on 4.75mm I S sieves. Coarse Aggregates are used as a filler in concrete to make it a more homogeneous mass.

Fly Ash – Fly ash is a fine powder that is produced as a by-product of burning pulverized coal in power plants. It typically ranges in size between 10 and 100 micron.

Super Plasticizer ECMAS HP 890 – It provides superior water reduction and workability retention, enabling for the manufacturing and placement of high-quality concrete with no predetermined time delays.

Table: 1.1- Material Properties

Material	Quantity (Kg)	Specific Gravity	Water absorption %
Cement	325	2.92	-
Fly Ash	139	2.45	-
Coarse aggregate	1149	2.85	0.5
Fine aggregate	623	2.65	2.5
Water	197	1	-
Admixture	004	1.08	-

1.3 Bacteria

The various bacteria that can be used are as follows:

1. Sporosarcina pasteurii.
2. Bacillus sphaericus.
3. Escherichia coli.
4. Bacillus subtilis.
5. Bacillus cohnii.
6. Bacillus balodurans.
7. Bacillus pseudofirmus.

By generating the urease enzyme, these bacteria can influenc e the precipitation of calcium carbonate. This precipitation occurs as a result of heterogeneous nucleation of the bacterial cell wall until supersaturation is reached. The ability of bacteria to act as a self-healing agent was investigated in reference and found to be effective

2. BIO-CONCRETE

While ordinary concrete can withstand significant compressi ve loads, it has limited tensile and flexural load carrying capac ity. Concrete, even when reinforced with steel rebars, is susce ptible to cracking. Water leakage, frost damage, and reinforci ng corrosion can all occur as a result of cracking.

Self-healing concrete is a cost-effective way to prevent costly maintenance and repairs. As a result, concrete can self-heal cracks, making structures more robust and extending their service life while lowering maintenance and repair expenses.

In brief, Self Healing Concrete will extend the life of structure s while minimising the cost of maintenance and repair. Owners who consider construction life cycle costs will choose this option.

2.1 Characteristics

It's made up of a biodegradable granular ingredient (healing agent) that closes and waterproofs cracks up to 1-mm wide. Concrete suitable limestone formation results in permanent sealing. Commercial concrete mixtures are compatible with this product.

2.2 Mode of Action

Precipitation of calcium carbonate at the cell wall. Figure(a) shows utilization of the CO32− source by the bacterium, and emission of ammonia and dissolved inorganic carbon; Figure(b) depicts Ca2+ ions in the bacterium's surroundings; Figure(c) shows that calcium carbonate crystals are formed when Ca2+ ions react with CO32- ions. Since unhydrated cement is present, concrete has an autogen ous healing capacity. When water comes into touch with unhydrated cement, it begins to hydrate. CaCO3 crystals are formed when dissolved CO2 interacts with Ca2+.

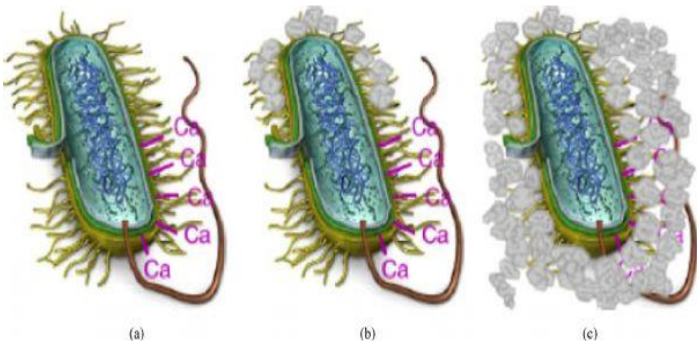

Fig -2a- Self healing process

2.3 Preparation of Bacterial Concrete

Bacterial concrete can be made in two distinct ways, they are as follows:

1) By direct application

2) By encapsulation

In the direct application approach, bacterial spores and calcium lactate are mixed directly into the concrete. The bacteria are visible when cracks appear in the structure. When water comes into touch with this bacteria, it germinates and begins to feed on calcium lactate, resulting in the formation of limestone. As a result, the cracks are sealed.

In encapsulation method, the bacteria and calcium lactate are inserted within treated clay pellets and concrete is made. To make bacterial concrete, approximately 6% of the clay pellets are introduced. Encapsulation is mostly employed in light- weight concrete. When a crack in a structure arises, bacteria germinate and eat down the calcium lactate, producing limestone, which hardens and seals the crack.

We used Direct Application Method for preparation of Bacterial Concrete.

2.4 Typical Application

- Tunnel elements
- Liquid-containing reservoirs
- Basement walls
- Subsurface constructions
- Marine constructions
- Bridge and parking decks
- Flooring systems

3. METHODOLOGY

Mix design of M40 concrete using IS-codes: The concrete mix design IS:10262 (2009) and IS:456 (2000).

●Tests on cement

- **Setting time:**
  (1) Initial setting time: It is the time taken by the cement paste to lose its plasticity.
  (2) Final setting time:
  This is the time it takes for the cement paste to harden into a solid mass.

- **Specific gravity:** It is defined as the mass of a certain volume of material divided by the mass of an equal volume of water.

- **Fineness:** The fineness of cement affects the rate of hydration, hydrolysis and strength development in mortar. The finer cement reacts faster with water and acquires early strength, but its eventual strength remains the same.

● Basic tests on aggregates

- **Specific gravity:** It is defined as the mass of a certain volume of material divided by the mass of an equal volume of water.

- **Water absorption:** It has a variety of effects on the behaviour of particles in concrete. As a result, determining the aggregate's water absorption is required in order to calculate the net water-cement ratio.

- **Sieve analysis:** It is the technique used for obtaining the particle size distribution in aggregates. The granular material is allowed to pass through a series of sieves with progressively decreasing mesh sizes, and the weight of aggregates that is stopped by each sieve is taken.

● Slump test:

It's a metric that indicates how workable or consistent concrete is. Workability refers to how easily a concrete may be mixed, poured, compacted, and finished. There should be no segregation or bleeding in a practical concrete.

●Specimen:

For this research we are used M40 grade of concrete and compared properties of conventional concrete and self healing concrete on concrete cubes and cylinder with 1% , 2%, 3% of bacteria replacement.

● Mix Design:

Table: 3.1- Mix Design M40

Ingredients	Cement	Fly Ash	Fine Aggregate	Coarse Aggregate
Quantity (Kg/m3)	325	139	765	1149
Ratio	1		1.64	2.47

● Compression test:

Concrete cubes were casted as per mix design. The cubes were cast with and without Bacteria. Dosage of bacteria was varied from 2nd trial in form of 1%, 2% and 3%. Cubes were then tested for compressive strength at 7 and 28 days as per I.S 516:1959. The specimens were casted instantly after the mixing. The specimens were removed from moulds after 24hours and kept for curing in water. After curing, the specimens were removed from curing tank and tested for compressive strength using compression testing machine. The application of load was done at an increasing rate of approximately 140 Kg/cm^2/min until the specimen failed to endure the load. The maximum load was noted down. Compressive strength was found by dividing maximum load to the area of cross-section. This test was conducted on 3 specimens and average value was taken.

Fig -3b- Compression test

● **Splitting tensile test:**

Initially, the specimen from curing tank was taken out after 28 days of curing. Then, on both ends of the specimen, diametrical lines were painted to check that they were in the same axial position. Then the specimen was placed on the plywood strip on the lower plate of the compression testing equipment. Align the specimen such that the vertical and centred lines on the ends are parallel to the bottom plate. Then the other piece of plywood was placed on top of the specimen. Lower the upper plate to the point where it just touches the plywood strip. The load was applied at a rate of 1.4 MPa/min without shock. The breaking load was finally recorded.

Fig -3b- Splitting tensile test

● **Water absorption test:**

The test was carried out to evaluate whether concrete has a higher barrier to water penetration. Cubic specimens with an d without bacteria were prepared. In a curing tank, the speci mens were cured for 28 days. The samples surfaces were allowed to dry after curing, and their masses were calculated after immersion. The specimens were dried in an oven at 115±5 and water absorption of the specimens was determined by using the following formula: Absorption after immersion (%) = [(W2 - W1) / W1] × 100
Where,
W1 = mass of oven dried sample.
W2 = mass of the sample after immersion with a dry surface.

4. RESULTS

4.1 Split tensile strength:

Table: 4.1- Split tensile strength

Specimen No.	**Bacteria variation (%)**	**Average Tensile Strength (MPa)**
1	0	3.88
2	1	4.05
3	2	4.07
4	3	4.27

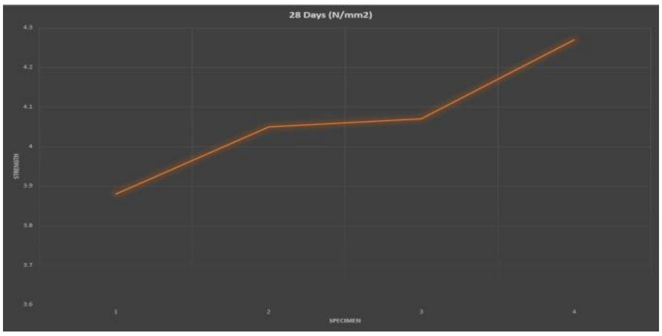

Chart -1: Average Tensile Strength

4.2 Compression Strength:

Table: 4.2- Compressive strength

Specimen No.	**Bacteria Variation (%)**	**Average Strength after 7 Days (MPa)**	**Average Strength after 28 Days (MPa)**
1	0	30.58	38.53
2	1	31.26	40.03
3	2	31.65	40.37
4	3	31.86	41.28

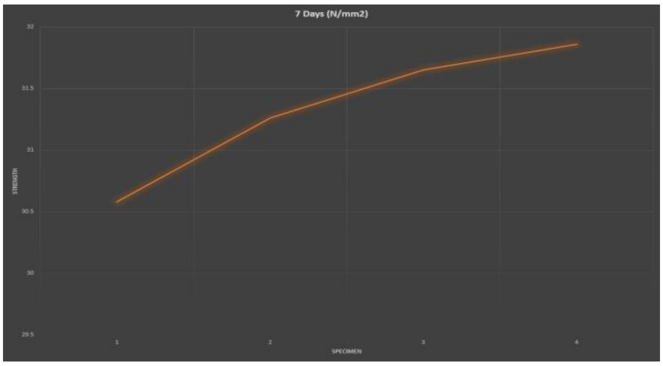

Chart -2: Average Compressive Strength after 7 days

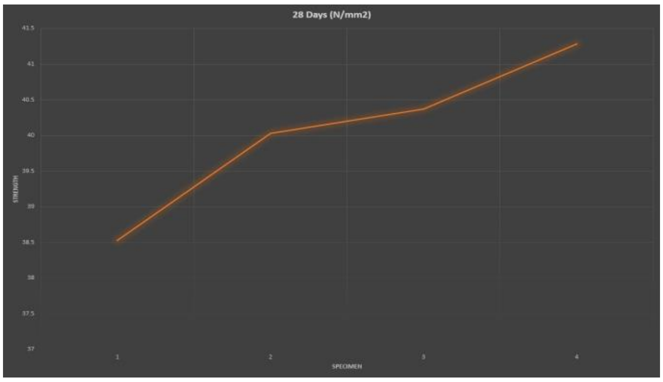

Chart -3: Average Compressive Strength after 28 days

4.3 Water Absorption:

Because calcite has precipitated on the surface of the specim en, the water absorption of the bacterial concrete has increas ed when compared to ordinary concrete. Water absorption was found to be reduced by 0.51 percent.

4.4 Healing of Cracks:

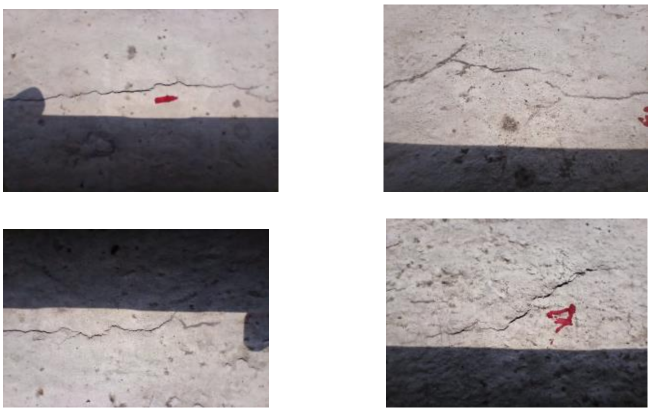

Fig -4a: Initial Crack in Fresh Concrete

Fig -4b: Partial healing of crack at 7 days

Fig -4c: Partial healing of crack at 14 days

Fig -4d: Fully healing of crack at 28 days

4.5 Cost Analysis:

Initial cost of self healing concrete is high. So, in this experiment we have used fly ash which is much cheaper than cement as a partial replacement of cement. During the research we found out that at around 30% replacement of cement by fly ash we got the most cost effective and high strength concrete.

- Prices:

  Price of cement per Kg = 6 Rs.

  Price of Fly ash per Kg = 1.5 Rs.

Table: 4.3 Comparative cost Analysis

Material	Nominal Concrete	Green Concrete
Cement	464 x 6 = ₹2784	325 x 6 = ₹1950
Fly ash	₹0	139 x 1.5 = ₹209
Total	₹2784	₹2159

Cost reduced by ₹625/m^3 i.e. 22.45%

5. ADVANTAGES AND DISADVANTAGES OF SELF-HEALING CONCRETE

5.1 Advantages

1) Self-repairing of cracks without any external help.
2) Significantly improves the compressive strength and flexural strength when compared to normal/conventional concrete.
3) Shows Resistance towards freeze-thaw attacks.
4) Reduction in permeability of concrete.
5) Increases the durability of steel reinforced concrete.
6) Overall maintenance cost of this concrete is much lower as compared to conventional concrete.

5.2 Disadvantages

1) The sprouting of bacteria is not suitable in every environment.
2) The clay pellets with the self-healing ingredient make up around 20% of the volume of the concrete in the encapsulation procedure. The concrete may develop a shear zone or fault zone as a result of this.
3) Initial cost of this concrete is higher than conventional concrete.
4) Design of mix concrete with bacteria is not available in IS code or any other code.

6. CONCLUSION

The Cost was reduced by 22.45% by using fly ash as a partial replacement of cement. The investigation also discovered that concrete's Split tensile strength has improved at 3% variation of bacteria. The investigation also discovered that concrete's compressive strength has significantly improved at 3% variation of bacteria. There was increase in strength due to addition of bacteria as compared to conventional specimen. Crack healing results with 3% of bacteria was more convincing and relatively faster than 1% and 2%. As a consequence of the research, it was discovered that emp loying self-healing
concrete can be a viable alternative and high-
quality concrete sealer that is environmentally friendly, cost-effective, and improves the durability
of construction materials.

ACKNOWLEDGEMENT

We would like to thank Mr. Bhausaheb Awhale, for sponsoring our project and allowing us to carry out this research at Shree Neelkanteshwar Infra Pvt. Ltd, Pune, Maharashtra, India.

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