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Experimental Study on Bacterial Concrete

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Abstract- Bacterial concrete, a recent advancement in building materials, offers self healing capabilities through the incorporation of bacteria. This abstract explores the potential of bacterial concrete by delving into its mechanisms, properties, and effectiveness through SEM analysis and durability compression tests. The ability of bacteria to induce self-healing in concrete stems from their biomineralization process. When cracks appear, the bacteria, often Bacillus subtilis or Sporosarcina, pasteurii, come into contact with water and nutrients. They then undergo metabolic processes that result in the precipitation of calcium carbonate, a key component of cement. This calcite precipitation fills and seals the cracks, effectively "healing" the concrete. SEM analysis provides valuable insights into the microstructure of bacterial concrete, revealing the morphology and distribution of the bacteria and the calcium carbonate precipitates. These analyses confirm the presence and activity of bacteria within the concrete matrix and demonstrate their ability to fill cracks with calcite deposits. By comparing the compressive strength of bacterial concrete to conventional concrete before and after crack formation and healing, researchers can evaluate the effectiveness of the self-healing mechanism. Studies have shown that bacterial concrete exhibits improved crack-healing capacity, reduced water permeability, and enhanced resistance to freeze-thaw cycles and chemical attack compared to conventional concrete. SEM analysis has visually confirmed the presence and activity of bacteria within the concrete matrix, while durability compression tests have demonstrated that bacterial concrete can regain a significant portion of its lost strength after crack formation. Nevertheless, the self-healing properties offered by bacteria hold immense potential for the construction industry, paving the way for more sustainable, durable, and resilient concrete structures.

Keywords- Bacterial Concrete, Mechanical Properties, Durability Test, Bacillus Subtilis

I. INTRODUCTION

1. General

An ever-evolving world needs constantly developing construction ways. In the present world, concrete is one of the most widely used construction materials. This can be due not alone to the large choice of applications that it offers, however, besides, its behaviour, strength, affordability, durability, and flexibility play vital roles. Therefore, constructing-building works have faith in concrete as a secure, strong, and simple object.

It is utilized in all sorts of buildings Concrete, an artificial stone-like mass, is the composite material that is created by mixing binding material as cement along with the aggregate such as, sand, gravel, stone, brick chips etc., water, admixtures, etc in specific proportions.

Sustainable concrete mixtures are prioritizing the use of supplementary cementitious materials like fly ash and slag, alongside recycled aggregates, to reduce cement content and environmental impact while maintaining strength. Self-healing concrete, incorporating microorganisms or encapsulated agents, autonomously repairs cracks, prolonging structural integrity and reducing maintenance costs. Advanced reinforcement techniques, including fibre-reinforced concrete and 3D-printed elements, enhance durability and customization while minimizing material waste.

Concrete is a widely used construction material which is a mixture of cement, aggregates, water. In addition to the three main ingredients, concrete may also contain additives such as admixtures, which can enhance certain properties such as workability, strength, and durability. These additives can include fly ash, silica fume, and plasticizers, among others.

These water particles hydrate the non or partial reacted cement and the cement expands, which in turn fills the crack. But when the cracks are of greater width, need of other remedial work is required. One possible technique is currently being investigated and developed was based on application of mineral producing bacteria in concrete. The bacteria used for self-healing of cracks are acid producing bacteria. These types of bacteria can be in dormant cell and be viable for over 200 years under dry conditions. These bacteria act as a catalyst in the cracks healing process.

2. Material Properties And Mix Design

Developing a functional bacterial concrete mix demands meticulous selection and evaluation of ingredients, considering their individual properties and intricate interactions. While this study employs conventional ingredients like cement, aggregates, and water, the inclusion of Bacillus subtilis bacteria distinguishes it from standard mixes.

In the collection of materials may include key elements such as:

- **Workability:** Ensuring ease of placement and compaction without segregation to achieve uniform distribution of bacteria and avoid compromising initial strength. Long-term Strength: Maintaining desired mechanical properties throughout the structure's service life, potentially enhanced by bacterial self-healing capabilities.
- **Early Strength Development:** Achieving sufficient strength early for construction progress, considering potential adjustments due to bacterial metabolic processes
- **Long-term Strength:** Maintaining desired mechanical properties throughout the structure's service life, potentially enhanced by bacterial self-healing capabalities.
- **Tough and Fracture Resistance:** Enhacing the mix ability to absorb energy and resist cracking,potentially Improved by bacterial-induced mineralization.

Mix Design Calculations

Grade design – M30
Type of cement – PPC 53 grade
Maximum nominal size of aggregate – 20mm
Minimum cement content - 300 kg/m3 (IS 456:2000)
Maximum W/C ratio - 0.45 (Table 5 of IS 456:2000)
Method of concrete placing – Inplant mix
Degree of supervision – Good
Type of aggregate – crushed angular aggregate
Maximum cement content – 340 kg/m3
Specific gravity of cement -3.15
Specific gravity of coarse aggregate - 2.65
Specific gravity of fine aggregate - 2.7
Coarse aggregate water absorption - 0.5%
Fine aggregate water absorption – 1%

Target Strength for Mix Proportioning

fck'= fck + 1.65 S

where, fck'= target average compressive strength at 28 days,

fck = characteristics compressive strength at 28 days, and

S = standard deviation.

From Table I of10262:2009, Standard Deviation,

s = 5 N/mm2.

Therefore, target strength = 30 + 1.65 x 5

fck'=38.25 N / mm2

- **Selection of Water – Cement Ratio**

Exposure condition - Severe

From the Table 5 of IS 456 for severe Exposure maximum Water Cement Ratio is 0.45.

i. Max W/C ratio = 0.45. ii. Adopted W/C ratio = 0.40.

0.40 < 0.45.

Hence OK.

Selection of Water Content

From Table 2 of IS 10262:2009, maximum water content for 20 mm aggregate = 186 litre (for 25 to 50 mm slump range)

- Estimated water content for 50mm slump = 186lit.
- Hence the arrived water content = 186 lit.

Calculation of Cement Content

Cement content = 186 / 0.40 = 465 kg / m3.

From Table 5 of IS 456, Minimum cement content for 'severe' exposure conditions 320kg/m3

465 > 320 kg / m3

Hence OK.

Proportion of Volume Of Coarse Aggregate & Fine Aggregate

- From Table 3 of (IS 10262:2009) Volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II) for water-cement ratio of 0.45=0.62.
- In the present case water-cement ratio is 0.45.
- Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content.
- As the water-cement ratio is lower by0.06.
- The proportion of volume of coarse aggregate is increased by 0.02 (at the rate of -/+ 0.01 for every ± 0.05 change in water-cement ratio).
- Therefore, corrected proportion of volume of coarse aggregate for the watercement ratio of 0.45 = 0.64.
- Therefore, Volume of coarse aggregate =0.64.
- Volume of fine aggregate content = 1 – 0.64= 0.36.

3. Mix Calculations

The mix calculations per unit volume of concrete shall be as follows:

a) Volume of concrete = 1 m³

b) Volume of cement = (mass of cement / specific gravity) x(1/1000)

= (465/3.15) x (1/1000)

= 0.147 m³

c) Volume of water = (mass of cement / specific gravity) x (1/1000)

= (186/1) x (1/1000)

= 186 m³

d) Volume of all in aggregate = [a - (b+c)]

= [1- (0.147+0.186)] = 0.667 m³

e) Mass of fine aggregate = d x Volume of Fine Aggregate x Specific Gravity of Fine Aggregate x 1000

= 0.667 x0.36x2.7x1000

=648 kg

Mix Proportions

- Cement=465kg/m^3.
- Water = 1861/m^3.
- Fine aggregate = 648kg/m^3.
- Coarse Aggregate = 1131kg/m^3.
- Density of concrete = 2500kg/m^3.

- Water -cement ratio= 0.45

II. RESULTS AND DISCUSSION

Compressive Strength

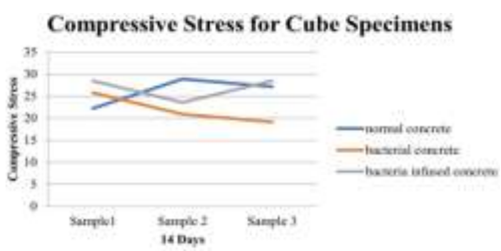
For the experimental project, three concrete variants were tested for compressive strength such as:

Phase 1: Normal M30 concrete.

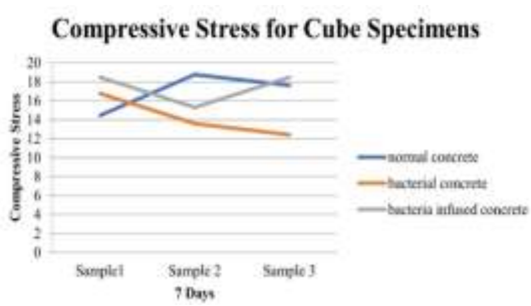
Phase 2: Bacterial concrete using Bacillus Subtilis.

Phase 3: Bacterial immersion concrete.

The results revealed that bacterial immersion concrete exhibited the greatest compressive strength, surpassing both normal M30 and bacterial concrete. This suggests that incorporating bacteria into the concrete during the immersion progress can significantly enhance its compressive strength. The 7,14,28 compressive strength results has been represented as graphs in the following,



7 DAYS COMPRESSIVE STRENGTH FOR

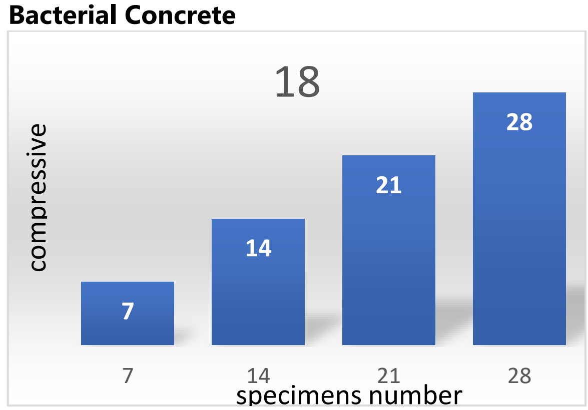


14 Days Compressive Strength For Concrete

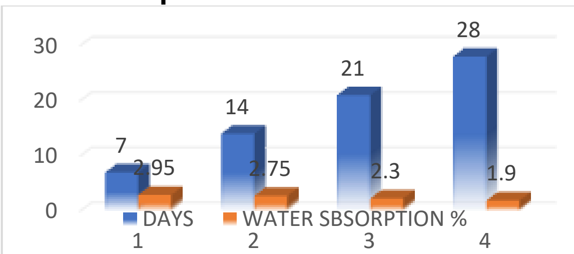
- **Scanning Electron Microscopy Analysis (Sem)** For SEM analysis, small fragments are typically obtained from concrete cores or fractured specimens. These fragments undergo a drying process to remove any moisture that could interfere with the analysis. Subsequently, a thin layer of gold or another conductive material is sputter-coated onto the sample surface to enhance image quality. SEM micrographs can reveal the morphology, size, and distribution of calcite crystals precipitated by bacteria within the concrete matrix and cracks. The Energy – Dispersive X – Ray Analysis (EDAX) image is included in the following,

Microscopical View Of Bacterial Immersed Concrete 9% Of Bacterial Concrete

Bacterial Concrete



Water Absorption



III. CONCLUSIONS

From this experimental study on bacterial concrete in three phases such as normal concrete, bacterial concrete, bacterial immersion concrete the following conclusions are arrived

- Bacterial immersion concrete significantly improves compressive strength compared to regular and other bacterial concrete methods.
- Naturally occurring bacteria in the concrete become active with water and calcium, promoting self-healing by filling cracks with calcite precipitate.
- Bacterial concrete uses natural bacteria, making it an eco-friendlier construction approach.

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