Retraction

Retraction: Experimental Investigation of Microbial Precipitation of Concrete with Bacillus Halodurans (*IOP Conf. Ser.: Mater. Sci. Eng. 1145 012111*)

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IOP Publishing regrets that our usual quality checks did not identify these issues before publication, and have since put additional measures in place to try to prevent these issues from reoccurring. IOP Publishing wishes to credit anonymous whistleblowers and the Problematic Paper Screener [1] for bringing some of the above issues to our attention, prompting us to investigate further.

[1] Cabanac G, Labbé C and Magazinov A 2021 arXiv:2107.06751v1

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Experimental Investigation of Microbial Precipitation of Concrete with Bacillus Halodurans

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Abstract. This study is about the potential for bacteria to fill the micro pores in the concrete the experimental investigation was to find the ability of the concrete with and without bacteria. The micro pores are filled by calcite precipitation created by the bacteria that will create autogenous healing to the concrete. The bacillus family bacteria was create the alkali- resistant spore this formation make as self-healing of the concrete. The active viable period of the bacteria was 4 months in water before adding to the concrete. The continuous decrease of the spore size diameter in concrete its helps to increase the compressive strength of the concrete. The life span and the concrete that is the durability of the concrete was increased we have a sustainable concrete. The present investigation is aimed to answer the following queries: Growth and culture of bacteria, effect of different cell concentration of bacteria embedded on the strength and durability characteristics of concrete.

1. Introduction
Construction, it's better-known to possess many limitations. Concrete is strong in compression but very weak in tensile force, concrete has restricted plasticity and tiny resistance to cracking. Most of the supported and continual analysis dispersed round the globe, varied modifications are made according to the period of time, and the deficiency of the cement is more by day-to-day development. The special concrete play's major role in the development stage it defers according to its application of the element each and every element the function should be varied according to the function the concrete can designed through mix design but the strength and durability is the big challenge in this situation [1]. For the sustainable concrete it should be pour less and durable this bacterium can act as the pour refilment to the concrete to increase the durability the admixture like oxide fume, metakaolin etc. added to increase the strength and durability of the concrete. This “Bacterial Concrete”. Recent studies have shown that bacterium exist that area unit ready to perpetually precipitate spar and in such the way will heal cracks. The planned study intends to research the thanks to turn out the “Bacterial Concrete” and conjointly the self-healing capability of this concrete with relation to each crack closure and restitution of mechanical properties [2].

The microorganism mineral is created as the precipitation in the concrete pores with its microbial activities, the calcite CaCO₃. Precipitation was formed this improves the Mechanical characteristics and durability of the concrete. In this method will occur within or outside the microorganism cell or maybe a long way away at intervals the concrete [3]. Typically, microorganism activities merely activate a modification in answer chemical primes to over the saturation and microbial precipitation. Use of those
Bio geology ideas in concrete ends up in budding invention of recent material referred to as microorganism Concrete.

2. **Taxonomy of bacteria**

2.1 *Taxonomy on the source of profiles*

Bacteria are typically categorised on the idea of their size and shapes. Widely, they'll be separated into rod-shaped bacterium (Bacilli), sphere-shaped bacterium (Cocci) and helix-shaped bacterium (Spirilla).

2.2 *Taxonomy on the origin of gram strain*

This cataloguing is predicated on the results of techniques in gram stain, within which Associate in Nursing agent is employed to the plasma membrane of the bacterium, they're gram positive and gram-negative.

2.3 *Taxonomy on the basis of oxygen constraint*

This grouping is predicated on the necessities of Oxygen level and endurance capacity of the bacteria. they're aerobic (use molecular Oxygen as terminal lepton acceptor) and anaerobic (do not use molecular Oxygen as fatal lepton acceptor) [4].

3. **Bacillus Halodurans**

Researchers with completely different bacterium planned different microorganism concretes, within the present study was created by exploitation the bacterium Bacillus Halodurans. The most benefit of entrenching bacterium within the concrete is that it will per petrify precipitous spar [5]. This development is named microbiologically induced calcite precipitate (MICP). Carbonate precipitate, a good unfold development among bacterium, has been investigated because of its big selection of scientific and technological implications [6]. Bacillus Halodurans may be a laboratory refined soil bacterium and its impact on the strength and sturdiness is studied here.

3.1 *Morphology*

Individual cells of strain were gram positive oval to rods, 0.6-0.8\(\mu m\) in width and 2.0 to 3.0\(\mu m\) in length, motile and multiplied by binary fission [7]. Biochemical characteristics various biochemical tests done on the organisms are given Biochemical characteristics of the pure culture Bacillus Halodurans. Table 1 below shows the Bio chemical characteristics.

| Characteristics          | Bacillus                              |
|--------------------------|---------------------------------------|
| Shape, size, gram stain  | Long rods, 0.65-0.85 \(\mu m\) in which and 2.5 to 3.5\(\mu m\) in length, gram positive |
| Fermentation :           |                                       |
| Dextrose                 | -                                    |
| Yeast extract            | -                                    |
| Peptone                  | -                                    |
| Nacl                     | -                                    |
| \(H_2S\) Production      | -                                    |
| Nitrate lessening        | -                                    |
| Indole creation          | -                                    |
### Methyl red test

Note: “+” : present  “-” : absent

### 3.2 Characteristics of Bacteria:
To characteristics all the bacterium, standard physiological and organic chemistry characterization tests were dispensed as delineated in bergey’s manual of systematic medical specialty. The bacterium that area unit capable of carbonate precipitation area unit gram positive, spore forming and enzyme positive. All the 3 strains of bacterium that were used for investigation were gram positive, spore forming and enzyme positive [8]. Additionally, the impact of hydrogen ion concentration on the expansion of the bacterium, generate on time, enzyme activity and quantity of carbonate precipitation was dispensed. The pure culture of bacterium was used for molecular identification. The extraction of DNA from the pure cultures was performed by Cetyl Tri alkyl amonu Bromide (CTAB) technique.

### 3.3 Effect of $P_H$ on the growth of bacteria:
Growth and survival of bacterium is influenced by of the setting. every microorganism species possesses an explicit growth vary and a definite growth optimum. The nutrient broth of differential starting from four to twelve was ready during a tube . microorganism culture was determined. The take a look at was dispensed by measurement turbidness (Optical density) of the sample exploitation exposure measuring system.

### 3.4 Preservation of stock cultures
Typical cultures of Bacillus area unit unit preserved on medium slats. The culturing is streaky on agar slants with Associate in Nursing protection loop and also the slants area unit incubated at 37C. once 2-3 days of growth, slants cultures area unit preserved beneath refrigeration (4C) till more use. Sub culturing is dispensed for each 90days. Contamination from different bacterium is checked sporadically by streaking on medium plates. Figure 1 -Figure 3 shows the compressive, tensile and flexural strength. Figure 4 and Figure 5 shows Modulus strength. Figure 6- Figure 13 shows the electron microscope and bacteria culture.
Figure 1. Compressive Strength 28 Days

Figure 2. Tensile Strength 28 Days

Figure 3. Flexural Strength 28 Days
Figure 4. Modulus of elasticity results of Conventional mix (28days)

Figure 5. Modulus of elasticity results of Bacteria mix (28days)

Figure 6. Bacteria from MTCC

Figure 7. Culture
Figure 8. Batch mixing of concrete

Figure 9. Scanning Electron Microscope Analysis

Figure 10. Scanning Electron Microscope Analysis of Bacterial concrete

Figure 11. Scanning Electron Microscope Analysis of concrete of Conventional concrete
4. Conclusion

- The microbiologically induced *Bacillus Halodurans* bacteria improves the characteristics compressive strength of cement mortar by 16.15%.
- At a particular microbial cell concentration i.e., $10^6$/ml characteristics compressive strength of cement mortar is maximum.
- Increase in compressive strength of cement mortar is lower at higher microbial cell concentration i.e., $10^7$/ml.
- The accumulation of *Bacillus Halodurans* bacteria progresses the internal pore structure of cement mortar cube.
- The characteristics compressive strength of cement mortar is extreme with the addition of *Bacillus Halodurans* bacteria for a cell concentration of $10^5$ cells per ml of mixing water.
- So, a bacterium with a cell concentration of $10^5$ cells per ml of mixing water has been used in the present exploration.
- In conventional concrete, the characteristics compressive strength is increased up to 13.93% at 28 days on accumulation of *Bacillus Halodurans* bacteria when compared to controlled concrete.
• In normal grade concrete, the split tensile strength has increased up to 12.60% at 28 days on accumulation of Bacillus Halodurans bacteria when equated to controlled concrete.
• When Stress-strain behaviour of controlled & Bacterial concrete is observed, the stress strain parameters will also increase by using the B. Halodurans.

References
[1] Kim Van Tittelboom, *Use of bacteria to repair cracks in concrete*, Magnel Laboratory for Concrete Research, Ghent University, Department of Structural Engineering, (Cement and Concrete Research, 40, pp 57–166, 2010.
[2] Virginie Wiktor, *Quantification of crack-healing in novel bacteria-based self-healing concrete*, Delft University of Technology, Faculty of Civil Engineering, (Cement & Concrete Composites, 30, pp 763–770, 2011.
[3] Willem DeMuynck, *Microbial carbonate precipitation in construction materials*, Magnel Laboratory for Concrete Research, Dept. of Structural Engineering, (Ecological Engineering, 36, pp 118–136, 2010.
[4] C. C. Gavimath, *Potential application of bacteria to improve the strength of cement concrete*, Dept. of Microbiology, Kankavli College, Kankavli, (Advanced Biotechnology and Research, ISSN 0976-2612, 3(1), pp 541-544, 2012.
[5] D. Devikanniga, A. Ramu, and A. Haldorai, *Efficient Diagnosis of Liver Disease using Support Vector Machine Optimized with Crows Search Algorithm*, EAI Endorsed Transactions on Energy Web, p. 164177, Jul. 2018. doi:10.4108/eai.13-7-2018.164177
[6] H. Anandakumar and K. Umamaheswari, *Supervised machine learning techniques in cognitive radio networks during cooperative spectrum handovers*, Cluster Computing, vol. 20, no. 2, pp. 1505–1515, Mar. 2017Ruth e. gordon, *Bacillus firmus-bacillus lentus: a series or one species* Institute of microbiology, Rutgers university, the state university of new jersey, piscataway, 27, pp 256-262, 1997.
[7] Henk M. Jonkers, *Crack repair by concrete-immobilized Bacteria*, Delft University of Technology, Faculty of Civil Engineering and GeoSciences / Microlab, Stevinweg 1, 2628 CN Delft, The Netherlands