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# SELF-HEALING CONCRETE SMART TECHNOLOGY

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**ABSTRACT**
Concrete is one of the most widely used construction materials, yet it is prone to cracking, which compromises structural integrity and leads to costly repairs. Self-healing concrete is an innovative smart technology designed to enhance the durability and longevity of concrete structures by autonomously repairing cracks. This technology integrates biological, chemical, or mechanical healing mechanisms to restore structural integrity without human intervention.
The most promising self-healing techniques include bacterial self-healing, where bacteria embedded in the concrete produce limestone to seal cracks, and capsule-based systems that release healing agents upon crack formation. Additionally, shape-memory materials and vascular networks mimic biological healing by supplying repair materials to damaged areas.
Self-healing concrete significantly reduces maintenance costs, improves sustainability, and extends the lifespan of infrastructure. It has applications in roads, bridges, buildings, and underground structures, making it a revolutionary advancement in modern construction technology. This project explores the mechanisms, advantages, and potential challenges of self-healing concrete while highlighting its role in smart infrastructure development.

**Keywords:**
Structural integrity, healing mechanism, smart infrastructure.

## 1. INTRODUCTION

Concrete is a mixture of cement, fine aggregate, coarse aggregate, and admixture. This mixture is then mixed with water in hand mixer or machine mixer for proper mixing. Fresh concrete or plastic concrete is a freshly mixed material which can be molded into any shape. The relative quantities of paste, collective and water assorted composed controller the goods of concrete in the damp state as well as in the hardened state. A theoretical water cement ratio calculated from the considerations is not successful to give a model condition for supreme forte. 100% compaction of concrete is an important parameter for contributing to the maximum strength. Absence of compaction will outcome in air vacuums whose harmful result on forte and toughness is likewise or extra major than the occurrence of capillary activities. Segregation of can be defined as separation of constituent material of concrete. A good concrete is the one in which all the ingredients are properly distributed to make a homogenous mixture. If a sample of concrete exhibits a tendency for separation of say, coarse aggregate from rest of the concrete then sample is said to be showing the tendency of segregation. Such concrete is not lone profitable to be puny; lack of similarity is likewise working to make all uninvited goods in the hardened concrete. There are considerable differences in sizes and specific gravities of constituent ingredients of concrete. Therefore, it is natural that the ingredients display a propensity to drop not together. Segregation may be of three types viz.

a. The coarse aggregate separating out or settling down from the rest of matrix
b. The paste or matrix separating away from coarse aggregate
c. Water separating out from rest of the material being a material of lowest specific gravity.

A well-made concrete taking into considerations various parameters such as grading, size, shape and superficial consistency of aggregate with optimal quantity of waters kinds a solid mix. Such concrete will not exhibit any tendency for segregation. The solid and full of fat appearances of medium do non allow the aggregate to fall apart, at the same time the matrix itself is sufficiently contained by the aggregate. Similarly, water also does not find it easy to move out freely from the rest of aggregate. Vibration of existing is one of the central devices of compaction. The problem would recollect that only comparatively dry mix should be vibrated. It too wet mix is

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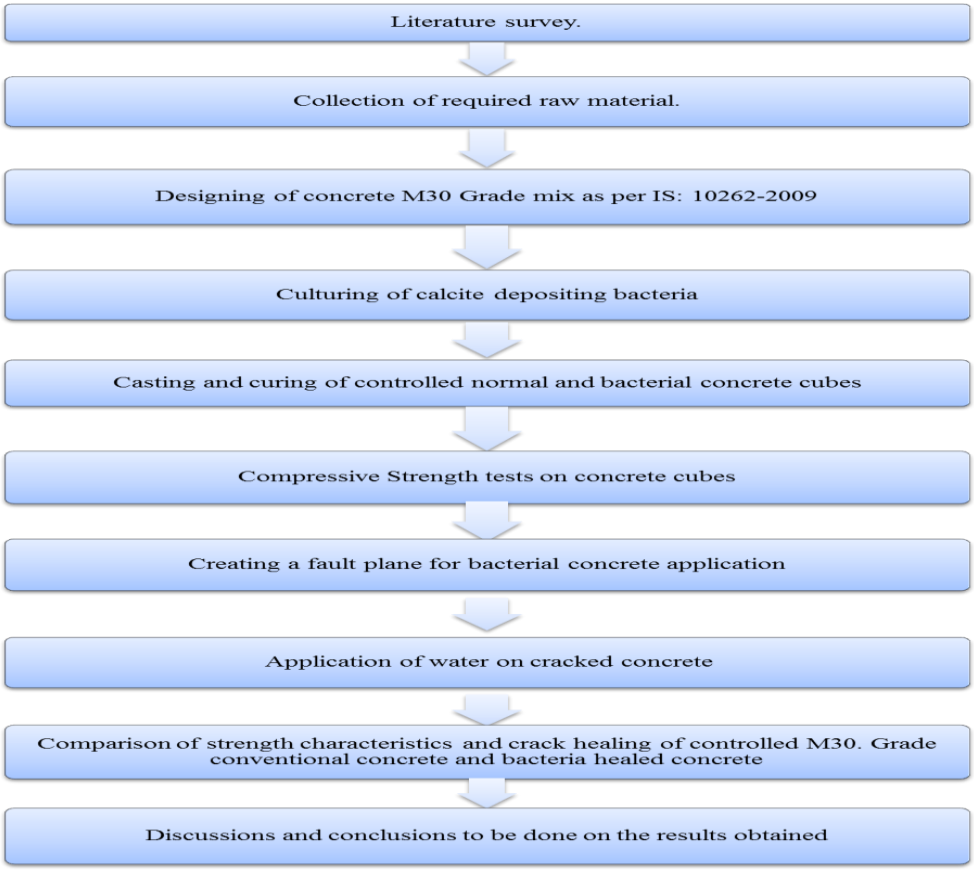
excessively vibrated; it is likely that the concrete gets segregated. It should also be remembered that vibration is continued just for required time for optimum results. If the vibration is continued for a long time particularly in a too wet mix it is likely to result in segregation of concrete due to settlement of coarse aggregate in concrete. Segregation is difficult to measure quantitatively but it can be observed at the time of concreting operation the pattern of subsidence of concrete with respect to segregation.
Bleeding is sometime referred to water gain. It is a particular form of segregation in which some of the water from concrete comes out to the surface of the concrete being of the lowest specific gravity among all the ingredients of concrete. Bleeding is predominantly observed in highly wet mix, badly proportioned and insufficient mixed concrete. In thin members like roof slab or road slab and when concrete is sited in sunlit climate expression undue flow.

## 2. OBJECTIVES

1. To fill cracks in concrete to avoid future leakage of building.
2. To improve compressive strength of concrete.
3.

## 3. METHODOLOGY




***Flow chart of methodology***

**Materials used in concrete**
**1.Cement**

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Crushed granite angular aggregate of size 20 mm nominal size from local source having specific gravity of 2.69 is used as coarse aggregate, The nominal maximum size of coarse aggregate should he as large as possible within the limits specified but in no case greater than one-fourth of the minimum thickness of the member, provided that the concrete can be placed without difficulty so as to surround all reinforcement thoroughly and till the comers of the form. For most work 20 mm aggregate is suitable. Where there is no restriction to the flow of concrete into sections, 40 mm or larger size may be permitted. Consideration should be given to the use of 10mm nominal maximum size.

**2.Coarse Aggregate**

**2.1Specific gravity for coarse aggregate**

**Procedure:**

1. Near 2 kg of total taster is wash away systematically to eliminate fines, exhausted and positioned in line hamper and absorbed in distilled water at a infection between 22- 32º C and a shelter of at least 5cm of water above the top of carrier.
2. Immediately after immersion the entrapped air is removed from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it to drop at the rate of about one drop per second. The basket and aggregate should remain completely immersed in water for a period of 24 hour afterwards.
3. The basket and the sample are weighed while suspended in water at a temperature of 22° – 32°C. The weight though postponed in water is distinguished =W1g.

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4. The basket and aggregates are removed from water and allowed to drain for a few minutes, afterward which the sums are moved to the dry permeable dresses. The empty basket is then returned to the tank of water jolted 25 times and weighed in water= W2g.
5. The masses sited on the leaky clothes are shallow dried till no extra moisture could be aloof by this cloth. Then the sums are transported to the next dehydrated cloth spread in only sheet and permissible to dry for at slightest 10 minutes until the aggregates are completely surface dry. The superficial dry combined is then considered =W3 g
6. The aggregate is placed in a shallow tray and kept in an oven maintained at a temperature of 110° C for 24 hrs. It is then uninvolved from the range, chilled in an air fitted vessel and weighted=W4 g.

**3.Fine Aggregate:**

Natural river sand having specific gravity of 2.60 and confirming to IS: 383-1970zone ll is used. The marking of fine aggregates, after determined as defined in IS: 2386(Part I) l963 shall be inside the limits and shall be designated as fine aggregates, Scaling Zones I. ll. Ill and N where the classifying falls outside the limits of any certain grading sector of sieves other than 600-micron lS Sieve by a total amount not above 5 percent. It shall be watched as falling within that marking zone. This acceptance shall not be useful near percentage transient the'600-micron lS Sieve or to percentage short-lived any extra sieve size on the coarse border of Grading Zone I or the finer limit of Grading Zone IV.

**4.Water**

Water is an imperative part of concrete as it dynamically participates in the Chemical reaction with cement. Later it helps to method the strength generous cement gel. The measure and value of water is essential to be seen into very cautiously. It has been conversed enough in section I about the quantity of intercourse liquid but so far the quality of liquid has non stood deliberated. In practice very often great control on possessions of cement and aggregate is work out, but the switch on the excellence of water is often abandoned. Since quality of water disturbs the forte, it is required for us to go into the cleanliness and quality of water.

Locally accessible portable water confirming to values specified in IS 456-2000 is used. Water used for partying and curative shall be new and free from distressing totals of oils, acids, alkalis, salt, sugar, organic supplies or other ingredients that may be harmful to concrete or steel. Drinkable water is generally measured suitable for mixing concrete.

**5. Bacteria**

- **Bacillus Subtilis-**

Bacillus subtilis, known also as the hay bacillus or grass bacillus, is a Gram-positive, catalase-positive bacterium found in soil and the gastrointestinal tract of ruminants and humans. B.subtilis is bar-molded, and can system a rough, caring endospore, permitting it to bear thrilling eco-friendly conditions. B. subtilis has archaeologically been confidential as an obligate aerobe, yet evidence exists that it is a elective aerobe. B. subtilis is measured the best considered Gram-positive bacteria and a model virus to study infectious chromosome imitation and cell variation. It is one of the infective champions in unseen enzyme production and used on an business scale by bioengineering companies.

B. subtilis can partition regularly to make two descendant cells (binary fission), or irregularly, manufacturing a single endospore that can endure viable for eras and is hardy to unfavourable environmental settings such as famine, salinity, inspiring pH, radiation, and diluents. The endospore is formed sometimes of nutritive stress, agreeing the bacterium to persevere in the atmosphere till conditions convert favourable. Erstwhile to the development of sporulation the cells valor become motile by producing flagella, take up DNA from the environment, or produce antibiotics. These responses are watched as tries to pursue out nutrients by looking for a more favourable atmosphere, allowing the lockup to make usage of new useful inherited material or only by assassination of competition.

Under demanding conditions, such as nutrient deficiency, B. subtilis suffers the process of monogenesis. This process has been same well calculated and has served as a classical bacterium for perusing monogenesis.

B. subtilis is a perfect organism secondhand to study infectious chromosome imitation. Replication of the only circular DNA freshmen at a only locus, the beginning. Repetition proceeds bidirectional and dual replication divides progress in round and counter helical directions laterally the DNA. Gene replication is completed when the splits reach the boundary region, which is sited opposite to the basis on the chromosome plot. The limit region holds several short DNA sequences that help replication detention. Specific proteins facilitate all the steps in DNA replication. Comparison among the proteins involved in chromosomal DNA replication in B. subtilis and

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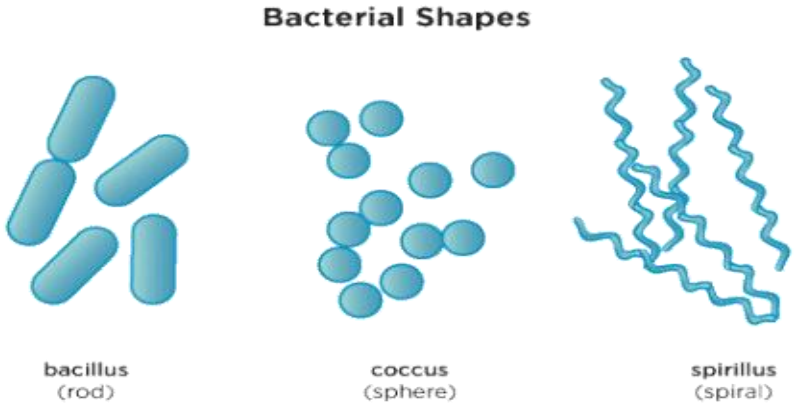
in Escherichia coli reveals similarities and variances. Even if the basic gears promoting initiation, extension, and close of replication are well-conserved, some important differences can be found. These differences underline the diversity in the mechanisms and policies that many bacterial type have adopted to transfer out the duplication of their genomes.

***Bacillus Subtilis***




***Shapes of Bacteria***

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***Bacillus Subtilis Bacteria Tubes***

## 4. RESULT

Compressive strength test was conducted to know the characteristics of the concrete cube. The test was conducted to investigate the optimum dosage of the bacterial solution under which the cube attains its maximum strength.

**Compressive Strength: -**

Compressive strength of concrete cube was carried out after curing period of 7 and 28 days. The results so obtained are tabulated below with their respective age.

***Table 1. Compressive strength of concrete at 7 day age***

| Sr.No | Grade | Type of concrete | Notation for cube | Date of casting | Date of testing | Load on cube (KN) | Strength (KN) | Average (KN) |
|---|---|---|---|---|---|---|---|---|
| 1 | M30 | Normal Concrete | N1 | 13/03/2024 | 10/04/2024 | 412 | 18.31 | 18.56 |
| 2 | M30 | Normal Concrete | N2 | 13/03/2024 | 10/04/2024 | 396 | 17.6 | |
| 3 | M30 | Normal Concrete | N3 | 13/03/2024 | 10/04/2024 | 445 | 19.77 | |
| 4 | M30 | 1% bacteria | A1 | 23/03/2024 | 30/04/2024 | 616 | 27.37 | 27.48 |
| 5 | M30 | 1% bacteria | A2 | 23/03/2024 | 30/04/2024 | 602 | 26.75 | |
| 6 | M30 | 1% bacteria | A3 | 23/03/2024 | 30/04/2024 | 637 | 28.31 | |
| 7 | M30 | 2% bacteria | B1 | 23/03/2024 | 30/04/2024 | 732 | 32.53 | 32.59 |
| 8 | M30 | 2% bacteria | B2 | 23/03/2024 | 30/04/2024 | 754 | 33.51 | |
| 9 | M30 | 2% bacteria | B3 | 23/03/2024 | 30/04/2024 | 714 | 31.73 | |
| 10 | M30 | 3% | C1 | 24/03/2024 | 30/04/2024 | 825 | 36.66 | 37.52 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | bacteria | | | | | | |
| 11 | M30 | 3% bacteria | C2 | 24/03/2024 | 30/04/2024 | 865 | 38.44 | |
| 12 | M30 | 3% bacteria | C3 | 24/03/2024 | 30/04/2024 | 843 | 37.46 | |

***Table 2. Compressive strength of concrete at 28 day age***

| Sr.No | Grade | Type of concrete | Notation for cube | Date of casting | Date of testing | Load on cube(KN) | Strength (KN) | Average (KN) |
|---|---|---|---|---|---|---|---|---|
| 1 | M30 | Normal Concrete | N4 | 13/03/2024 | 10/04/2024 | 639 | 28.4 | 30.42 |
| 2 | M30 | Normal Concrete | N5 | 13/03/2024 | 10/04/2024 | 742 | 32.97 | |
| 3 | M30 | Normal Concrete | N6 | 13/03/2024 | 10/04/2024 | 673 | 29.91 | |
| 4 | M30 | 1% bacteria | A4 | 24/03/2024 | 30/04/2024 | 1028 | 45.68 | 47.12 |
| 5 | M30 | 1% bacteria | A5 | 24/03/2024 | 30/04/2024 | 1044 | 46.4 | |
| 6 | M30 | 1% bacteria | A6 | 24/03/2024 | 30/04/2024 | 1109 | 49.28 | |
| 7 | M30 | 2% bacteria | B4 | 24/03/2024 | 30/04/2024 | 1268 | 56.35 | 54.96 |
| 8 | M30 | 2% bacteria | B5 | 24/03/2024 | 30/04/2024 | 1238 | 55.02 | |
| 9 | M30 | 2% bacteria | B6 | 24/03/2024 | 30/04/2024 | 1204 | 53.51 | |
| 10 | M30 | 3% bacteria | C4 | 24/03/2024 | 30/04/2024 | 1296 | 57.65 | 58.02 |
| 11 | M30 | 3% bacteria | C5 | 24/03/2024 | 30/04/2024 | 1304 | 57.95 | |
| 12 | M30 | 3% bacteria | C6 | 24/03/2024 | 30/04/2024 | 1317 | 58.53 | |

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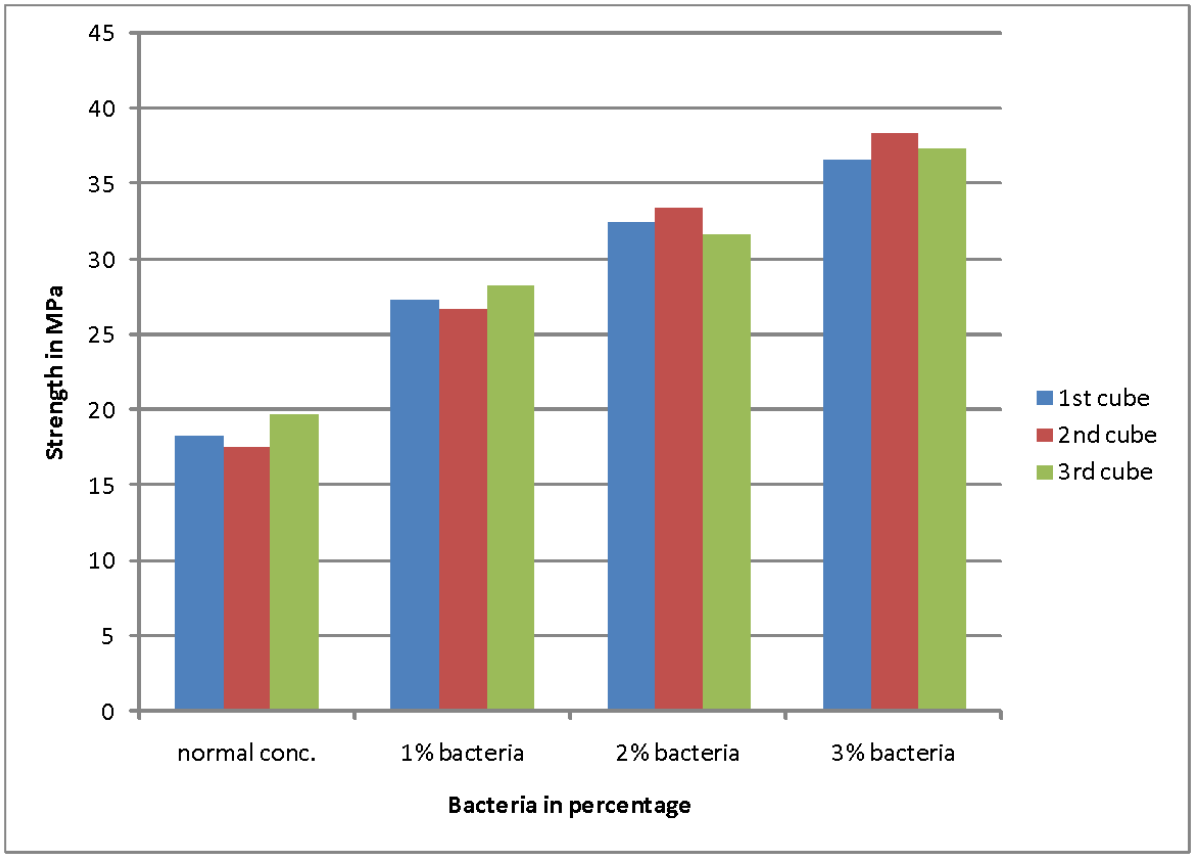


***Graph 1: 7 Day Compressive Strength Tests on Concrete Cube***

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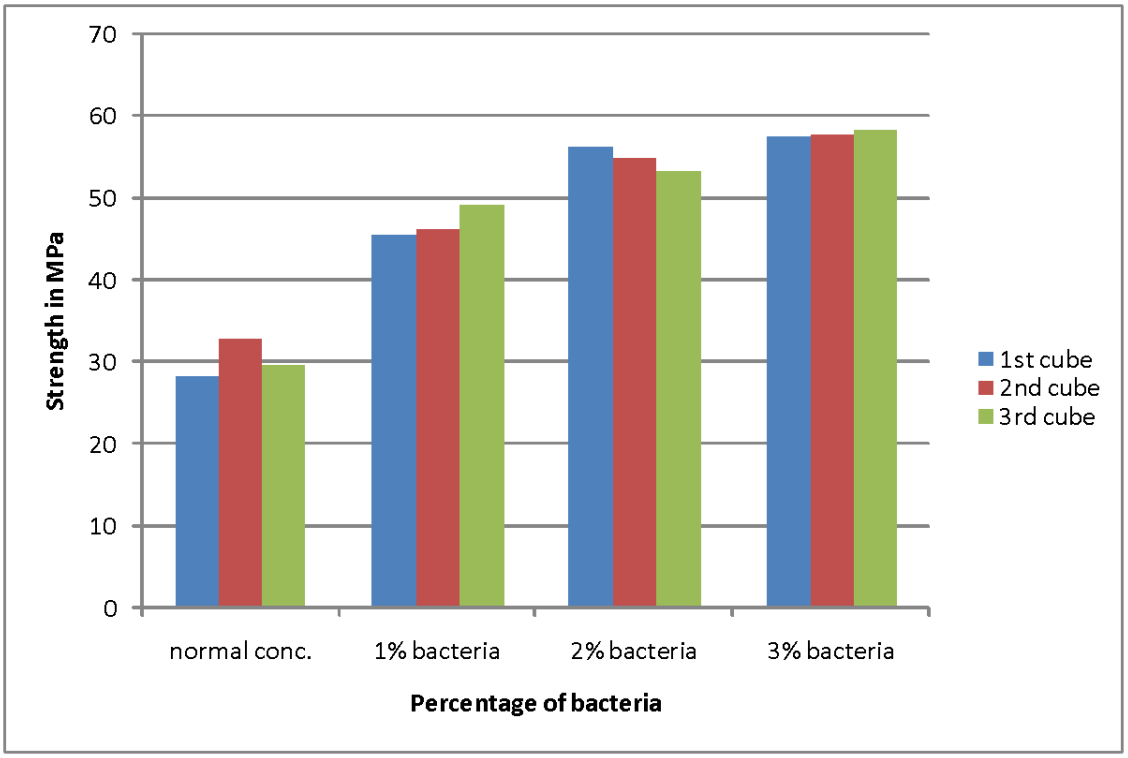
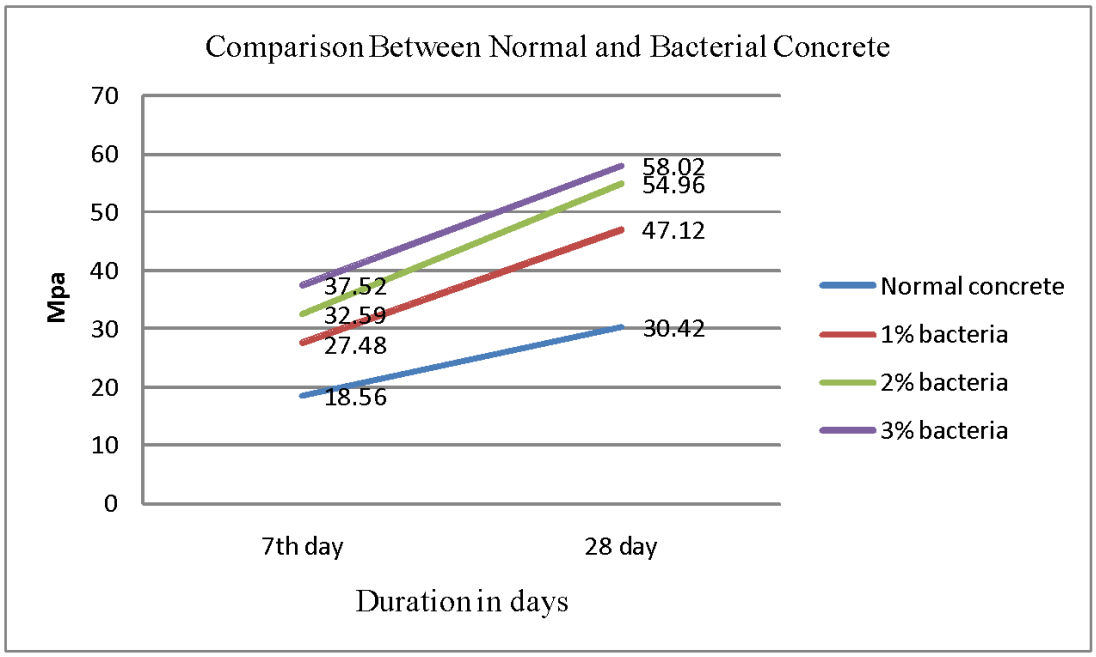



*Graph 2 :28 Days Compressive Strength Test On Concrete Cube*




*Graph 3 Comparison Between Conventional Concrete And Bacterial Concrete*

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## 5. CONCLUSION

The microbe proved to be efficient in enhancing the properties of the concrete by achieving a very high initial strength increase and thus we concluded that the produced calcium carbonate has filled some percentage of void volume thereby making the texture more compact and resistive to seepage. When bacterial concrete is fully developed it may become another alternative method to replace and its hazardous effect on environmental pollution. From the experimental study, it concluded that the bacillus subtilis improve the characteristics of cement composite and strength of bacterial concrete increases up to twice of normal concrete.

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