

Effect of Bacteria “Bacillus Subtiliosus” On Mechanical Properties of Concrete

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ABSTRACT

Cracks in concrete are inevitable and are one of the inherent weaknesses of concrete. Water and other salts seep through these cracks, corrosion initiates, and thus reduces the life of concrete. Concrete structures usually show some self-healing capacity, i.e. the ability to heal or seal freshly formed micro-cracks. This property is mainly due to the presence of non-hydrated excess cement particles in the materials matrix, which undergo delayed or secondary hydration upon reaction with water. Scientists have developed a new type of self-healing concrete in which bacteria mediate the production of minerals which rapidly seal freshly formed cracks, a process that concomitantly decreases concrete permeability, and thus better protects embedded steel reinforcement from corrosion. Bacterial concrete is a material, which can successfully remediate cracks in concrete. This technique is highly desirable because the mineral precipitation induced as a result of microbial activities is pollution free and natural. As the cell wall of bacteria is negatively charged, metal accumulation (calcite) on the surface of the wall is substantial, thus the entire cell becomes crystalline and they eventually plug the pores and cracks in concrete. It was found that use of bacteria improves the stiffness and compressive strength of concrete. Initial results show that the addition of specific organic mineral precursor compounds plus spore-forming alkaliphilic bacteria as self-healing agents produces up to 100- μm sized calcite particles which can potentially seal micro- to even larger-sized cracks. Further development of this bio-concrete with significantly increased self-healing capacities could represent a new type of durable cement.

Keywords:- BACILLUS, SUBTILIOUS , Concrete

I. INTRODUCTION GENERAL

Concrete is one of the most widely used construction materials in the world today. It is made by mixing small pieces of natural stone (called aggregate) together with a mortar of sand, water, Portland cement and possibly other cementations materials. Properly designed and constructed, concrete structures compare favourably with regard to economy, durability and functionality with structures made from other structural materials, such as steel and timber. It is the second most widely consumed substance on earth, after water. Micro cracks are the main cause to structural failure. One way to circumvent costly manual maintenance and repair is to incorporate an autonomous self healing mechanism in concrete. One such an alternative repair mechanism is currently being studied, i.e. a novel technique based on the application of bio mineralization of bacteria in concrete. The applicability of specifically calcite mineral precipitating bacteria for concrete repair and plugging of pores and cracks in concrete has been recently investigated and studies on the possibility of using

specific bacteria as a sustainable and concrete embed self healing agent was studied and results from ongoing studies are discussed. Bacteria like BACILLUS SUBTILIOUS is currently being used for repair of concrete, hence the use of a biological repair technique in concrete is focused. Recently, it is found that microbial mineral precipitation resulting from metabolic activities of favourable microorganisms in concrete improved the overall behaviour of concrete.

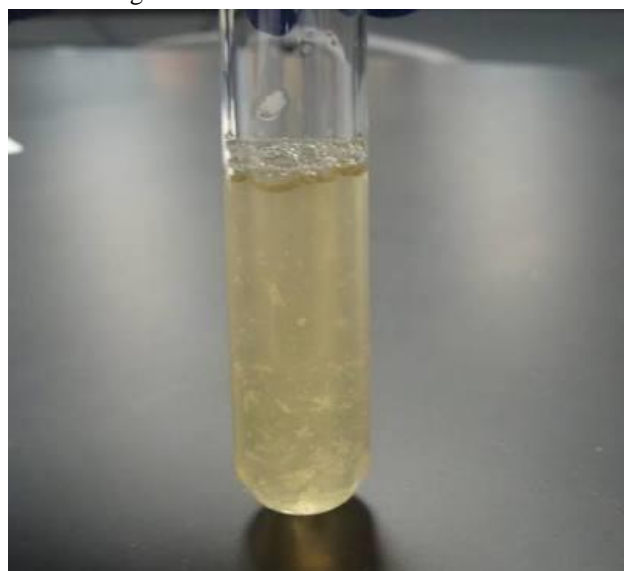
The Bacterial spores start germinating only when they make contact with concrete – triggered by the very specific pH of the material – and they have a built-in self-destruct gene that prevents them from proliferating away from the concrete target. Once the cells have germinated, they swarm down the fine cracks in the concrete and are able to sense when they reach the bottom because of the clumping of the bacteria, or so-called quorum sensing.

This clumping activates the concrete repair process and the cells differentiate into three types: cells which produce calcium carbonate crystals, cells which

become filamentous – acting as reinforcing fibres – and thirdly cells that produce a glue that acts as a binding agent and fills the gap.

1.2 ABOUT BACTERIA (BACILLUS SUBTILIOSUS)

BACILLUS SUBTILIOSUS is a common bacterium found in soil like peat and humus. such bacteria can sometimes cause diseases when touched direct to human skin. such bacteria can be used in concrete in some concentrations to increase compressive strength and remediating cracks in concrete. it has to be used with proper care only. very less concentration of it shall be added to water, diluting it properly with high concentration of water and thus mixed to cement under certain design mixes.



1.2.1 BACTERIA AS A COMPOUND ADDED TO CONCRETE:

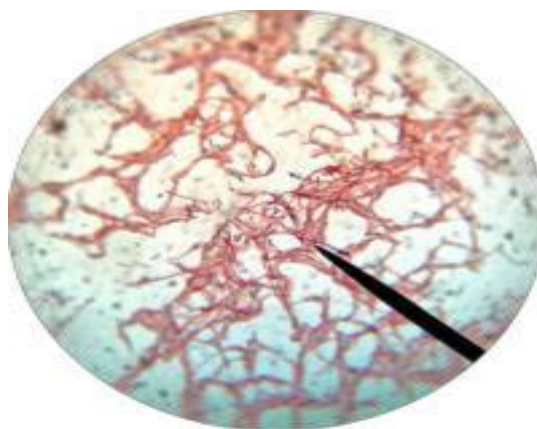
Crack formation in concrete is a phenomenon that can hardly be complete avoided due to addition of bacteria. for example, shrinkage reactions of setting concrete and tensile stresses occurring in set structures. While larger cracks can potentially hamper a structures' integrity and therefore require repair actions, smaller cracks typically with a crack width smaller than 0.2 mm are generally considered unproblematic. Although such micro cracks do not affect strength properties of structures they do on the other hand contribute to material porosity and permeability.

Viable bacteria as self-healing agent The bacteria to be used as self-healing agent in concrete should be fit for the job, i.e. they should be able to perform long-term effective crack sealing, preferably during the total constructions life time. The principle mechanism of

bacterial crack healing is that the bacteria themselves act largely as a catalyst, and transform a precursor compound to a suitable filler material.

Bacteria that can resist concrete matrix incorporation exist in nature, and these appear related to a specialized group of alkali-resistant spore-forming bacteria. Interesting feature of these bacteria is that they are able to form spores, which are specialized spherical thick-walled cells somewhat homologous to plant seeds. These spores are viable but dormant cells and can withstand mechanical and chemical stresses and remain in dry state viable for periods over 50 years. However, when bacterial spores were directly added to the concrete mixture, their life-time appeared to be limited to one-two months. The decrease in life-time of the bacterial spores from several decades when in dry state to only a few months when embedded in the concrete matrix may be due to continuing cement hydration resulting in matrix pore-diameter widths typically much smaller than the 1- μ m sized bacterial spores.

1.2.2 ADVANTAGES OF USING BACTERIA IN CONCRETE:



Around five per cent of all man-made carbon dioxide emissions are from the production of concrete, making it a significant contributor to global warming. Finding a way of prolonging the lifespan of existing structures means we could reduce this environmental impact and work towards a more sustainable solution.

- This could be particularly useful in earthquake zones where hundreds of buildings have to be flattened because there is currently no easy way of repairing the cracks and making them structurally sound."

- fills the crack in an efficient period of time so that the life period of a concrete structure can be expected over 200years.
- prevents the use of cement in future used as a maintenance for repairing the existing structure by drilling and grouting process.so in this way, less use of cement can be seen.
- as we know, more of cement content is manufacture, the more carbon dioxide gases will be released causing global warming ,soon effecting the ozone layer. by using this bacteria, the structure does not need to be repaired except for the less cases and so results in less use of cement.

1.2.3 NORMAL CONCRETE

the concrete used in the whole project is an ordinary Portland cement of 53 grade, coarse sand ,20mm sized aggregates mixed one under the M20 mix design

1.3 OBJECTIVE OF STUDY

The objective of the project is to determine and compared the mechanical properties of Bacterial concrete and normal concrete such as compressive strength, tensile strength, split tensile strength.

1.4 SCOPE OF STUDY

Bacteria used in concrete can also be used while the construction of buildings, so the entire scope of study is based on using bacteria under cool condition, added to concrete, properly cured in water, tests concocted for fresh concrete and hardened concrete.

The compatibility of Bacterial concrete in taking up load coming to the frame of the building is being found out by testing the laboratory specimen of beams and columns.

II. MIX

2.1 MIX DESIGN OF CONCRETE

The strength is mainly influenced by water cement ratio, and is almost independent of the other parameters the properties of concrete with a compressive strength of 25MPa, are influenced by the properties of aggregate in addition to that of water cement ratio. To obtain good strength, it is

necessary to use the lowest possible w/c ratio which affects the workability of the mix. In the present state of art, concrete which has a desired 28days compressive strength of minimum 25 MPa can be made by suitable proportion of the ingredients using normal methods for compacting the mixes.

2.2MIX DESIGN PROCEDURE

1. The strength of the cement as available in the country today has greatly improved since 1982. The 28-day strength of A, B, C, D, E, F. Category of cement is to be reviewed.

2. The graph connecting, different strength of cements and W/C is to be re-established.

3. The graph connecting 28-day compressive strength of concrete and W/C ratio is to be extended up to 80Mpa, if this graph is to be cater for high strength concrete.

4. As per the revision of 456-2000, the degree of workability is expressed in terms of slump instead of compacting factor. This results in change of values in estimating approximate sand and water contents for normal concrete up to 35Mpa and high strength concrete above 35Mpa. The table giving adjustment of values in water content and sand % for other than standard conditions, requires appropriate changes and modifications.

5.In the view of the above and other changes made in the revision of IS456-2000, the mix design procedure as recommended in IS 10262-82 is required to be modified to the extent considered necessary and examples of mix design is worked out.

2.3 5ML BACTERIAL MIX:

5ml of bacteria (*Bacillus subtilious*) was added to every 500 ml of water while mixing concrete, so a total of 65ml of bacteria was added to 6.5 liters of water used for mixing cement of 14kgs.

2.4 10ML BACTERIAL MIX: 10ML of bacteria (*Bacillus subtilious*) was added to every 500 ml of water while mixing concrete, so a total of 126ml of bacteria was added to 6.5 liters of water used for mixing cement of 14kgs.

2.5 15ML BACTERIAL MIX:

15ML of bacteria (*Bacillus subtilis*) was added to every 500 ml of water while mixing concrete, so a total of 195ml of bacteria was added to 6.5 liters of water used for mixing cement of 14kgs.

III. TESTING OF CONCRETE SPECIMENS

3.1 COMPRESSION TEST

- Remove the specimens from water after specified curing time and wipe out excess water from the surface.
- Leave the specimen in the atmosphere for 24hours before testing.
- Place the specimen in the machine in such a manner that the load shall be applies to the opposite sides of the specimen cast.
- Align the specimen centrally on the base plate of the machine for a cubic or cylindrical specimen.
- Rotate the movable portion gently by hand so that it touches the top surface of the specimen.
- Apply the load gradually without shock and continuously at the rate of $140\text{kg}/\text{cm}^2$ /minute till the specimen fails.
- Increase the load until failure and note the maximum load



Figure 7.1 Showing Compressive testing of cube with Compression testing Machine

This compression test is done as per IS: 269 – 1976 and IS: 4031 – 1968

3.2 SPLIT TENSILE TEST

- Remove the specimens from water after specified curing time and wipe out excess water from the surface.
- Leave the specimen in the atmosphere for 24 hours before testing.
- Place the specimen horizontally in the machine in such a manner that the load shall be applies to the opposite sides of the specimen
- Align the specimen centrally on the base plate of the machine for a cylindrical specimen.
- Rotate the movable portion gently by hand so that it touches the top surface of the specimen
- Apply the load gradually without shock and continuously at the rate of $140\text{kg}/\text{cm}^2$ /minute till the specimen fails.
- Increase the load until failure and note the maximum load



Figure 7.2 Showing Split Tensile testing of cylinder with Compression testing Machine

This Split tensile strength test is done as per IS 5816 : 1999

3.3 FORMING A CRACK

- A crack was formed in two cubes of 15ML bacterial concrete and these cracks were formed to a depth of 10mm.
- due to formation of crack, we had checked that whether the bacteria had formed precipitate like calcite when coming into contact with water and how well is the bacteria percolating to the inner surface of the crack.
- we had tested these specimens after 28 days under the compression testing machine and values were taken.



3.4 WORKABILITY TESTS:

3.4.1 SLUMP TEST:

Principle:

The slump test result is a slump of the behaviour of a compacted inverted cone of concrete under the action of gravity. It measures the consistency or the wetness of concrete.

Apparatus:

Metal mould, in the shape of the frustum of a cone, open at both ends, and provided with the handle, top internal diameter 4 in (102 mm), and bottom internal diameter 8 in (203 mm) with a height of 1 ft (305 mm). A 2 ft (610 mm) long bullet nosed metal rod, 5/8in (16 mm) in diameter.

Procedure:



The test is carried out using a mould known as a slump cone or Abram's cone. The cone is placed on a hard non-absorbent surface. This cone is filled with fresh concrete in three stages, each time it is tamped using a rod of standard dimensions. At the end of the third stage, concrete is struck off flush to the top of the mould. The mould is carefully lifted vertically upwards, so as not to disturb the concrete cone. Concrete subsides. This subsidence is termed as slump,

and is measured in to the nearest 5 mm if the slump is <100 mm and measured to the nearest 10 mm if the slump is >100 mm

Interpretation of results

The slumped concrete takes various shapes, and according to the profile of slumped concrete, the slump is termed as true slump, shear slump or collapse slump. If a shear or collapse slump is achieved, a fresh sample should be taken and the test repeated. A collapse slump is an indication of too wet a mix. Only a true slump is of any use in the test. A collapse slump will generally mean that the mix is too wet or that it is a high workability mix, for which slump test is not appropriate. Very dry mixes; having slump 0 – 25 mm are used in road making, low workability mixes; having slump 10 – 40 mm are used for foundations with light reinforcement, medium workability mixes; 50 - 90 for normal reinforced concrete placed with vibration, high workability concrete; > 100 mm

3.4.2 VEE-BEE CONSISTOMETER TEST:

Objective:

To determine the workability of freshly mixed concrete by the use of Vee – Bee consistometer.

Apparatus:

- 1) Cylindrical container, Vee-Bee apparatus (consisting of vibrating table, slump cone)
- 2) Standard tamping rod, o Stop watch and trowels.
- 3) Remove the cone from the concrete immediately by raising it slowly and carefully in the vertical direction. Lower the transparent disc on the top of concrete. Note down the reading on the graduated rod.
- 4) Determine the slump by taking the difference between the readings on the graduated rod recorded in the steps and above.
- 5) Switch on the electrical vibrations and start the stopwatch. Allow the concrete to remould by spreading out in the cylindrical container. The vibrations are continued until the concrete is completely remoulded, i.e, the surfaces becomes horizontal and the whole concrete surface adheres uniformly to the transparent disc.
- 6) Record the time required for complete remoulding seconds which measures the workability expressed as number of Vee-Bee seconds.

Procedure:

(1) Place the slump cone in the cylindrical container of the consistometer. Fill the cone in four layers, each approximately one quarter of the height of the cone. Tamp each layer with twenty-five strokes of the rounded end of the tamping rod. The strokes are distributed in a uniform manner over the cross-section of the cone and for the second and subsequent layers the tamping bar should penetrate into the underlying layer. After the top layer has been tamped, struck off level the concrete with a trowel making the cone exactly filled.

(2) Move the glass disc attached to the swivel arm and place it just on the top of the slump cone in the cylindrical container. Adjust the glass disc so as to touch the top of the concrete cone, and note the initial reading on the graduated rod.

(3)

Observations and Calculation:

Initial reading on the graduated rod, **a** Final reading on the graduated rod, **b** Slump = **(b) – (a)**, in cm
Time for complete remoulding, seconds

Results:

The consistency of the concrete is reported in seconds.

3.4.3 COMPACTION FACTOR:

AIM:

To study the workability of concrete

APPARATUS:

Compaction factor apparatus' trowels, hand scoop (15.2 cm long), a rod of steel or other suitable material (1.6 cm diameter, 61 cm long rounded at one end) and a balance.

SAMPLING:

Concrete mix (M25) is prepared as per mix design in the laboratory

PROCEDURE

- i. Place the concrete sample gently in the upper hopper to its brim using the hand scoop and level it.
- ii. Cover the cylinder
- iii. Open the trap door at the bottom of the upper hopper so that concrete fall in to the lower

hopper. Push the concrete sticking on its sides gently with the rod.

- iv. Open the trap door of the lower hopper and allow the concrete to fall in to the cylinder below
- v. Cut of the excess of concrete above the top level of cylinder using trowels and level it.
- vi. Clean the outside of the cylinder.
- vii. Weight the cylinder with concrete to the nearest 10 g. This weight is known as the weight of partially compacted concrete (w1).
- viii. Empty the cylinder and then refill it with the same concrete mix in layers approximately 5cm deep, each layer being heavily rammed to obtain full compaction.
- ix. Level the top surface.
- x. Find the weight of empty cylinder

NOTE

The test is sufficiently sensitive to enable difference in work ability arising from the initial process in the hydration of cement to be measured. Each test, there for should be carried out at a constant time interval after the mixing is completed, if strictly comparable results are to be obtained. Convenient time for releasing the concrete from the upper hopper has been found to be two minutes after the completion of mixing.

CALCULATION

- 1. The compaction factor is defined as the ratio of the weight of partially compacted concrete to the weight of fully compacted concrete. It shall normally to be stated to the nearest second decimal place.
- 1. Compaction Factor= $(W1-W2 / W2-W)$

RESULT

Compaction factor of the concrete

IV. EXPERIMENTAL RESULTS

4.1 INITIAL SETTING TIME OF CEMENT

Weight of cement sample taken =400gms

Consistency of cement =28% as obtained above

Volume of water to be added = $0.85*28/100*400=95.2m$

Initial setting time obtained =32 minutes.

(x) Weigh the cylinder with fully

Weight of cement sample taken =400gms

Consistency of cement obtained = 28% as
 Above Volume of water to be added =
 $0.85 \times 28 / 100 \times 400 = 95.2 \text{ m}$
 Final setting time = 400 minutes.

4.3 Specific gravity of cement

Weight of empty specific gravity bottle W1 = 44.1 gm.
 Weight of sp.gr. bottle + wt. of cement W2 = 70.00 gm.
 (1/3 rd to 2/3 rd of bottle full)
 Weight of specific gravity bottle + cement + kerosene W3 = 106.20 gm
 Weight of specific gravity bottle + kerosene W4 = 83.80 gm.
 Specific gravity of kerosene = 0.79
 Specific gravity of cement = $(W2 - W1) / \{(W4 - W1) - (W3 - W2)\} = 3.117$

4.4 SPECIFIC GRAVITY OF COARSE AGGREGATES

Weight of pycnometer + fine agg + water W3 = 1769.2 gm.
 Weight of pycnometer + water W4 = 1450 gm.

- 1) Dry weight of aggregate = $W2 - W1$
- 2) Weight of equivalent volume of water = $(W2 - W1) - (W3 - W4)$

Specific gravity = $(W2 - W1) / (W2 - W1) - (W3 - W4) = 2.085$

4.5 WATER ABSORPTION

TEST

Weight of oven dried aggregate = 500g
 Weight of aggregate soaked in water for 24 hours = 600g
 Percentage of water absorbed = $(600 - 500) / 100 = 1\%$

4.6 WORKABILITY TEST RESULTS

4.6.1 CONVENTIONAL

CONCRETE:

Compaction factor = 0.88
 Vee-bee value = 8 sec
 Slump loss = 5mm
 Weight of saturated aggregates A = 500gms
 Weight of dry aggregates
 D = 409.2gms

Weight of pycnometer = 610gms
 Weight of pycnometer + Water C = 1502.8gms
 Weight of pycnometer + Water + aggregates B = 1816.8gms
 Specific gravity = $D / \{A - (B - C)\} = 2.20$

4.5 SPECIFIC GRAVITY OF FINE AGGREGATES

Weight of empty pycnometer W1 = 610 gm.
 Weight of pycnometer + fine aggregate W2 = 1110 gm.

4.6.2 5ML BACTERIAL CONCRETE

compaction factor = 0.89
 vee-bee value = 4 sec
 slump loss = 13mm

4.6.3 10 ML BACTERIAL CONCRETE

compaction factor = 0.94
 vee-bee value = 4 sec
 slump loss = 15mm

4.6.4 15 ML BACTERIAL CONCRETE

compaction factor = 0.95
 vee-bee value = 3 sec
 slump loss = 17mm

CONCLUSION

From the tests conducted on bacterial and Conventional Concrete Specimens, the following conclusion have been drawn

- The Compressive strength of bacterial Concrete is added by 65% when compared to Conventional concrete of M20 grade with addition of 5ml bacteria..
- The above addition in strength is because of adding bacterial liquid to concrete, which generates calcite precipitate in concrete matrix.
- Therefore, due to addition of small amount (5ml) of bacterial liquid to the conventional concrete, a great addition in compressive, Split tensile & Flexural strengths are observed. This is mainly due to production of calcite precipitate in concrete (hardened) when it is cured properly with water, thus this calcite acts as a cement agent and recovers the whole cracked area to the inner side of concrete surface.

- However, among the different proportions of bacteria added (5ml, 10ml, 15ml) to concrete mix, 15ml bacterial concrete gives the best results in Compressive, Split Tensile, Flexural Strength tests Comparatively.
- The main advantage of bacterial concrete is that we can improve the life span of a concrete structure up to 200 years if this technology has been further enhanced and bring into special importance.
- These bacterial concrete is a self-healing concrete which heals cracks for effective duration of initial 5 hours up to as long as possible and the bacterial cell life is 200years.
- This bacterial usage can save the cement and the construction of a building can be made economical, as we know cement production gives rise to production of carbon dioxide to the higher levels, so further controlling is made very effective.
- This bacterial concrete usage can be made common in next few decades heading towards victory of civil engineering structures as per the scientific view of highly authorized laboratories in Delhi and Mumbai.

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