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# Strength and Water Absorption of Bacterial Concrete Prepared with M.sand – A Study:-

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***Abstract*— A new and advanced way of improving durability of concrete is through mineralization of bacterial isolates. Bacterial organisms have the ability to produce $CaCO_3$ through metabolic activity. Bacteria incorporated concrete have enhanced durability as cracks in concrete can be rectified through mineral precipitation ($CaCO_3$). Bacillus species are aerobic spore forming gram positive bacteria with specialized thick walled dormant cells, viable for more than 200 years under dry condition. The purpose of this research is to compare the Strength and durability (water absorption) of different concentrations ($10^4$, $10^5$ and $10^6$cells/ml) of bacterial concrete with bacteria free specimen of M25 grade and to identify the optimum concentration. Bacterial concretes shows better durability and compressive strength compared to bacterial free concrete. The concentration $10^5$ cells/ml gives optimum result compared to other concentrations.**

***Keywords*— Bacterial concrete; Microbial induced calcium carbonate precipitation; Water absorption; Compressive strength; Bacillus species; Durability.***

## I. INTRODUCTION

Bacterial concrete has the potential ability to play a crucial role in new age of construction. Concrete is a porous material which provides easy ways of ingress of aggressive material into the concrete. As a result cracks are formed. Cracks with width less than 0.2 mm do not affect durability. Bacterial concrete have high durability than ordinary concrete as cracks in concrete can be healed through mineral precipitation of $CaCO_3$ (MICP). The basic principle in the process is that the microbial urease which hydrolyzes urea, to produce ammonia and carbon dioxide and the ammonia released in surroundings subsequently increases the pH, leading to precipitation of insoluble calcium carbonate.

### *1.1. Mechanism of Calcium Carbonate Precipitation.*

During MICP, 1mole of urea is hydrolyzed to 1mole of ammonia and 1mole of carbonate, which spontaneously hydrolyses to form additional 1 mol of ammonia and carbonic acid. The equation is as follows:

$$CO(NH_2)_2 + H_2O \rightarrow NH_2COOH + NH_3$$
$$NH_2COOH + H_2O \rightarrow NH_3 + H_2CO_3$$

These products equilibrate in water to form bicarbonate, 1mol of ammonium and hydroxide ions which increases the pH.

$$H_2CO_3 \rightarrow 2H^+ \ +2CO_3^{2-}$$
$$NH_3 + H_2O \rightarrow NH^{4-} + OH^-$$
$$Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3$$

Further microorganisms have negative cell surface charge which attracts cations including $Ca^{2+}$from the environment to deposit on the cell surface. The equation for the same is given below.

$$Ca^{2+} + Cell \rightarrow Cell\text{-}Ca^{2+}$$
$$Cell\text{-}Ca^{2+} + CO_3^{2-} \rightarrow Cell\text{-}CaCO_3$$

The bacteria act as nucleation site which facilitates the precipitation of calcite which can eventually plug the pores and cracks in the concrete and enhance the durability of concrete.

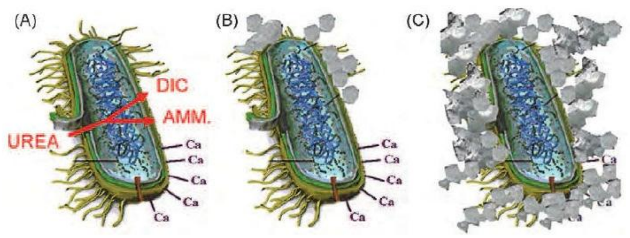


Fig. 1. Calcium Carbonate precipitation mechanism.

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*1.2. Advantages of Bacterial Concrete.*

Bacterial concrete have following advantages,

1. Improved compressive strength.
2. Better freeze thaw resistance.
3. Reduced permeability.
4. Reduction in corrosion of reinforced concrete.
5. Eco- friendly.
6. Increased durability.
7. Used as self healing agent

## II. EXPIRIMENTAL INVESTIGATIONS

*2.1. Materials.*

The following are the material used for investigation

*a) Cement.*

Ordinary Portland cement of 53 Grade confirming to IS: 2269-1987 with specific gravity of 3.15 used for the investigation.

*b) Manufactured sand.*

Manufactured sand passing through 4.75mm sieve with specific gravity 2.62 is used. Sieve analysis identified the M.sand to be in Zone II.

*c) Coarse Aggregate.*

Coarse aggregate passing through 12.5mm sieve and retained on 10mm sieve with a specific gravity of 2.8 is used.

*d) Water.*

Locally available water confirming to IS: 456 were used.

*e) Bacterial Strains.*

Aerobic alkaliphilic strain of bacillus species isolated from M.sand is used in the present study. *Bacillus megaterium* obtained from RndBio Private Limited 274/4, Anna Private Industrial Estate, Villankurichi Road, Coimbatore - 641 035, India. The sporulated bacterial isolates were added in three different concentrations, $10^4$cells/ml, $10^5$cells/ml and $10^6$cells/ml. It was mixed with lukewarm water.

*2.2. Mix design.*

Mix proportion for M25 mix was done using IS 10262-1982. It is 1:1.37:2.44 and the w/c ratio were taken as 0.45.

*2.3. Test Procedure.*

Three cubes of 150mmx150mmx150mm size and three cubes of 100mmX100mmX100mm size were casted for bacterial free concrete and each bacterial cell concentration of $10^4$cells/ml, $10^5$cells /ml and $10^6$cells/ml. After 28 days of curing, the 150mmx150mmx150mm sized cubes were used to test compression in Compression Testing Machine as per IS 516.1959 and strengths were calculated. After 28days of curing, 100mmX100mmX100mm sized cubes were immersed in water for water absorption test.

Fig. 2. Compression Testing of cubes

Fig. 3. Specimen subjected to water absorption

## III. RESULT AND DISCUSION

Bacterial concretes having high strength and durability than bacterial free concrete. Bacterial concentration of $10^5$cells/ml gives better strength compared to other concentrations and bacterial free concrete are 21.33MPa and 31.5 MPa at 7 days and 28 days of curing.

The table I shows that compressive strength of bacterial concrete and bacterial free concrete at 7 days and 28 days of curing. Percentage increases in compressive strength of bacterial concrete ($10^4$ cells/ml) compared to bacterial free concrete are 4.02%, and 4.94% in 7days and 28days of curing respectively. Percentage increases in compressive strength of bacterial concrete ($10^5$ cells/ml) compared to bacterial free concrete are 22.58%, and 11.3% in 7days and 28 days curing respectively. Percentage increases in compressive strength of bacterial concrete ($10^6$ cells/ml) compared to bacterial free concrete are 13.62% and 6.36% in 7days and 28 days of curing respectively.

TABLE I. AVARAGE COMPRESSIVE STRENGTH OF SPECIMENS CURED AT 7 DAYS AND 28 DAYS

| Sl. No. | Cell Concentrations per ml of Mixing Water. | Average Compressive Strength of Cubes (N/mm$^2$). | |
|---|---|---|---|
| | | 7 Days | 28 Days |
| 1 | 0 | 17.4 | 28.3 |
| 2 | $10^4$ | 18.1 | 29.7 |
| 3 | $10^5$ | 21.33 | 31.5 |
| 4 | $10^6$ | 19.77 | 30.1 |

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The table II shows that water absorptions of bacterial free concrete and bacterial concrete after 28 days. Bacterial concrete have less percentage of water absorption than bacterial free concrete. The bacterial concrete prepared with $10^5$cell/ml has less percentage of water absorption after 28 days of curing is 0.576%. Percentage decreases in water absorption of bacterial concrete compared to bacterial free concrete after 28 days of curing are 16.65%,50% and 34.0% respectively for $10^4$, $10^5$, $10^6$ cell concentrations.

TABLE II. AVARAGE WATER ABSORPTION OF SPECIMEN AFTER 28 DAYS OF CURING.

| Sl. No. | Cell concentrations (Cells/ml) | Water absorption (%) |
|---|---|---|
| 1 | 0 | 1.153 |
| 2 | $10^4$ | 0.961 |
| 3 | $10^5$ | 0.576 |
| 4 | $10^6$ | 0.76 |

## CONCLUSIONS

Bacterial concrete is a special concrete useful in present day construction industry. This study is on bacterial concrete with M.sand as fine aggregate and for different concentration of the selected type of bacteria, namely, *Bacillus megaterium*. Different bacterial cell concentrations of $10^4$cells/ml, $10^5$cells/ml and $10^6$cells/ml of were used in this project for the comparative study. The bacterial concentration was added to concrete mix along with lukewarm water.

Conclusions drawn from the experimental investigations and analysis are presented here,

1. Bacterial concrete is observed as having more strength and durability than bacteria free concrete.
2. The optimum concentration of bacteria that gives more strength and durability is found as $10^5$cells/ml than other concentrations made in the study.
3. Percentage increase in compressive strength is to the tune of 11.30% and 22.58 for 7 days and 28 days of curing for the identified optimum concentration.
4. Water absorption is less for the bacterial concrete due to microbial induced calcium carbonate precipitation.
5. A decrease in percentage water absorption of the bacterial concrete with optimum concentration of bacteria compared to bacterial free concrete is 50% after 28 days of curing.

The above finally concludes that bacterial concrete with $10^5$cells/ml gives enhanced strength and durability (less water absorption) in concrete with M sand as fine aggregate.

## SCOPE OF FUTURE RESEARCH

The following are recommended to be investigated.

- Split tensile strength test and flexural strength test may also be investigated for concrete with M.sand as fine aggregate and for different concentration of *Bacillus megaterium*.
- The durability test like permeability test, chloride penetration test and corrosion test may also be done with different concentration of *Bacillus megaterium*.
- The performance of bacterial concrete with M.sand can be investigated with various concentrations of different bacterial bio mass.
- The durability tests may be done after a longer age.

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