Experimental Investigations on Influencing of Strength in Concrete by Using Bacillus Sphaericus Bacteria

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Abstract- *Concrete is the most commonly used building material, the cracks in concrete create problem. Cracks in concrete occur due to various mechanisms such as - shrinkage, freeze-thaw reactions and mechanical ompressive and tensile forces. Cracking of the concrete surface may enhance the deterioration of embedded steel bars as ingression rate of corrosive chemicals such as water and chloride ions in to the concrete structure increased. Therefore a novel technique has been developed by using a selective microbial plugging process. One such thought has lead to the development of a very special concrete known as Bacterial Concrete where bacteria is induced in the mortars and concrete to heal up the faults. In this study, Bacillus Sphaericus bacteria of concentration 1x106 cells/ml are used. The properties of control concrete and bacterial concrete are studied by conducting various tests such as compressive strength, split tensile strength, flexural test with varying grades of concrete M20, M25, M30. This study showed a significant increase in the strength was observed due to the addition of bacteria for a cell concentration of 10^6 cells per ml of mixing water and therefore calcium carbonate precipitation deposited in micro cracks.*

Keywords- Bacillus pasteurii, Bacillus sphaericus, Escherichia coli, Bacillus subtilis

I. INTRODUCTION

Concrete is the most widely used construction material. Despite its versatility in construction, it is known to have several limitations. It is weak in tension, has limited ductility and little resistance to cracking. Cracks and fissures are a common problem in building structures, pavements, historic monuments and other structural members which are subjected to stress in different service conditions. Methods currently used for crack remediation often use synthetic polymers that need to be applied repeatedly, which requires continuous monitoring and recurring expenses. Because of these disadvantages of conventional surface treatments, attention has been drawn to alternative techniques for the improvement of the durability of concrete and also environmentally friendly. Based on the continuous research carried out around the globe, various modifications have been made from time to time to overcome the deficiencies of cement concrete. A novel technique in remediation cracks and fissures in different structural members is by utilizing microbiologically induced calcite (CaCo3) precipitation. This is a process by which living organism form inorganic solids. Calcite has a coarse crystalline structure that readily adheres to surfaces in the form of scales which highly insoluble in water. Due to its inherent ability to continuously precipitate calcite, bacterial concrete can be used for repairing concrete structures.

II. BACTERIAL CONCRETE

Bacterial Concrete refers to a new generation of concrete in which selective cementation by microbiologically induced CaCo3 precipitation has been introduced for remediation of micro cracks. The “Bacterial concrete” can be prepared by adding spore forming bacteria in the concrete that are able to continuously precipitate calcite, this process of production of calcite precipitation is called Microbiologically Induced Calcite Precipitation (MICP) . The process can occur inside or outside the microbial cell or even some distance away within the concrete. Often bacterial activities simply trigger a change in solution chemistry that leads to over saturation and mineral precipitation. Use of these Bio mineralogy concepts in concrete leads to potential invention of new material called Bacterial Concrete.

Need of Bacterial Concrete

Self healing of concrete is a product that will biologically produce limestone to heal cracks that appear on the surface of concrete structures. Specially selected types of the bacteria genus bacillus, along with calcium based nutrient known as calcium lactate, and nitrogen and phosphorous, are added to the ingredients of the concrete when it’s being mixed. These self healing agents can lie dormant within the concrete for up to 200 years. However, when a concrete structure is damaged and water seeps through the cracks that appear in the concrete, the spores of bacteria germinate on contact with the water and nutrients. Having been activated the bacteria start to feed on calcium lactate. As the bacteria feeds oxygen is consumed and soluble calcium lactate is converted to insoluble limestone. The limestone solidifies on the cracked surface , thereby sealing it up. The consumption of oxygen during the bacterial conversion of calcium lactate to limestone has an additional advantage. Oxygen is an essential element in the process of corrosion of steel and when bacterial activity has consumed it all it increase the durability of steel reinforced concrete constructions. The two self healing agent parts (the bacterial spores and the calcium lactate based nutrients) are introduced to the concrete within the expanded clay pellets 2-4 mm wide, which ensures that the agents will not be activated during the cement mixing process. Only when cracks open up the pellets and incoming water brings the calcium lactate into contact with the bacteria do these become activated. Testing has shown that when water seeps into the concrete, the bacteria germinate and multiply quickly.

III. MATERIAL PROPERTIES

A. BACILLUS SPHAERICUS BACTERIA

Procurement of Bacteria and culturing:

Two different bacteria classified as Bacillus sphaericus and Sporosarcinapastuerii. These bacteria are obtained from the Microbial Type Culture Collection and Gene Bank (MTCC) , Chandigarh in a freezed dried condition. Bacteria is first cultured in solid media (agar) are then transferred to nutrient broth (liquid media) which is sterile and kept in shaking incubator (to ensure uniform growth) for about 48 hrs.

Bacterial Count:

Concentration of cells is measured by Haemocytometer and optical density is found by spectrophotometer analysis before adding bacteria to cement composites.

Gram Staining:

Gram staining method was used to determine the morphology of the bacterial strains.

Bacterial Activity:

Bacterial cultures are tested for urealytic activity and also calcium carbonate precipitation.

Bacterial Growth Process:

Bacterial growth follows three phases. When a population of bacteria first enters a high-nutrient environment that allows growth, the cells need to adapt to their new environment. The first phase of growth is the lag phase, a period of slow growth when the cells are adapting to the high-nutrient environment and preparing for fast growth. The lag phase has high biosynthesis rates, as proteins necessary for rapid growth are produced.

The second phase of growth is the logarithmic phase (log phase), also known as the exponential phase. The log phase is marked by rapid exponential growth. The rate at which cells grow during this phase is known as the growth rate, and the time taken for the cells to double is known as the generation time. During log phase, nutrients are metabolised at maximum speed until one of the nutrients is depleted and starts limiting growth. The final phase of growth is the stationary phase and is caused by depleted nutrients. The cells reduce their metabolic activity and consume non-essential cellular proteins.

B. Cement

Portland Pozzolana Cement was used in casting the specimens. Portland Pozzolana Cement (PPC) is manufactured by the inter grinding of OPC clinker with 10 to 25 percent of pozzolanic material (as per latest amendment, it is 15 to 35%). A pozzolanic material is essentially a silicious or aluminous material which while in itself possessing no cementitious properties, which will, in finely divided form and in the presence of water, react with calcium hydroxide, liberated in the hydration process, at ordinary temperature, to form compounds possessing cementitious properties. It produces less heat of hydration and offers greater resistance to the attack of aggressive waters than ordinary Portland cement. Moreover, it reduced the leaching of calcium

S.No	Descriptions	Result
1	Specific gravity	3.15
2	Fineness modulus	2%
3	Consistency	3%
4.	Initial Setting Time	53 Minutes

C. Coarse Aggregates

The Hard granite broken stones of less than 20mm size were used as coarse aggregate. The specific gravity, fineness modulus, water absorption and bulk density of the coarse aggregate were tested.

Properties of Coarse Aggregate

a. Specific Gravity
b. Bulk Density
c. Water Absorption
d. Fineness Modulus

S.No	Descriptions	Result
1	Specific Gravity	2.75
2	Bulk density	1648.73 Kg/m^3
3	Water Absorbtion	1%
4	Fineness Modulus	4.67

D .Fine Aggregates

River sand size less than 4.75 mm size were used as fine aggregate. The specific gravity, fineness modulus, water absorption and bulk density of the fine aggregate were tested.

Properties of Fine Aggregate

a. Specific Gravity
b. Bulk Density
c. Water Absorption
d. Fineness Modulus

S.No	Descriptions	Result
1	Specific Gravity	2.69
2	Bulk density	1648.73 Kg/m^3
3	Water Absorbtion	1%
4	Fineness Modulus	2.72

E. Water

Portable water in laboratory with pH value of not less than 6 and the requirement of IS 456-2000 was used formixing concrete and curing the specimen.

IV. MIX DESIGN

The process of selecting suitable ingredients of concrete and determining their relative proportion with the object of producing concrete of certain minimum strength as economically as possible is known as Mix Design M25 is carried out to achieve specified age workability of fresh concrete and durability requirements by using IS 10262-2009. The following data are required for mix proportioning of a particular grade of concrete.

Water	Cement	Fine Aggregate	Coarse Aggregate
188.79	503.00	673.27	1250.27
0.375	1	1.338	2.58

V. EXPERIMENTAL RESULTS

A. TESTS ON FRESH CONCRETE

Fresh concrete or plastic concrete is a freely mixed material which can be moulded into any shapes. The relative quantities of cement, aggregates and water mixed together, to control the properties of cement in wet and the hardened state.

a. Slump Test

Slump test is the most commonly used method of measuring workability of concrete. The apparatus for conduction the slump test consists of a metallic mould in the form of a frustum of a cone having the internal dimensions as follows

Bottom Diameter = 20 cm
Top Diameter = 10 cm
Height = 30 cm

b. Compaction Factor test:

The sample of concrete to be tested is placed on the top hopper upto the brim. The trap door is opened so that the concrete falls into the lower hopper. Then the trap door of the bottom hopper is opened and the concrete is allowed to fall into the cylinder.

Table.1 Control concrete

S.No	Name of Specimen	Grade of concrete		
		M20	M25	M30
1	Cubes	6	6	6
2	Cylinder	6	6	6
3	Prism	6	6	6
4	Slab	3	3	3

Bacterial concrete

Table.1 Bacterial concrete

S.No	Grade of concrete	Grade of concrete		
		M20	M25	M30
1	Cubes	6	6	6
2	Cylinder	6	6	6
3	Prism	6	6	6
4	Slab	3	3	3

B. TESTS ON HARDENDED CONCRETE

a. Compressive Strength

Compressive test are made at recognized ages of the test specimens. Least three specimens, preferably from different batches shall be made for testing at each selected age. The load is applied at the rate of 140 kg/cm2/min (approximately) until the failure of the specimen.

Compressive strength, FC= P/A

Where,

Fc = Compressive Strength (N/mm2)

P = Ultimate Load (N) and

A = Loaded Area (150mm x 150mm)

b. Split Tensile Strength Test

Tensile strength of concrete is determined by splitting the cylinder across the vertical diameter.Split tensile strength is an indirect method of finding out the tensile strength of concrete. The splited tensile strength is calculated using the formula,

F=2P/ΠdL

Where P = applied load

D = diameter of the specimen

L = length of the specimen

C. Flexural Strength Test

The standard size of the specimens 10 x 10 x 50 cm is used. The mould should be made of metal or cast iron, with sufficient plate thickness to prevent spreading or warping. The testing machine may be of sufficient capacity for the testing and rate of loading as specified. The load is applied through the roller placed at middle(central point load). The flexural strength of specimen is expressed as modulus of rupture, fb.

Flexural strength, fb= P x l / (bd^2)

Where,

P = Applied load

l = Length of specimen

b,d=Cross section dimensions of specimen

D. Two Point Loading Test

The specimen is placed in such a manner that the load is applied to the uppermost surface as cast in the mould, along two lines spaced 40 cm apart. The axis of the specimen is carefully aligned with the axis of loading device. The load is applied without shock and increasing continuously at a rate such that the extreme fibre stresses increasing gradually. The load is increased until the specimen fails, and the maximum applied during the test is recorded. The appearance of the fractured faces of concrete and any unusual features in the type of failure is noted.

VI. CONCLUSIONS

The examinations of the control concrete and bacterial concrete cubes are done to determine the mechanical properties. The results reveal that the bacteria incorporated concrete specimens shows better compressive strength after 7th and 28th days of curing than control concrete. The percentage increase in compressive test at 7 days of curing are 6.22%, 4.23% and 4.85% for M20, M25 and M30 grade of concrete respectively. Similarly, at 28 days of curing, the percentage increase in strength was found to be 7.62%, 5.02%, 6.92% for M20, M25 and M30 grade of concrete respectively.

The split tensile strength of cylindrical specimens were tested at the end of 7 days and the percentage increase in strength was found to be 9.04%, 13.62%, 10.73% for M20, M25 and M30 grade of concrete respectively. Similarly, for 28 days of curing, the percentage increase in strength was found to be 3.07%, 1.41%, 1.82% for M20, M25 and M30 grade of concrete respectively

The flexural strength of prismatic beam specimens were tested at the end of 7 days and the percentage increase in strength was found to be 12.12%, 15.29%, 6.89% for M20, M25 and M30 grade of concrete respectively. Similarly, for 28 days of curing, the percentage increase in strength was found to be 4.58%, 2.09%, 1.91% for M20, M25 and M30 grade of concrete respectively.

From above results, due to the incorporation of bacteria, the compressive strength of concrete increases remarkably. Whereas, the split tensile strength and flexural strength were increases for 7 days of curing. But after 28 days, very small amount of strength is increased. The bacteria incorporated R.C.C. slab specimen withstands more load before starts yielding than that of control concrete slab specimen. The various behavior of beam such as deformation, equivalent stress, equivalent strain are studied for the following grade of concrete such as M20,M25 and M30 grade of concrete for normal and bacterial concrete.

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