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Use of Bacillus Bacteria in Self-Healing Concrete

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Abstract – *Due to low tensile strength cracks are common phenomenon of concrete through which transport of harmful substances causes early deterioration of concrete structure. Other methods to fill cracks like Epoxy injection, Routing and sealing of cracks, Drilling and plugging method, Gravity filling method, Dry packing are expensive.*

So as sustainable development self-healing concrete is best solution to fill cracks. microbial concrete is recent trend in concrete technology. Many researchers works on different bacteria considering parameters to find out best outcome. Comparative study of normal concrete and concrete with direct inserted bacteria is going to be taken under consideration. For this work M30 grade of concrete is going to be selected and test like compression is before insertion and after insertion of bacteria is going to be conducted. Cultivation of bacteria is going to be conducted along with finding out best suitable bacterial count and cells/ml count. Crack healing capacity of bacteria is also going to be find out.

Key Words: **Self-Healing Concrete, Bacillus Pasteurii, Crack Healing Capacity**

1. INTRODUCTION

Concrete is the most common material used in construction industry all over the world. Natural processes such as weathering, faults, land subsidence, earthquakes, and human activities creates cracks in concrete structures. Concrete expands and shrinks with changes in moisture and temperature and this tendency to shrink and expands causes cracks in concrete. Cracks lead to water leakage, and reduction of the stability of civil systems such as reservoirs, retaining walls, Residential buildings and tunnels. Cracks often encourage the ingress of hostile agents by supplying gas and water delivery pathways, often harmful to the stability of cement. Moreover; degradation of cracks is one of the most major sources of risk that has a significant impact on the stability and longevity of reinforced concrete [6].

The Self-healing Concrete is a concept in which cracks in concrete reacts to cure itself without any human intervention. It is a product that will biologically produce limestone to heal cracks. Specially selected types of the bacteria from bacillus family gives desired results. These self-healing agents can lie dormant within the concrete for up to 200 years [1]. Jonkers states that the bio-deposition of the calcium carbonate crystals in the between the concrete pores acts as a filler material and helps in reducing capillary pores of the concrete. As a result concrete capillaries are significantly reduced due to the filling of pores and it decreases the permeability of the concrete thus significantly increasing the durability of the concrete[7]. When a concrete structure damages and water starts to penetrate in the cracks present in it the bacteria starts to feed on the calcium lactate consuming oxygen and converts the soluble calcium lactate into insoluble limestone. The limestone formed thus seals the cracks present. Consumption of oxygen in the bacterial conversion has an additional advantage. Oxygen which becomes an essential element for the corrosion of steel to take place is being used in the bacterial conversion. Hence the durability of steel in construction becomes higher [5].

*Sporosarcina pasteurii (*formerly known as *Bacillus pasteurii)* is a bacterial species that is well known for producing urease and hydrolyzing urea to form ammonia and bicarbonate ions, and was thus used in this study [2]. The selection of the bacteria is depend on the survive capability of bacteria in the alkaline environment. Most of the microorganisms die in an environment with pH value of 10 or above [4]. *Bacillus pasteurii* had the growth in pH range of 7-9.

2. EXPERIMENTAL ANALYSIS

2.1 Cultivation of Bacteria

In order for bacillus pasteurii to create limestone, reach crystallization, it needs food. Initially, sugar was an option; however, sugar makes concrete weak and it retards the curing of concrete. So, the food chosen was calcium lactate [3]. Culture of Bacillus pasteurii is taken from National Chemical Laboratory (NCL).The pure culture of bacteria i.e. Bacillus Pasteurii is preserved on nutrient agar slants. It forms irregular dry white colonies on nutrient agar slants. One colony of the bacteria are inoculated into nutrient of 500 ml conical flask and incubated at the temperature of 37^0 C and 150 rpm orbital shaker incubator. The medium composition used for growth of bacterial culture consist of peptone, NaCl, yeast extract.

The nutrient agar content is taken as described on nutrient agar bottle prescription. For 1 lit of distilled water 13 gram of nutrient agar was taken.

Use of digital calorimeter is done for taking bacterial count. The amount of light absorbed by the sample is displayed on the screen. By using that data we can calculate the no of bacteria present in that solution. After several iterations we

got the actual bacterial count for bacillus pasteurii is 600nm =10^6 cells/ml

Best solution amount is found out which is 50 ml of bacterial solution for volume of 1 cube (150 X 150 X 150 mm).

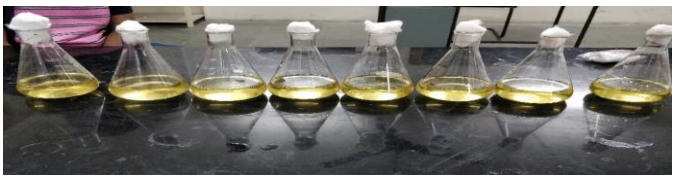


Figure 1. Bacterial Culture

2.2 Materials

For this research work, M30 grade of concrete has been used. The cement used is 53 grade ordinary Portland cement. 70kg of fly ash is used. And admixture 4.18kg was used. Water cement ratio was 0.45. Cubes with size 150 X 150 X 150 mm was used for compression test.

2.3 Mix Proportion

Table -1: Mix design for M30 Grade

Material	Quantity (in Kg)
Cement	320
Fly ash	70
Crushed Sand	810
10 mm aggregate	390
20 mm aggregate	775
water	186
Admixture	4.18

2.4 Compression Test

According to IS 516-1959, Cubes of size 15cm x 15cm x 15cm should be cast. The specimen should be given sufficient time for hardening and then it should be cured for 3, 7, 14 and 28 days. After 3, 7, 14 and 28 days, it should be loaded in the compression testing machine and tested for maximum load. measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross-sectional area. Average of three cubes taken under consideration for finding out compressive strength.

Compressive strength (N/mm^2) = load applied/cross sectional area of cube

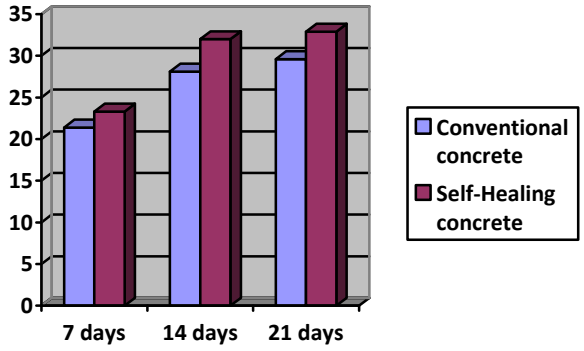
Figure 2. Testing of concrete cube using CTM

3. RESULTS

Table - 2: Compressive Strength Results.

Days	Conventional Concrete	Bacterial Concrete	% increased
7	21.4	23.315	8.95
14	28.1	31.994	13.86
28	29.6	32.903	11.16

Chart -1: Compressive Strength Graph



4. CONCLUSION

This paper describes that by the application of bacteria in concrete it was found that the compressive strength of concrete increased with a decrease in corrosion of reinforcement compared to that of conventional concrete. SHC (Self-Healing Concrete) also significantly influenced the durability characteristics of the structure by healing of cracks in the structure.
Conventional concrete gave results as per grade and mix design. The maximum percentage increase in strength observed on 14 days compressive strength whereas

minimum % increase was for 7 days which is 8.95%. For complete 28 days compressive strength 11.16 percentage increased found out. Also SHC healed cracks after getting in touch with water and moisture.

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