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EXPERIMENTAL STUDY ON MECHANICAL PROPERTIES OF SELF-HEALING CONCRETE BY USING BACTERIA *Bacillus Sphaericus*

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Abstract:

This experimental study deals with the crack healing ability of the bacteria. The crack in the concrete is the major problem in construction field. Crack in concrete structure tend to expand further and eventually require costly repairs. To solve this problem, we have introduced a novel technique by fitting crack with environmentally friendly biological procedure that is a continuous self-remediating process. In this study Bacillus Sphaericus that is abundant in soil have been used and it is added in different proportions in M25 concrete in the form of liquid. The cubes and cylinders specimen should undergo compressive and split tensile test at 7, 14, 28 days. This study showed increase in strength by addition of bacterial solution, precipitation of Calcium Carbonates in micro cracks and test results are been compared.

1. Introduction:

Concrete is a strong and relatively cheap construction material and therefore presently used all over the world and usually considered as indestructible because of their longer service it e as compared with the most constructional products. It is a composite material inclusive of cement, lime aggregate, coarse aggregate and water. However, they can get destroyed for a variety of reasons including the material limitations, design gaps and construction practices, as well as exposure conditions. Manual repair of damaged concrete is the traditional solution to restore strength or increase the service life of constructions. However, since about two decades the possibility to make use of self repair features of concrete or even specifically implement a self-healing system into concrete constructions is considered by scientific researchers it was recognized in the past that most types of concrete feature some crack-sealing potential. it was observed that crack ingress water can activate partially or non-hydrated cement particles present on crack surfaces which due to hydration can bridge cracks resulting in reduced permeability or even complete sealing of micro-cracks. This type of so-called 'autogenous' healing. Examples of specially designed autonomous self-healing concretes are those with inbuilt encapsulated sealants or adhesives, special fibres or tubes used for storage of chemicals, incorporation of specific expansive components which upon coming into contact with moisture expand thereby filling voids and cracks.

2. Objectives:

The integrated bacteria applied to alkali resistant spore forming species of the genus bacillus. Bacteria of this group, and particularly their thick-walled spores .Bacillus Sphaericus is used in concrete by liquid form. The use of bacteria is to precipitate calcite in cracks of concrete. With this method relatively large cracks in reinforced concrete can be filled. In this method by filling cracks the path of reinforcement is blocked. For this study M25 grade is used with the adding of Bacillus Sphaericus.

- ✓ To determine the mechanical properties of concrete
- ✓ To determine the optimum quantity of the bacteria
- ✓ To compare the results with conventional concrete

3. Scope of Work:

- ✓ To develop sustainable construction materials
- ✓ To regain the maximum strength of concrete after cracking rectification
- ✓ To develop methods of concrete after cracking rectification
- ✓ To improve the compressive strength of cracked concrete
- ✓ To develop Eco friendly construction materials

4. Materials and Methods:

Cement: The most common cement is used is ordinary Portland cement. Out of the total production, ordinary Portland cement accounts for about 80-90 percent. Many tests were conducted to cement some of them are consistency tests, setting tests, etc.

Fine Aggregate: Locally available free of debris and nearly riverbed sand is used as fine aggregate. The sand particles should also pack to give minimum void ratio, higher voids content leads to requirement of more mixing water. In the present study the sand conforms to zone II as per the Indian standards6. The specific gravity of sand is 2.61. Those fractions from 4.75 mm to 150 micron are termed as fine aggregate, and the bulk density of fine aggregate (loose state) is 1552.91kg/m3 and rodded state is 1642.85kg/m3.

Coarse Aggregates: The crushed aggregates used were 20mm nominal maximum size and are tested as per Indian standards and results are within the permissible limit. The specific gravity of coarse aggregate is 2.69; the bulk density of coarse aggregate (loose state) is 1498.25kg/m^3 and rodded state is 1711.64kg / m^3.

Water: Water available in the college campus conforming to the requirements of water for concreting and curing as per IS: 456-2009.

Bacillus Sphaericus Bacteria: Bacillus sphaericus is strictly aerobic gram positive rod shaped bacterium. It is an insecticide against certain strains of diseased mosquitoes .Bacillus sphaericus are pore forming bacterium dormant for several years and

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would be able to withstand extreme temperature .It forms spherical endospores. It forms chains-Medium –sized, smooth colonies with an entire margin and also rod shaped cells. Gram variable, large spore- forming rods with a diameter < 0.9µm. Does not attack sugars. Growthning range of temperature 37ºc optimum temperature 35-37ºc.

Preparation of Bacteria: The mixing proportion of the bacteria is Luria Berta-powder form (6.75 gm) + 500 ml of distilled water + peptone (3 gm) + yeast extract (1.5 gm) +Beef extract (1.5 gm) + Sodium chloride(3 gm/100 ml) + Loop of Bacteria (gel medium) =Incubator 37°C.Then it is prepared in the nutrient agar and processing of bacteria is done. After this is done the culturing and isolation process is done.

5. Experimental Procedure:

In this experiment, cubes of size 150mmx150mmx150mm and cylinders of size 150mm diameter and 300mm long were used. The mix design of concrete was done according to Indian guidelines of Indian Standard 10262 for M25 grade concrete consists of cement, fine aggregate, coarse aggregate with water cement ratio are 0.45.For bacterial concrete the quantity of bacteria was added as 6%,8%,10% volume of water. The ingredients of concrete were thoroughly mixed manually till uniform consistency was achieved. Before casting, machine oil was smeared on the inner surfaces of the cast iron mould. Concrete was poured into the mould and compacted thoroughly using tamping rod. The top surface was finished by means of a trowel. The specimens were removed from the mould after 24hr and then cured under water for a period of 7, 14 and 28 days. The specimens were taken out from the curing tank just prior to the test. The tests for compressive, split tensile strength were conducted using a 2000KN compression testing machine.

6. Experimental Results:

The strength results obtained from the experimental investigations are showed in tables. All the values are the average of the two trails in each case in the testing program of this study. The results are discussed as follows.

Properties of Concrete:

Fresh Concrete: The workability results are obtained from experimental investigations. All the values are average of the two trails in each case in the testing program of this study. The results are discussed as follows.

- ✓ **Workability:** A high-quality concrete is one which has acceptable workability (around 6.5 cm slump height) in the fresh condition and develops sufficient strength. Basically, the bigger the measured height of slump, the better the workability will be, indicating that the concrete flows easily but at the same time is free from segregation. Maximum strength of concrete is related to the workability and can only be obtained if the concrete has adequate degree of workability because of self-compacting ability. The workability of CC and M series concrete are presented in table 1. The table 1 shows the influence of Bacterial content on the workability of mixtures at constant water to binder ratio of 0.45. The results show that unlike the CC series, all investigated Bacterial mixtures had high slump values and acceptable workability.

Table 1: Fresh Concrete Test

MIX	% of bacterial solution	Workability	
		Slump (mm)	Compaction factor
CC	0	78	0.95
M1	6	82	0.96
M2	8	88	0.97
M3	10	100	0.97

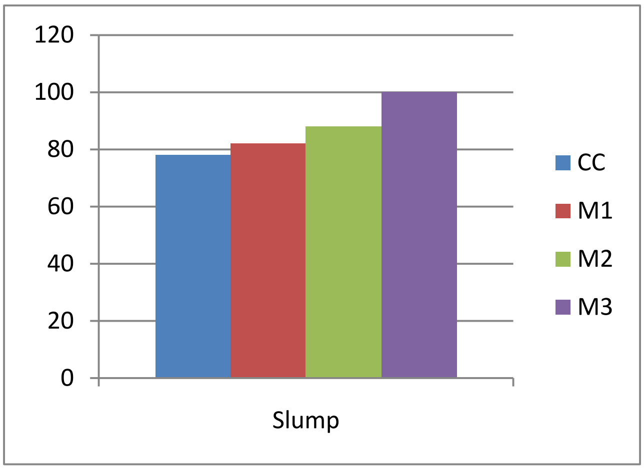

Chart 1: Slump cone test

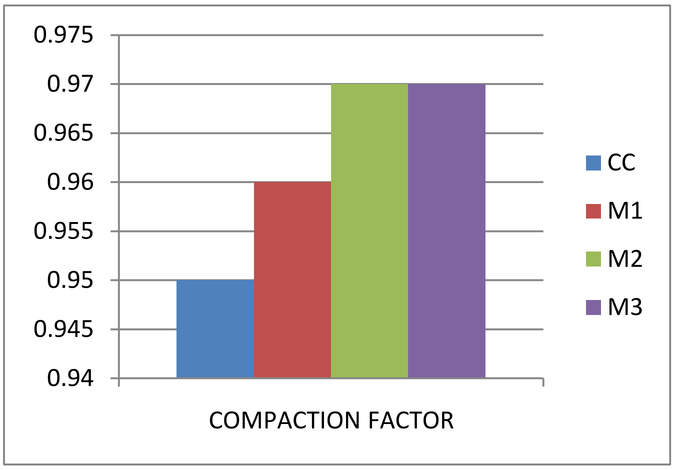

Chart 2: Compaction factor test

Hardened Concrete: The strength test results obtained for concrete cube and cylinder specimens with addition bacterial solution are shown in Table 2, 3, 4 and 5. From tables, it is clear that the addition of bacterial solution in different percentage 6, 8, 10% in cement increases its strength under compression and tension. The initial compressive strength of the cubes were found by giving initial load. The bacterial concrete was applied up to initial crack. The ultimate compressive strength of the cubes were found by giving ultimate load. The bacterial concrete was placed in the compression testing machine and ultimate load was applied. The tensile strength at initial crack of the cylinders were found by giving initial load. The bacterial concrete was placed in compression

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testing machine and ultimate load was applied up to initial crack. The tensile strength at initial crack of the cylinders were found by giving ultimate load. The bacterial concrete was placed in compression testing machine and ultimate was applied.

Table 2: Result comparison of Initial compressive strength of Cubes

Mix	Initial Compressive Strength(N/mm^2)			After Healing of Concrete Compressive Strength (N/mm^2)		
	7 days	14 days	28 days	7 days	14 days	28 days
CC	12.57	15.72	18.55	_	_	_
M1	12.77	17.39	20.83	12.17	13.19	16.19
M2	14.46	17.24	21.64	13.32	14.52	19.44
M3	15.82	17.87	22.89	15.16	16.79	22.43

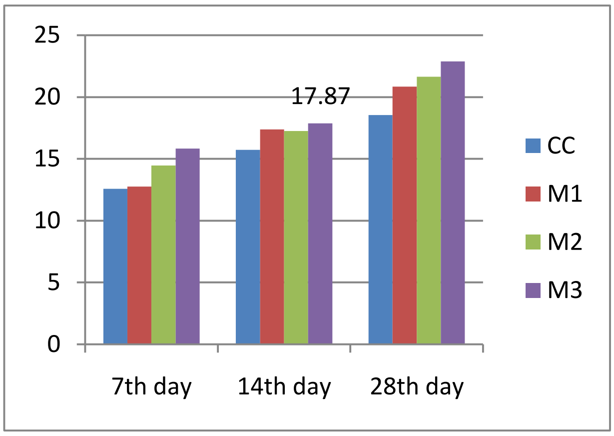

Chart 3: Initial Compressive strength on 7, 14 and 28 days

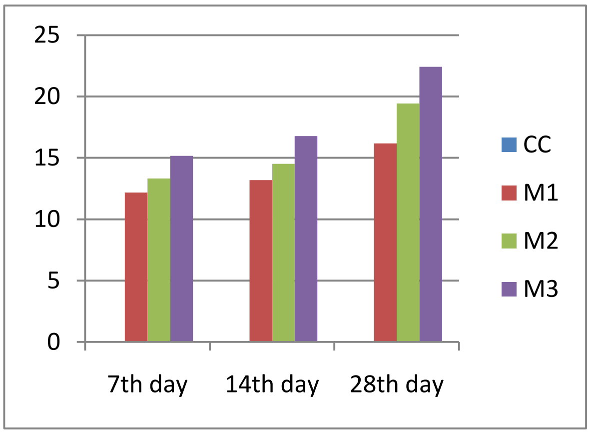

Chart 4: Initial compressive strength on 7, 14, 28 days after healing

Table 3: Result comparison of Ultimate Compressive strength for Cubes

Mix	Ultimate Compressive Strength(N/mm^2)			After Healing of Concrete Compressive Strength (N/mm^2)		
	7 days	14 days	28 days	7 days	14 days	28 days
CC	18.23	22.36	27.29	-	-	-
M1	19.47	22.52	28.53	17.65	20.94	25.31
M2	19.47	23.83	29.25	17.32	21.68	27.78
M3	21.98	25.36	31.36	20.22	23.33	30.73

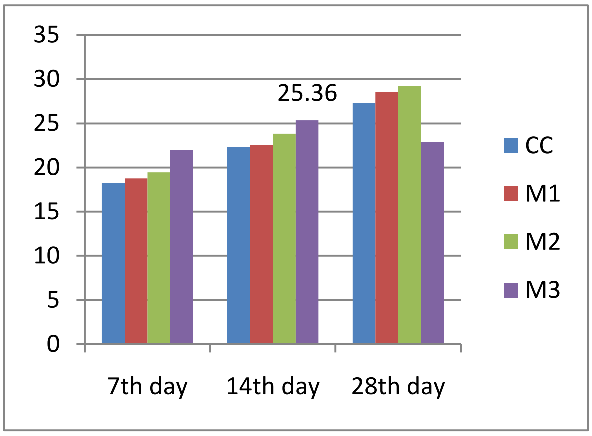

Chart 5: Ultimate compressive strength on 7,14,28 days

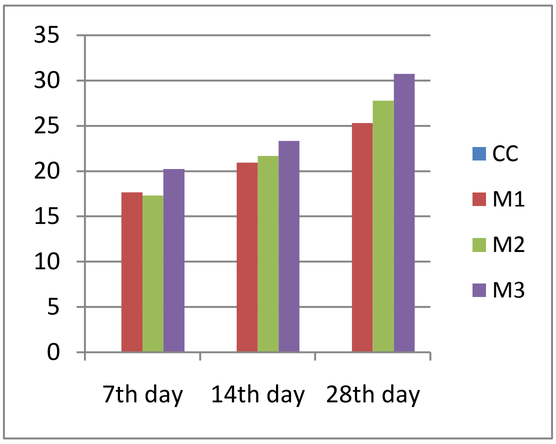

Chart 6: Compressive strength on 7, 14 and 28 days after healing

Table 4: Initial Split tensile strength of Cylinders

Mix	Initial Split Tensile Strength (N/mm2)			After Healing of Concrete Split Tensile Strength (N/mm2)		
	7days	14 days	28 days	7 days	14 days	28 days
CC	2.38	2.77	3.01			
M1	2.50	2.91	3.19	2.22	2.67	2.79
M2	2.62	3.12	3.38	2.43	3.02	3.24
M3	2.86	3.31	3.41	2.60	3.27	3.34

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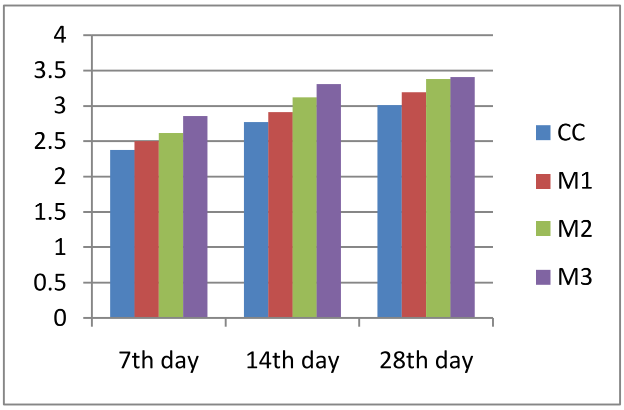

Chart 7: Initial split tensile strength on 7,14,28 days

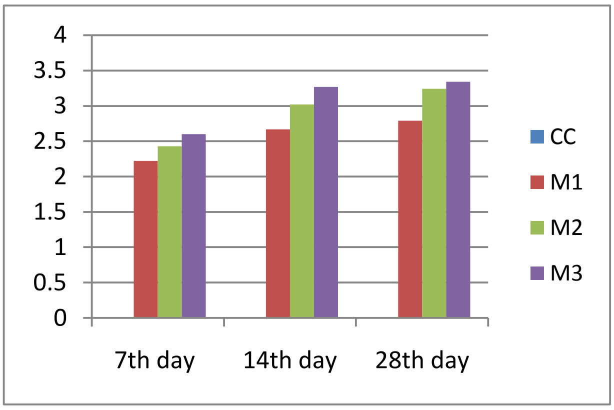

Chart 8: Initial split tensile strength after healing on 7,14,28 days

Table 5: Initial Split tensile strength of Cylinders

Mix	ultimate Split Tensile Strength(N/mm^2)			After Healing of Concrete Split Tensile Strength (N/mm^2)		
	7 days	14 days	28 days	7 days	14 days	28 days
CC	2.98	3.35	3.65			
M1	3.17	3.32	3.78	2.72	2.95	3.4
M2	3.23	3.41	3.81	2.93	3.04	3.73
M3	3.42	3.57	4.34	3.35	4.2	4.32

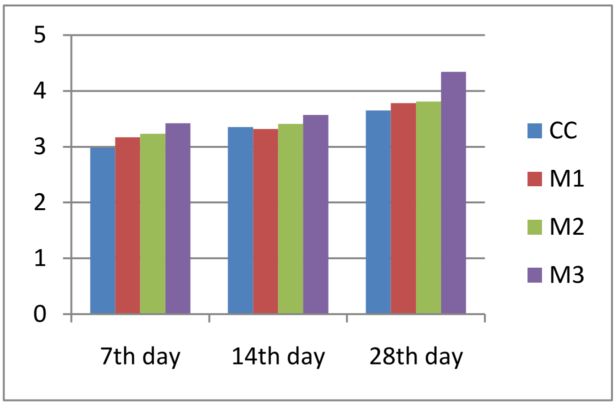

Chart 9: Ultimate split tensile strength on 7, 14, 28 days.

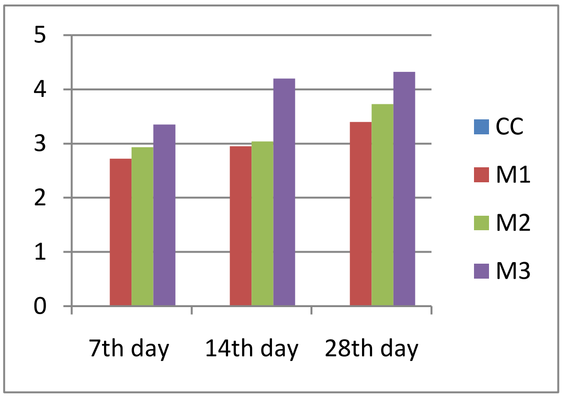

Chart 10: Ultimate split tensile strength after healing on 7, 14, 28 days

Comparison of the results from the 7, 14 and 28 days samples shows that the compressive strength and Split Tensile strength increases with Mix 3 (10%).

7. Conclusion:

In this investigation the crack-healing ability of concrete was studied. The compressive strength and split tensile strength for cubes and cylinders were increased due to addition of bacterial solution at various proportions. The influence of bacteria added in concrete in the repair of cracks in the concrete was examined by addition of bacterial solution at various mixes. Based on the investigation the following conclusions were drawn.

- ✓ When the Bacterial concentration increases, the Calcium Carbonate ($CaCo_3$) precipitation increases.
- ✓ The crack-healing ability of the concrete is increased and enhanced.
- ✓ Optimum quantity of the bacteria was found in mix 3 (M3) which is 10% of bacteria by amount of water.
- ✓ Compressive strength for M3 is 20% higher when compared to Conventional Concrete.
- ✓ Split tensile strength for M3 is 30% higher when compared to Conventional Concrete.

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