Experimental Study of Self Healing Concrete (SHC)

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Abstract

In modern days, the use of technology has taken the standards of construction to a new high level. Different types of procedures, methods and materials are used to attain a very good, sustainable and economic concrete construction but due to human mistakes, incorrect handling and unskilled labors. An efficient building is hard to sustain its designed life. Many problems like weathering, cracks, leaks and bending etc., arises after the construction. Cracking of concrete is a common phenomenon without immediate and proper treatment, cracks in concrete structures tend to expand further and eventually require costly repairs. Concrete will continue to be the most important building material for infrastructure but most concrete structures are prone to cracking. Tiny cracks on the surface of the concrete make the whole structure vulnerable because water seeps in to degrade the concrete and corrode the steel reinforcement, greatly reducing the lifespan of a structure. Self-healing 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 Bacillus Subtilis, Escherichia Coli, along with a calcium based nutrient known as calcium lactate, and nitrogen and phosphorus, are added to the ingredients of the concrete when it is being mixed. These self-healing agents can lie dormant within the concrete for up to 200 years. Also the compressive strength of concrete is enhanced.

Key Words: *Bacillus Subtilis, Escherichia Coli, Bacterial Concrete or Self-Healing Concrete, compressive strength.*

1. INTRODUCTION

Bacterial concrete or self healing concrete fills up the cracks developed in structures by the help of bacterial reaction in the concrete after hardening. Self Healing Concrete means that repairs its own cracks. Self healing is the tightening of cracks due to the precipitation of lime and the clogging of particles. Self healing can only occur for cracks smaller than 0.2 mm. Another healing mechanism is the tightening of cracks by the use of microorganisms. So we can use the non pathogenic bacteria's such as Bacillus Subtilis, Pseudomonas Fluorescens and Escherichia Coli and they are non host based bacteria which are capable of multiplying and recharged to be refilled within the concrete. Thus crack can be refilled by these bacteria. When cracks appears in a concrete structure and water starts to seep in through the spores of the bacteria starts microbial activities on contact with the water and oxygen

1.1 Bacillus Subtilis

Bacillus Subtilis is also known as hay bacillus or grass bacillus. Bacillus subtilis are rod-shaped bacteria that are Gram-positive found in soil and gastrointestinal tracts of humans. Bacillus Subtilis can grow in the mesophilic temperature ranges between 25-35 degree Celsius.

1.2 Escherichia Coli

The main advantage of embedding This Bacteria into concrete is that continuous precipitation of $CaCo_3$.This bacteria are genrally gram negative and also harmless in nature. Escherichia Coli can survive at temperature of 37 degree Celsius.

1.3 COMMON REASONS OF FORMATION OF CRACK

- Due to heat of hydration in concrete.
- Concrete expands and shrinks due to temperature differences.
- Settlement of structure.
- Due to heavy load applied.

- Due to loss of water from concrete surface shrinkage occurs.
- Insufficient vibration at the time of laying the concrete.
- Improper cover provided during concreting.
- High water cement ratio to make the concrete workable.
- Due to corrosion of reinforcement steel.

2.0 MATERIALS

Ordinary Portland Cement

The cement is a binding material. It conforming to IS456-2000-53 grade. It consists of grinding the raw materials, mixing them intimately in certain proportion depending upon their purity and composition and burning them in a kiln at a temperature of about 1300 - 1500 degree centigrade at which temperature, the material Cinter and partially fuses to form modular chapped clinker. The clinker is cooled and ground to a fine poeder with addition of 2 to 3% of gypsum the product formed by using this procedure Portland cement. Of all the materials that influence the behaviour of concrete, cement is the most important constituent, because it is 11 used to bind sand and aggregate and it resists atmospheric action. Portland cement is a general term used to describe hydraulic cement.

Graded fine aggregates

The materials smaller than 4.75 mm size is called fine aggregates. Natural sand is generally used as fine aggregate. In this experimental work replacement of river sand by quarry waste (fineness modulus of crushed sand equal to 3.2) conforming to grading Zone III of IS - 383 - 1970 was used as fine aggregates.

Graded coarse aggregates

Locally available well graded granite aggregates of normal size greater than 4.75 mm and less than 16mm having fineness modulus of 2.72 was used as coarse aggregates.

Water

Potable water has been used for casting concrete specimens. The water is free from oils, acids, and alkalis and has a water-soluble Chloride content of 140 mg/lit. As per IS 456 – 2000, the permissible limit for chloride is 500 mg/lit for reinforced concrete; hence the amount of chloride present is very less than the permissible limit.

Bacteria

1. Bacillus Subtilis & 2. Escherichia Coli -
It is found that Bacillus subtilis & Escherichia Coli can precipitate maximum amount of calcite when compared to other urease positive bacteria, which results in more increase in compressive strength and higher efficiency of crack-healing. Bacillus subtilis & Escherichia Coli grow in the mesophilic temperature range. The optimal temperature is 25-35 degrees Celsius. The bacteria which need to be added should fit such special norms i.e., it should be alkali resistant and it should also be able to withstand the harsh environmental conditions of the concrete.

Table -1: Mix Design Material Proportions

S.N.	INGREDIENT	QUANTITY (Kg/m3)	RATIO
1	CEMENT	394	1
2	F.A.	732.34	1.85
3	C.A.	1139.04	2.90
4	WATER	197 Lit.	0.50
5	BACTERIA	10,20,30 (ml)	-

2.1 PREPARATION OF BACTERIA

PREPARATION OF MEDIA

Media may be liquid (broth) or solid (agar). Any desired nutrients may be in corporate in to the broth (or) agar to grow bacteria. Organism grown in broth cultures causes turbidity, (or) cloudiness, in the broth. On agar, masses of cells known as colony, appear after a period of inoculation certain separated on agar so that as the cell divines and produces a visible mass. The colony isolated from other colonies, isolated colonies are assumed to be pure culture.

MEDIA

A solution containing the nutrients necessary for the survival and growth of micro organisms is known as cultural media. Agar is an extract of weed; a complex carbohydrate composed mainly of galactose and is without nutritional value. It liquefies at hundred degrees Celsius and solidifies at 40 degree Celsius, so pathogens can be cultivated at 37.5◦ C or slightly higher temperature without the fear of the medium liquefying. When the agar is taken in test tube and hardened in a slant position, agar slants are produced. These are useful for pure maintaining pure cultures for longer periods of time. Similarly agar deep tubes are used to study the gaseous requirements of microorganisms and also to absorb the air motility.

LABORATORY PROCEDURE

A) Sub-culturing

i) The broth solution is prepared for the given composition.

ii) The broth solution is inoculated in the laminar condition.

iii) Then it is placed in the shaker at 37◦C and a speed of 125rpm for 12 hours.

B) Culturing

i) The nutrient agar was prepared in 6 conical flask of 100 ml and pH of the medium was checked and then autoclaved.

ii) The test tubes were sterilized in the hot air oven.

iii) Under sterile condition, the slants were inoculated with the given culture.

iv)Then culture was inoculated in the agar plate by streak plate method.

v) Then the plates, stabs and slants were inoculated 24 to 48 hours at 37◦C.

C) Broth solution composition

Distilled water - 100 ml in each conical flask

Nutrient Broth - 1.3 mg in each conical flask

2.2 PROCEDURE OF CASTING AND TESTING OF CUBES

PREPARATION OF MOULDS

First all moulds are prepared by joining plates with the help of nut & bolts and all are of size 150 x 150 x 150 (mm) & then oil is applied on internal surface of all moulds.

MATERIAL SELECTION

Then material is taken for preparation of concrete by adopting weight batching method.

MIXING OF MATERIAL & CASTING OF CUBES

The calculated quantity of coarse aggregate, fine aggregate and cement was taken into mixer. First dry mix is done and then water & Bacteria are added to it and mixed for 5 minutes. Then the concrete mix is taken out for casting of cubes and total 63 no's of cubes were casted.

CURING & TESTING OF CUBES

After 24 hours of casting the prepared specimens are removed from mould and placed for curing in the water tank for 28 days from date of casting. After curing all cubes were tested in compression testing machine at the interval of 7 days, 14 days and 28 days simultaneously.

2.3 COMPRESSIVE STRENGTH TEST RESULTS

Table 2: Compressive Strength Test Results for Normal Concrete and Escherichia Coli Bacterial Concrete

SR.NO.	TYPE OF CUBE	TESTING DAYS	COMPRESSIVE STRENGTH (N/MM2)			AVERAGE STRENGTH
1	NORMAL CONCRETE	7	15.66	16.95	14.66	**15.75**
	(M25)	14	16.77	17.98	23.75	**19.50**
		28	28.43	27.85	29.87	**28.72**
2	BACTERIAL CONCRETE	7	16.15	18.48	16.64	**17.09**
	ESCHERICHIA COLI	14	20.66	22.11	23.20	**21.99**
	(10ML)	28	31.91	29.10	29.95	**30.32**
3	BACTERIAL CONCRETE	7	14.70	15.83	16.68	**15.73**
	ESCHERICHIA COLI	14	20.87	20.71	17.68	**19.75**
	(20ML)	28	28.84	30.89	31.16	**30.29**
4	BACTERIAL CONCRETE	7	13.35	14.40	23.66	**17.14**
	ESCHERICHIA COLI	14	19.27	17.70	18.88	**18.61**
	(30ML)	28	36.03	32.84	33.56	**34.14**

2.4 COMPRESSIVE STRENGTH TEST RESULTS

Table 3: Compressive Strength Test Results for Normal Concrete and Bacillus Subtilis Bacterial Concrete

SR.NO.	TYPE OF CUBE	TESTING DAYS	COMPRESSIVE STRENGTH (N/MM2)			AVERAGE STRENGTH
1	NORMAL CONCRETE	7	15.66	16.95	14.66	**15.75**
	(M25)	14	16.77	17.98	23.75	**19.50**
		28	28.43	27.85	29.87	**28.72**
2	BACTERIAL CONCRETE	7	17.28	15.53	13.48	**15.43**
	BACILLUS SUBTILIS	14	20.14	20.84	17.37	**19.45**
	(10ML)	28	29.64	26.20	29.28	**28.37**
3	BACTERIAL CONCRETE	7	20.95	18.04	17.24	**18.74**
	BACILLUS SUBTILIS	14	24.54	16.64	14.76	**18.65**
	(20ML)	28	32.99	26.80	29.23	**29.67**
4	BACTERIAL CONCRETE	7	21.40	18.82	21.04	**20.42**
	BACILLUS SUBTILIS	14	21.07	15.73	16.17	**17.66**
	(30ML)	28	28.02	32.02	29.79	**29.94**

3.0 RESULTS

When compressive strength is compared, it is clear that bacterial concrete performed better than conventional concrete. The increase in compressive strength of bacterial concrete was found to be greater than conventional concrete by 15 to 20 %.

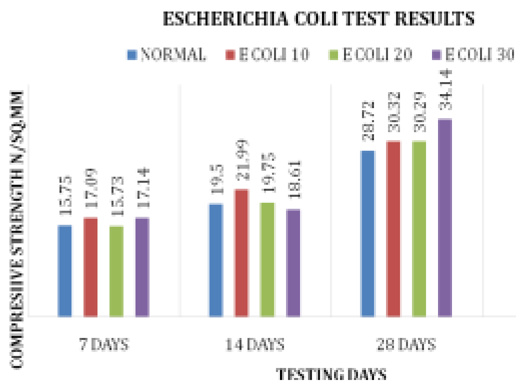

Chart -1: Compressive strength test results For Normal Concrete & Escherichia Coli Bacterial Cubes

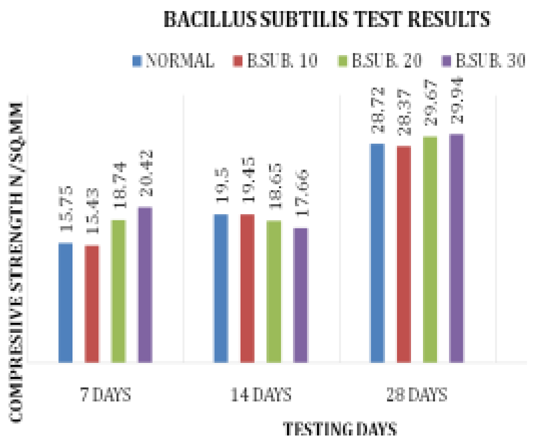

Chart -2: Compressive strength test results For Normal Concrete & Bacillus Subtilis Bacterial Cubes

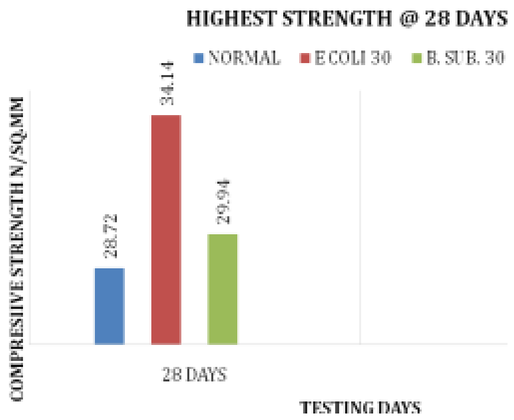

Chart -3: Highest Compressive Strength Test Results at 28 Days.

APPLICATIONS OF SELF HEALING CONCRETE

(1) SHC can be used for all types of concrete works.

(2) The SHC can be used for marine structures.

(3) It can be also used for tunnel lining and for highway bridges.

(4) The SHC can be used for all types of infrastructure buildings.

ADVANTAGES OF SELF HEALING CONCRETE

(1) It helps to fill the cracks rapidly.

(2) Reduction in corrosion of reinforced concrete.

(3) It helps to reduce maintainance and repairs.

(4) Self-repairing of cracks without any external aide.

(5) Reduction in permeability of concrete.

(6) Significant increase in compressive strength and flexural strength when compared to normal concrete.

DISADVANTAGES OF SELF HEALING CONCRETE

(1) Cost of SHC is double than conventional concrete.

(2) Growth of bacteria is not good in every atmosphere.

(3) Investigation of calcite precipitate is costly.

(4) No IS code or any other code is available for design of mix concrete with bacteria.

CONCLUSIONS

(1) Escherichia Coli bacteria have positive impact on concrete's compressive strength than bacillus subtilis bacteria.
(2) Change in compressive strength as bacterial proportion changes.
(3) When compressive strength is compared, it is clear that bacterial concrete performed better than conventional concrete. The increase in compressive strength of bacterial concrete was found to be greater than conventional concrete by 15 %.
(4) The project reviewed about different types of bacteria that can be used for remedying cracks in concrete.
(5) The project describes that due to its self healing abilities, eco-friendly nature, increase in durability etc, it is better than the conventional technology. It is very effective in increasing the strength and durability of concrete.

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