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Durability Enhancement of Structure by Using Bacterial Concrete

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Abstract – *Concrete is a tough long lasting material mixture of cement, aggregate and water and most used building material in the world. Concrete has an ultimate load carrying capacity under compression but the material is weak in tension. Even though preventive measures during the construction phase are often execute but prior corrosion may still occur. The development and application of a bio-chemical agent which, when incorporated in the concrete matrix, autonomously and actively prevents premature reinforcement corrosion in a two fold mode. The produced bio-minerals block and seal cracks resulting in a delay of further ingress of water as well as to a decrease of inward diffusion rate of chloride and oxygen. Form a new type of self-healing concrete in which bacteria mediate the making of minerals which seal freshly formed cracks and reduce permeability. The addition of particular organic mineral predecessor compounds with spore-forming alkali loving bacteria as over heal materials manufacture up to 100µm size calcite particles which can seal micro to macro sized cracks. Further development of this bio-concrete with significantly increased self-healing capacities could represent a new type of durable and sustainable concrete with a wide range of potential applications.*
Keywords – *Self healing, Sustainable Concrete, Bio-Chemical Agents, Building materials, Cracks*

I. Introduction

Crack development in concrete is a concept that can hardly be complete avoided due to shrinkage reactions of hardening concrete and tensile stresses occurring in form structures. While larger cracks can potentially hamper a structures' integrity and therefore require repair actions, smaller cracks typically with a crack width smaller than 0.2 mm are generally considered unproblematic. Although such micro cracks do not affect strength properties of structures they do on the other hand contribute to material porosity and permeability. Ingress of aggressive chemicals such as chlorides, sulphates and acids may result on the longer term in concrete matrix degradation and premature corrosion of the embedded steel reinforcement and thus hamper the structures' durability on the long term. The actual capacity of micro crack healing arises basically related to the composition of the concrete mixtures. Mixtures based on a high binder content show exceptional crack recovering properties due to secondary hydration of matrix implant non-hydrated cement and binder particles upon reaction with crack entrance water.

Autogenously self-healing of cracks in traditional but also high-binder content mixtures appear limited to cracks with a width smaller than 0.2 mm. This somewhat limited effectiveness appears largely due to the restricted expansive potential of the small non-hydrated cement particles lying exposed at the crack surface. Another limitation to application of high-binder content mixtures solely for the purpose of increasing self-healing capacities are current policies which advocate sparse use of cement in concrete for sustainability reasons as current cement production contributes about 7% to global anthropogenic CO_2 emissions. One possible mechanism is currently being investigated and developed in several laboratories, i.e. a technique depend on the mineral-producing bacteria e.g. efficient sealing of surface cracks by mineral precipitation was observed when bacteria-based mixtures were sprayed or applied onto damaged surfaces or manually inserted into cracks. As in those studies bacteria were manually and externally applied to existing structures, this mode of repair cannot be categorized as truly self healing.

The exercise can occur away within or outside the microbial cell of the concrete. Often bacterial activities simply trigger a change in solution chemistry that leads to over saturation and mineral precipitation. Use of this Bio mineralogy theory in concrete guides to potential invention of new material called Bacterial Concrete. Bacterial cells and organic mineral predecessor compounds are packed in porous swell clay particles before addition to the concrete mixture. It is hypothesized that protection of bacterial spores within porous light weight aggregates extends there viability period and thus concrete self healing functionality when embedded in the material matrix.

II. Materials & Methodology

Grade of concrete: M35
Cement: PPC 53 Grade The cement used has been tested for various properties as per IS:4031-1988 and found to be confirming to various specifications of IS:12269-1987.

Aggregate : C.A.= 20mm sized crushed angular aggregate.
F.A. = Natural sand.
Water: Clean water free from salt

III. Methodology

Selecting Viable Bacteria as Self Healing Agent: Bacteria that can resist concrete matrix incorporation exist in nature, and these appear related to a specialized group of alkali-resistant spore-forming bacteria. Important feature of this bacterium is that they are able to form cells, which are especially spherical thick-walled cells little bit similar to plant seeds. These cells are feasible but resting cells and can withstand mechanical and chemical stresses and remain in dry state for time about 50 years. When bacterial cells were added to the concrete mixture, their life appeared to be up to one-two months. The less life of bacterial cells from several decades, when it is in dry state and few months when embedded in the concrete. It may be due to constant cement hydration resulting pore-diameter widths smaller than the 1-μm sized bacterial cells. If directly add organic bio-mineral precursor compounds to the concrete mixture will not result in unwanted loss of other concrete properties. In order to significantly hike the lifetime and concrete incorporated bacteria, the effect of bacterial cell and at the same time organic bio-mineral predecessor compound i.e. calcium lactate disable in porous enlarged clay particles was tested. It was notice that, care of bacterial cells by disable inside porous enlarged clay particles before addition in concrete in fact it increases their life. After 6 months concrete fusion no loss of feasibility is noticed and suggesting that long term feasibility also noticed in dried state when not incorporated in concrete is maintained. In subsequent experiments the expanded clay particles loaded with the two-component bio chemical healing agent were applied as additive to the concrete mixture to test self healing potential of bacterial concrete.

Preparation of Bacteria: Primarily 12.5g of Nutrient broth (media) is added to a 500ml conical flask containing distilled water. It is then covered with a thick cotton plug and is made air tight with paper and rubber band. It is sterilized by using a cooker for about 20 minutes. After that flasks are opened up and 1ml of the bacterium is added to the sterilized flask and is kept in a shaker at a speed of 150-200 rpm overnight.

Preparation of Bacterial Concrete: Self healing bacterial concrete can be prepared in two ways.

1) By Direct Application: By the method of direct application bacterial spores and calcium lactate are added directly while making the concrete and mixed. When the crack forms in the concrete bacterial cells broke and bacteria comes to life and feed on the calcium lactate and limestone is produced which fill the cracks.

2) By Encapsulation in Light Weight Concrete: By encapsulation method the bacteria and its food, calcium lactate, are placed inside treated clay pellets and concrete is made. Approximate 6% of the clay prill are added forming bacterial concrete. When concrete structures are made with bacterial concrete, the crack occurs in the structure and clay prill are broken and bacterial treatment starts and hence the concrete is healed. Cracks approximately 0.5 mm width can be treated by using bacterial concrete Bacillus bacteria are not harmful to human life and hence used effectively.

Preparation of Test Specimens: Bacterial concrete casted by using ordinary Portland cement mixed with bacterial concentration 10^6 cells/ml of water. Conventional concrete samples are also casted in parallel. The specimens are cured under tap water at room temperature and tested at 7, and 28 days.

Test to be conduct on Bacterial Concrete: Concrete is prepared by containing the porous aggregates filled with food and bacteria. The specimens are cured for 28 days and then tested in a controlled tensile splitting loading and form a crack partially. Present in the crack ingress water with Portlandite (calcium hydroxide) present in the concrete mixture according to the following reaction:

$CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H2O$

As Portlandite is a rather soluble mineral in fact most of it present on the crack surface will dissolve and diffuse out of the crack into the overlying water mass.

$Ca(C_3H5O_2)_2 + 7O_2 \rightarrow CaCO_3 + 5CO_2 + 5H_2O$

This gives result in efficient crack sealing.

IV. Results & Discussion

Concreting is done by containing the porous aggregates filled with food and bacteria. The specimens are cured for 7, 14 and 28 days and then test in a control loading and form a crack partially.

Table-1 Physical Properties of Cement

Sr. No.	Properties	Test Results	Requirement as per IS
1	Normal Consistency	31%	-
2	Specific Gravity	3.10	-
3	Initial Setting Time	55 min	Not less than 30 min

	Final Setting Time	540 min	Not more than 600 min
4	Soundness	3 mm	Not more than 10 mm
5	Fineness of Cement	6.8%	Less than 10 %

Table-2 Properties of Fine & Coarse Aggregate

Sr. No.	**Property**	**Fine Aggregate**	**Coarse Aggregate**
1	Specific Gravity	2.65	2.78
2	Loose Density	1438 Kg/m^3	1438 Kg/m^3
3	Rodded Density	1622 Kg/m^3	1610 Kg/m^3

Table -3 Compare the result of traditional and bacterial concrete

COMPRESSIVE STRENGTH OF CONCRETE (N/Sq.mm)			
	7 days	**14 days**	**28 days**
CONVENTIONAL CONCRETE	14.30	21.70	34.15
BACTERIAL CONCRETE	13.78	23.20	27.80

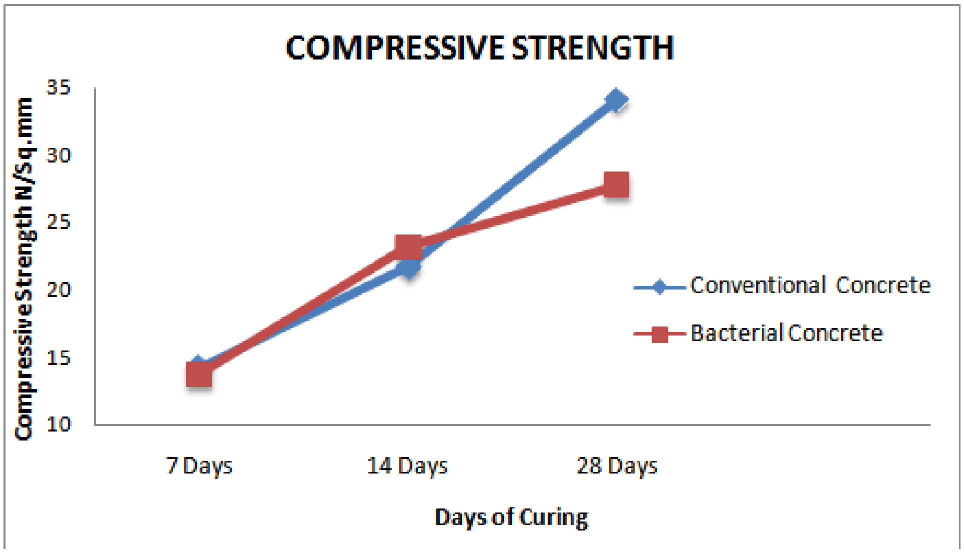


Fig.-1 Compressive strength of Concrete

From above graph, it can be discuss that at 14 days of curing the compressive strength bacterial concrete is increase but after 28 days of curing it decrease the compressive strength as compared to traditional concrete.

Table -4 Compare the result of traditional and bacterial concrete

SPLIT TENSILE STRENGTH OF CONCRETE (N/Sq.mm)			
	7 days	**14 days**	**28 days**
CONVENTIONAL CONCRETE	4.03	5.18	6.36
BACTERIAL CONCRETE	3.53	6.68	7.41

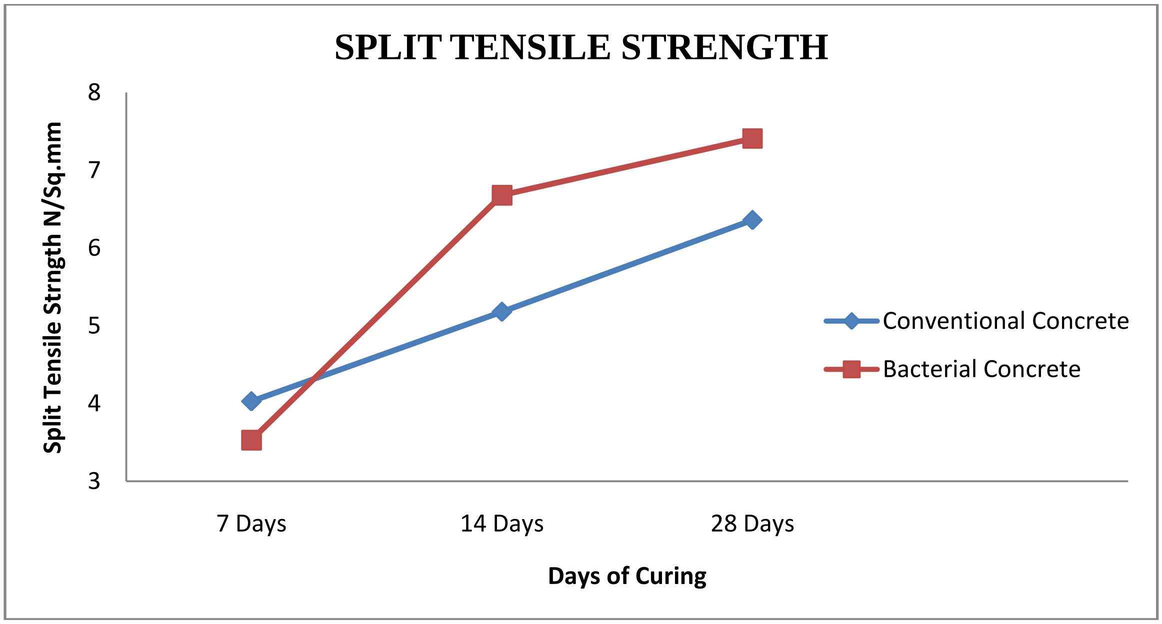
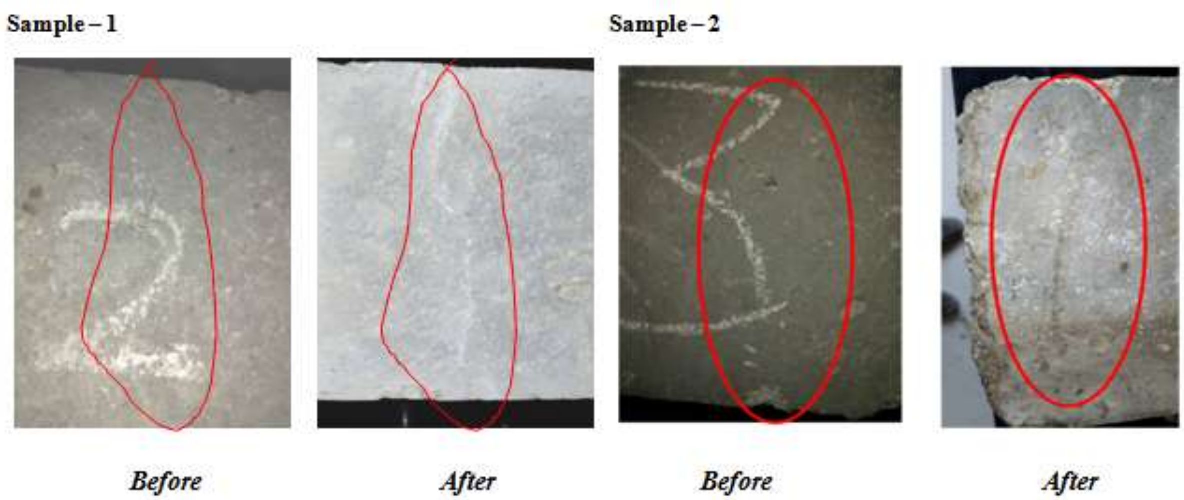


Fig. 2 Split Tensile Strength of Concrete

From above graph, it can be state at 28 days of curing the spilt tensile strength of bacterial concrete is more increase than the traditional concrete at same days of curing.

Healing of Cracked Bacterial Concrete cubes



This sealing of cracks suggests that the cracks can be kept in check from the very beginning which prevents further exposure of reinforcement to oxygen and moisture and ultimately corrosion. This will increases the useful life of a structure and increases durability.

I. Conclusion

In bacterial concrete the water was also reduced by volume equal to the bacterial solution so that the final amount of water added is as required by the control sample.

1) The compressive strength shows a decrease of about 20%. So target mean strength should be increased nearly 23% at 28 days for ordinary, standard and high grades of concrete when compared to controlled concrete at the time of mix designing.
2) Addition of Bacillus Subtilis bacteria shows increase in the split tensile strength of concrete. The strength increase is clearly visible for 14^{th} and 28^{th} days curing of split tensile strength test and is about 15 – 21 %.
3) The width of cracks that can be effectively sealed appears to be from 0.25 to 0.75 mm as observed in our tests.

4) This should also reduce leakages and long term maintenance.
   To conclude it can be state that the application of bacteria as a self-healing agent in concrete appears promising. Concrete-immobilized bacterial spores revive and produce copious minerals after stimulation by suitable medium, i.e. water containing an organic growth substrate such as calcium lactate.

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