Self-Healing Concrete or Bio- Concrete used in Construction Industry

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***Abstract*: Micro-cracks are the main cause to structural failure. One way to circumvent costly manual maintenance and repair is to incorporate an autonomous self -healing mechanism in concrete. One such an alternative repair mechanism is currently being studied, i.e. a novel technique based on the application of bio-mineralization of bacteria in concrete. The applicability of specifically calcite mineral precipitating bacteria for concrete repair and plugging of pores and cracks in concrete has been recently investigated and studies on the possibility of using specific bacteria as a sustainable and concrete -embedded self-healing agent was studied and results from ongoing studies are discussed. Synthetic polymers such as epoxy treatment etc. are currently being used for repair of concrete are harmful to the environment, hence the use of a biological repair technique in concrete is focused.**

1. INTRODUCTION:- Crack formation is a commonly observed phenomenon in concrete structures. Although micro crack formation hardly affects structural properties of constructions, increased permeability due to micro crack networking may substantially reduce the durability of concrete structures due to risk of ingress of aggressive substances particularly in moist environments. In order to increase the often observed autogenous crack-healing potential of concrete, specific healing agents can be incorporated in the concrete matrix. The aim of this study was to quantify the crack-healing potential of a specific and novel two-component bio-chemical self-healing agent embedded in porous expanded clay particles, which act as reservoir particles and replace part of regular concrete aggregates. Upon crack formation the two-component bio-chemical agent consisting of bacterial spores and calcium lactate are released from the particle by crack ingress water. Subsequent bacterially mediated calcium carbonate formation results in physical closure of micro cracks. Experimental results showed crack-healing of up to 0.46 mm-wide cracks in bacterial concrete but only up to 0.18 mm-wide cracks in control specimens after 100 days submersion in water. That the observed doubling of crack-healing potential was indeed due to metabolic activity of bacteria was supported by oxygen profile measurements which revealed O_2 consumption by bacteria-based but not by control specimens. We therefore conclude that this novel bio-chemical self-healing agent shows potential for particularly increasing durability aspects of concrete constructions in wet environments.

Types of bacteria:- There are various types of bacteria were used in construction area

- Bacillus pasteurii
- Bacillus sphaericus
- Escherichia coli
- Bacillus subtilis
- Bacillus cohnii
- Bacillus balodurans
- Bacillus pseudofirmus

2. LITERATURE REVIEW

RECENT ADVANCES ON SELF HEALING OF CONCRETE. SCHLANGEN, H. JONKERS, S. QIAN & A. GARCIA DELFT UNIVERSITY OF TECHNOLOGY, MICROLAB, DELFT, NETHERLANDS

In this paper an overview is given of new developments obtained in research on self-healing of cracks in cement based materials and asphalt concrete. At Delft University various projects are running to study self-healing mechanisms. The first project that is discussed is Bacterial Concrete, in which bacteria are mixed in concrete, that can precipitate calcite in a crack and with that make concrete structures water tight and enhance durability. In a second project hybrid fiber reinforced cementations materials are studied that can mechanically repair cracks when they occur. The last project described in this paper is on the ravening of porous asphalt concrete and how to heal this damage by incorporating embedded microcapsules or steel fibers. The state of the art results in all projects show that self-healing is not just a miracle, but materials can be designed for it.

Following are the findings:

1. The water tightness of the structure increased.
2. The endurance durability enhanced.
3. Ravening of porous asphalt concrete replenishment.

DEVELOPMENT OF A BACTERIA-BASED SELF HEALING CONCRETE HENK M. JONKERS & ERIK SCHLANGEN DELFT UNIVERSITY OF TECHNOLOGY, FACULTY OF CIVIL ENGINEERING AND GEOSCIENCES/MICRO LAB, DELFT, THE NETHERLANDS.

Concrete structures usually show some self-healing capacity, i.e. the ability to heal or seal freshly formed micro-cracks. This property is mainly due to the presence of non-hydrated excess cement particles in the materials matrix, which undergo delayed or secondary hydration upon reaction with ingress water. In this research project we develop a new type of self-healing concrete in which bacteria mediate the production of minerals which rapidly seal freshly formed cracks, a process that concomitantly decreases concrete permeability, and thus better protects embedded steel reinforcement from corrosion. Initial results show that the addition of specific organic mineral precursor compounds plus spore-forming alkaliphilic bacteria as self- healing agents produces up to 100. I sized calcite particles which can potentially seal micro- to even larger- sized cracks. Further development of this bio-concrete with significantly increased self-healing capacities would represent a new type of durable and sustainable concrete with a wide range of potential applications.

Following are the findings:

1. Bacteria mediate the production of minerals.

2.. Rapidly heal cracks.

3. Decreases permeability and corrosion.

4. Introduction of new advanced sustainable concrete

3. OBJECTIVES:

- To increase the life of concrete
- To increase the compressive strength of concrete.
- To increase flexural strength of concrete.
- To decrease effect of global warming and ozone layer depletion.
- To decrease maintenance cost.
- To develop self-healing of bio concrete using biological based techniques.

4. SCOPE OF PROJECT:

The use of microbial concrete in Bio Geo Civil Engineering has become increasingly popular. From enhancement in durability of cementations materials to improvement in sand properties, from repair of limestone monuments, sealing of concrete cracks to highly durable bricks, microbial concrete has been successful in one and all. This new technology can provide ways for low cost and durable roads, high strength buildings with bearing capacity, long lasting river banks, erosion prevention of loose sands and low cost durable housing. Another issue in conventional building materials is the high production of greenhouse gases and high energy consumed during production of these materials and these greenhouse gases leads to global warming. High construction cost of building materials is another drawback in such cases. These drawbacks have led to use of novel, eco-friendly self-healing and energy efficient technology where microbes are used for remediation of building materials and enhancement in the durability characteristics.

5. METHODOLOGY:-

PREPARATION OF BACTERIAL SOLUTION.

CASTING OF NORMAL AND BACTERIAL CONCRETE BLOCKS, BEAMS AND CYLINDERS.

TESTING OF BLOCKS AND CYLINDERS.

COMPARISON OF TESTS OF BLOCKS AND CYLINDERS.

PREPARATION OF BACTERIAL SOLUTION:

1. Combination of harmless bacterias-Bacillus Sphaericus and Portius Vulgarius are going to be used to give good result.

2. For making of Bio concrete, bacterial solution will be use.

Image No. 1

3.Preparation of bacterial solution will be done primarily by adding 12.5 g of nutrients growth to 500 mL conical flask containing distilled water and it is covered.
4.A colony of an overnight culture used to inoculate 30 mL of media in a 250 mL conical flask.
5. The culture is then going to be incubated at 37oc for 24 hrs.

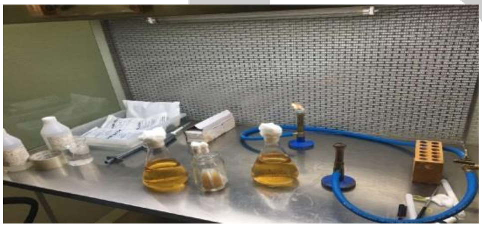

Image No. 2

6. EXPERIMENTAL ANALYSIS

COMPRESSION STRENGTH TEST

The cubical Moulds of size l50mm x l50mm x l50mm were cleaned and checked against the joint movement. A coat of oil was applied on the inner surface of the Moulds and kept ready for the concreting operation.
Meanwhile the required quantities if cement, fine aggregate and coarse aggregate (passing through IS sieve of 20 mm size and retained on 4.75 mm) for the particular mix are weighed accurately for concreting.
Fine aggregate and cement were mixed thoroughly in a hand mixer such that the colour of the mixture is uniform.

Image No.3 Concrete block under compression

Now weighed quantity of coarse aggregate is added to the mixer and then it rotated till uniform dry mixture is obtained. Then, calculated quantity of bacterial solution and water was added and mixing was continued for about 3 to 5 minutes to get a uniform mix.

The wet concrete is now poured into the Moulds and for every 2 to 3 layers and compacted manually. After concreting operations, the upper surface is levelled and finished with a masons trowel. The corresponding identification marks were labelled over the finished surface and they were tested for 7 and 28 day strengths in a compressive strength testing machine.

Compressive strength = Total failure load/Area of the cube

Image No.4 Cube after compression

4.1.1 Test Results

The test results showed a significant difference in the specimens tested, with and without bacteria.

For 7 Days NC

Specimen No.	Size of Specimen (mm)	Load taken by Specimen (KN)	Compressive Strength (N/mm^2)
1	150x150x150	459	20.40
2	150x150x150	441.9	19.64
3	150x150x150	470.7	20.92

Specimen No.	Size of Specimen (mm)	Load taken by Specimen (KN)	Compressive Strength (N/mm^2)
1	150x150x150	489.15	21.74
2	150x150x150	442.8	19.68
3	150x150x150	490.95	21.82

Specimen No.	Size of Specimen (mm)	Load taken by Specimen (KN)	Compressive Strength (N/mm^2)
1	150x150x150	477	21.2
2	150x150x150	463.95	20.62
3	150x150x150	484.65	21.54

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For 28 days NC

Specimen No.	Size of Specimen (mm)	Load taken by Specimen (KN)	Compressive Strength (N/mm^2)
1	150x150x150	650.7	28.92
2	150x150x150	708.525	31.49
3	150x150x150	702.9	31.24

Specimen No.	Size of Specimen (mm)	Load taken by Specimen (KN)	Compressive Strength (N/mm^2)
1	150x150x150	635.4	28.24
2	150x150x150	685.8	30.48
3	150x150x150	618.75	27.5

Specimen No.	Size of Specimen (mm)	Load taken by Specimen (KN)	Compressive Strength (N/mm^2)
1	150x150x150	709.2	31.52
2	150x150x150	649.35	28.86
3	150x150x150	712.35	31.66

For 7 days BC

Specimen No.	Size of Specimen (mm)	Load taken by Specimen (KN)	Compressive Strength (N/mm^2)
1	150x150x150	565.2	25.12
2	150x150x150	566.775	25.19
3	150x150x150	626.4	27.84

Specimen No.	Size of Specimen (mm)	Load taken by Specimen (KN)	Compressive Strength (N/mm^2)
1	150x150x150	572.85	25.46
2	150x150x150	585.00	26.00
3	150x150x150	624.15	27.74

Specimen No.	Size of Specimen (mm)	Load taken by Specimen (KN)	Compressive Strength (N/mm^2)
1	150x150x150	622.8	27.68
2	150x150x150	649.8	28.88
3	150x150x150	672.75	29.90

For 28 Days BC

Specimen No.	Size of Specimen (mm)	Load taken by Specimen (KN)	Compressive Strength (N/mm^2)
1	150x150x150	822.6	36.56
2	150x150x150	860.85	38.26
3	150x150x150	828.225	36.81

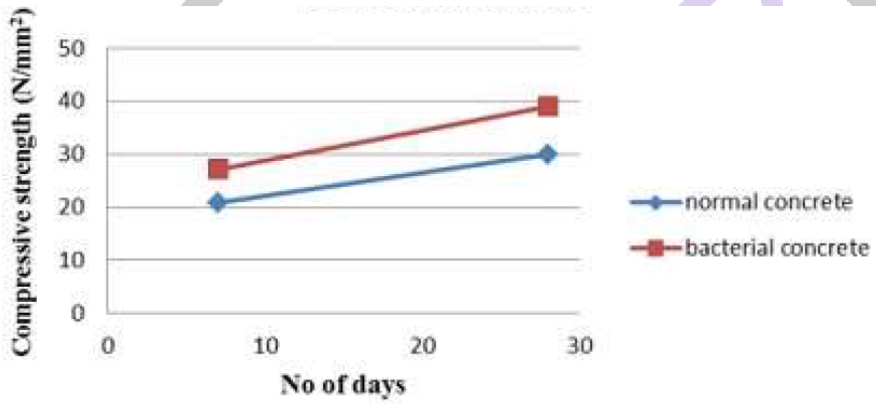
Specimen No.	Size of Specimen (mm)	Load taken by Specimen (KN)	Compressive Strength (N/mm^2)
1	150x150x150	866.70	38.52
2	150x150x150	882.675	39.23
3	150x150x150	937.125	41.65

Specimen No.	Size of Specimen (mm)	Load taken by Specimen (KN)	Compressive Strength (N/mm^2)
1	150x150x150	915.075	40.67
2	150x150x150	916.65	40.74
3	150x150x150	863.55	38.38

Average Compressive strength for 7 and 28 Days

Sr.No	Days	Normal Concrete (N/mm^2)	Bacterial Concrete (N/mm^2)
1	**7**	**20.84**	**27.09**
2	**28**	**29.99**	**38.98**

Graph No. 1 Compressive strength vs. No. of Days



FLEXURAL STRENGTH TEST

Moulds of lOcm x lOcm x 5Ocm is used and the Moulds are cleaned and the joints between the sections of Moulds shall be thinly coated with Moulds oil and a similar coating of Moulds oil shall be applied between the contact surfaces of the bottom of the Moulds and the base plate in order to ensure that no water escapes during the filling.

- The interior faces of the assembled Moulds shall be thinly coated with Moulds oil to prevent adhesion of the concrete.

- Meanwhile the required quantities of cement, fine aggregate and corresponding coarse aggregate for the particular mix are weighed accurately for concreting.

7. RESULTS AND DISCUSSION

1. After carrying out various tests on cube blocks, beam, and cylinder specimens it has been observed that bacterial concrete is better than conventional concrete if cost is neglected.
2. Cost of bacterial concrete is more than conventional concrete, because cost of bacteria is more.
3. After carrying out compressive strength test on Cube Blocks of size 150x150x150(mm) it has been observed that the compressive strength of bacterial concrete block is more than the conventional concrete block.
4. After carrying out flexural strength test on specimen of size 100x100x500(mm) it has been observed that the flexural strength of bacterial concrete block is more than conventional concrete block.

5. After carrying out Split Tensile strength test on Cylinder blocks of 150mm Diameter and 300mm Length, it has been observed that the split tensile strength of bacterial concrete block is more than conventional concrete block.
6. The problem with bacterial concrete is that the culturing of bacteria is difficult. The bacteria can't be cultured in atmosphere. Particular temperature is required for culturing and growing bacteria. But by using bacterial concrete large amount of maintenance cost can be saved.

8. CONCLUSION

1. Bacterial concrete technology has proved to be better than many conventional technologies because of its eco- friendly nature, self-healing abilities and increase in durability of various building materials.

2. Work of various researchers has improved our understanding on the possibilities and limitations of biotechnological applications on building materials.

3. Enhancement of compressive strength, reduction in permeability, water absorption, reinforced corrosion have been seen in various cementations and stone materials.

4. In bacterial concrete interconnectivity of pores is disturbed due to plugging of pores with calcite crystals. Since interconnected pores are significant for permeability; the water permeability is decreased in bacteria treated specimens.

5. Cementation by this method is very easy and convenient for usage.

6. This will soon provide the basis for high quality structures that will be cost effective and environmentally safe but, more work is required to improve the feasibility of this technology from both an economical and practical viewpoints.

7. The application of bacterial concrete to construction may also simplify some of the existing construction processes and revolutionize the ways of new construction processes.

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