International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.10 No.8, pp 778-786, 2017

Feasibility of using Ground Water to Grow Bacteria in Bacterial Concrete

S.krishnapriya*, S.Dhakshayeni

Department of civil engg,Sns College of Technology, Coimbatore Tamilnadu, India

Abstract : Cracks in concrete are a common problem .cracks are the result for ingress of water and other deleterious substances[1]. Cracks if not treated, it would lead to corrosion of reinforcement due to the entry of water and deleterious substances[2,4]. Hence, there is a need to treat cracks and increase the durability of concrete.so, self-healing of concrete cracks with calcite precipitating bacteria has been proposed as a bio-based and pollution –free method. Bacterial strains namely bacillus licheniformis were selected based on their urease activity ability to form endospores, and ability to precipitate calcium carbonate .concrete mix of M25 grade was designed. Prepared bacterial solution is mixed with normal water in various % and compressive strength, split tensile strength, flexural strength for 7,14 and 28 days was found. Weekly inspection of cracked beam specimen was seen to quantify the self-healing of cracks with bacterial self-healing agent. Flexural strength was found in the complete healed bacterial beam specimen. Substantial increase in strength and complete healing of cracks was observed in concrete specimen casted with bacillus licheniformis bacteria. The enhancement of strength and healing of cracks can be attributed to the filling of cracks in concrete by calcite was visualized by SEM,X-RAY and EDAX analysis results.
Keywords : Bacterial Concrete, Bacillus Licheniformis, Strength, Healing of Cracks.

1.0 Introduction

1.1 Bacteria

Bacteria come in different shapes and the sizes. Bacteria are ubiquitous in every habitat on Earth, growing in soil, acidic hot springs, radioactive waste, water, and deep in the Earth's crust, as well as in organic matter and the live bodies of plants and animals[5]. There are typically 40 million bacterial cells in a gram of soil and a million bacterial cells in a milliliter of fresh water; in all, there are approximately five nonillion (5×1030) bacteria on Earth (Whitman et al. 1998, Vol.95)[7] forming much of the world's biomass.

1.2 Classification of Bacteria

1.2.1 Classification on the Basis of Shapes

Bacteria are usually classified on the basis of their shapes. Broadly, they can be divided into three types. They are,

- Rod-shaped bacteria (Bacilli),
- Sphere-shaped bacteria (Cocci) and
- Spiral-shaped bacteria (spirilla)

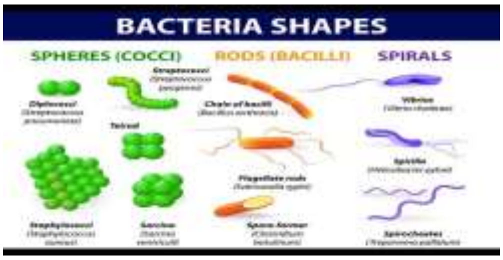

Fig. 1.1 Classification of bacteria on the Basis of Shapes.

1.2.2 Classification on the Basis of Gram Strain

This classification is based on the results of Gram Staining Method, in which an agent is used to bind to the cell wall of the bacteria. They are

- Gram-positive and
- Gram-negative.

1.2.3 Classification on the Basis of Oxygen Requirement

This classification is based on the requirement of oxygen for the survival of the bacterium. They are,

- Aerobic (Use molecular oxygen as terminal electron acceptor) and
- Anaerobic (Do not use molecular oxygen as terminal electron acceptor).

1.3 Various Bacteria used in the Concrete

The different types of bacteria used in the concrete are given as below

- Bacillus pasteurii
- Bacilluesphaericus
- Escherichia coli
- Bacillus subtilis
- Bacillus licheniformis(used in project)

Fig 1.1 Bacillus licheniformis

1.4 Bacterial Concrete:

Concrete is the most widely used construction material. Despite its versatility in construction, it is known to have several limitations. It is weak in tension, has limited ductility and little resistance to cracking[7]. Based on the continuous research carried out around the globe, various modifications have been made from time to time to overcome the deficiencies of cement concrete. Recently, it is found that microbial mineral precipitation resulting from metabolic activities of favorable microorganisms in concrete improved the overall behavior of concrete.

1.4.1 Chemical process to remediate cracks by bacteria:

If the crack occurs in the structure, water enters into the cracks and makes the structure damage. But in bacterial concrete when the water penetrates into the crack the bacteria germinates and produces the calcium carbonate precipitate which heals the cracks.

The calcium carbonate is formed by the following reaction.

$CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$.

1.5 Objectives of the Project

Objective of the project is:

1) To prepare the bacterial culture in ground water used for bacterial concrete.
2) To compare the compressive strength of bacterial concrete and conventional concrete.
3) To compare the split tensile strength of the bacterial concrete. and conventional concrete.
4) To compare the flexural strength of the bacterial concrete. and conventional concrete.
5) To asses the self healing property of bacterial concrete in beam specimen.

1.6 Advantages

- Incorporation of the agent in the concrete will be relatively cheap as well as easy when the aggregate is immobilized in porous light weight aggregate prior to addition to the concrete mixture.
- The self-healing bacterial concrete helps in reduced maintenance and repair costs of steel reinforced concrete structures.
- Oxygen is an agent that can induce corrosion, as bacteria feeds on oxygen tendency for the corrosion of reinforcement can be reduced.

1.7 Disadvantages

- If the volume of self-healing agents (bacteria and calcium lactate) mixed becomes greater than 20%, the strength of the concrete is reduced.
- Growth of bacteria is not good in any atmosphere.
- No IS-Code is available for the design of mix concrete with bacteria.

1.8 Applications

Self-healing bacterial concrete can be used for sectors such as tunnel-lining, structural basement walls, highway bridges, concrete floors and marine structures.

Fig 1.3 Marine structure **Fig 1.4Base wall**

2.0 Materials used for Concrete

OPC cement of 53 grades was used in the project work. 4.75 mm was used as fine aggregate and angular metal with nominal size of 20 mm was used as coarse aggregate .Both the fine aggregate and coarse aggregate were conforming to IS: 383-1970. Water fit for drinking with ph 7 was used for mixing and curing of specimen.

2.1 Ground Water

- Ground water in laboratory with pH value of not less than 6 and the requirement of water as per IS 456-2000 is used for preparation of bacteria culture.
- Groundwater is often cheaper, more convenient and less vulnerable to pollution than surface water. Therefore, it is used for the preparation of bacterial solution and it is mixed with the concrete

2.1.1 Properties of Ground Water

a. Taste and odour
b. Turbidity
c. Colour
d. Dissolved Oxygen
e. Hardness
f. Alkalinity

2.1.2 Use of Ground Water in Bacteria Culture

Generally,bacteria is cultured in distilled water and it is very costly in using the bacterial solution in bacterial concrete.So,in this project bacteria is cultured using ground water. Groundwater is often cheaper, more convenient and less vulnerable to pollution than surface water. Therefore, it is commonly used for public water supplies. For example, groundwater provides the largest source of usable water storage in the United States, and California annually withdraws the largest amount of groundwater of all the states

2.3 Type of Bacteria used for Investigation:

Bacillus licheniformis

- Bacillus licheniformis is a bacterium commonly found in the soil. It is found on bird feathers, especially chest and black plumage, and most often in ground –dwelling birds (like sparrows) and aquatic species (like ducks).Bacillus licheniformis is a gram positive bacterium, with rod shaped cells that form chains.
- Bacillus (genus Bacillus), any of group of rod shaped ,gram-positive, aerobic or (under some conditions) anaerobic bacteria widely found in soil and water. The term bacillus has been applied in a general sense to all cylindrical or rod likes bacteria. The largest species are about 2µm across by 7µm long and frequently occur in chains.

2.3.1 Preparation Of Bacterial Solution

- Primarily 12.5g of nutrient broth (media) is added to a 500ml conical flask containing ground water.It is then covered with a thick cotton plug and is made air tight with paper and rubber band.It is then sterilized using a cooker for about 10-20 minutes.Now the solution is free from any contaminants and the solution is clear orange in color before the addition of bacteria.Later the flasks are opened up and an exactly 1ml of the bacterium is added to the sterilized flask an 200 rpm overnight.

3.0 Test Results on Hardened Concrete

3.1Compressive Strength On Conventional And Bacterial Cube

Table-3.1 Compressive Strength results Of Cube

Sl.No	No of Days	Conventional Concrete (N/mm^2)	Compressive Strength of Bacterial Concrete by addition of bacterial solution with water (N/mm^2)				
			5%	10%	15%	20%	100%
1	7	22.56	23.01	23.62	24.6	22.2	17.1
2	14	25.12	28.82	29.17	30.8	27.6	20.02
3	28	31.42	39.61	40.6	41.82	28.2	23.56

3.2 Split Tensile Strength On Conventional And Bacterial Cylinders

Table-3.2 Split Tensile Strength test results of Cylinder

Sl.No	No of Days	Conventional Concrete (N/mm2)	Split tensile strength of Bacterial Concrete by addition of bacterial solutionwith water (N/mm^2)				
			5%	10%	15%	20%	100%
1	7	2.82	2.96	3.01	3.26	2.91	2.56
2	14	3.65	3.78	3.92	4.28	3.76	2.92
3	28	3.86	4.12	4.56	4.78	4.02	3.01

3.3. Flexural Strength On Conventional And Bacterial Cylinders

Table-3.3 Flexural Strength test results of Beam

Sl. No	No of Days	Conventional concrete (N/mm2)	Flexural Strength of Bacterial Concrete by addition of bacterial solution with water(N/mm^2)				
			5%	10%	15%	20%	100%
1	7	2.88	3.01	3.13	3.32	3.12	2.12
2	14	3.73	3.52	3.72	4.42	3.81	2.34
3	28	3.92	3.61	4.12	4.72	4.02	2.44

4.0 Self Healing of Cracks By Bacteria

4.1 Self-Healing Of Concrete

The concept of bacteria-based self-healing concrete was developed in the Netherlands, has received considerable interest from the press and is the subject of numerous UK research programmes. Cracks in concrete are a common phenomenon due to the relatively low tensile strength. Durability of concrete is impaired by these cracks since they provide an easy path for the transportation of liquids and gasses that potentially contain harmful substances. If micro-cracks grow and reach the reinforcement, not only the concrete itself may be attacked, but also the reinforcement will be corroded. Therefore, it is important to control the crack width and to heal the cracks as soon as possible.

Since the costs involved for maintenance and repair of concrete structures are usually high, this research focuses on the development of self-healing concrete. Self-healing of cracks in concrete would contribute to a longer service life of concrete structures and would make the material not only more durable but also more sustainable.

Concrete often cracks due to a variety of processes and in certain circumstances can self-heal those cracks up to a width of 0.3mm. Chemical additives (usually crystalline) can also be added to fresh concrete to improve this self-healing process.

The principle mechanism of bacterial crack healing is that the bacteria themselves act largely as a catalyst, and transform a precursor compound to a suitable filler material which effectively seals newly formed cracks. When bacteria spores are directly added to the concrete their lifetime was found to be limited.

Fig. 4.1 Self healing Mechanism

4.2 Autogenous Healing of Cracks by Bacteria

Concrete has an autogenous healing capacity as unhydrated cement is present in the matrix. When water contacts the unhydrated cement, further hydration occurs. Furthermore, dissolved CO_2 reacts with Ca^{2+} to form $CaCO_3$ crystals. These two mechanisms, however, may only healSmall cracks.

Fig. 4.2Autogenous healing

4.2.1 Different Mechanism Involved In Autogenous Healing

To enhance the healing mechanism, microfibres are added to the mixture. By mixing microfibres in the concrete, multiple cracking occurs. So, not one wide crack, but several small cracks are formed, which close more easily due to autogenous healing.

Cracks can be healed by using calcium carbonate precipitating micro-organisms. These organisms are embedded in the concrete matrix after immobilization on diatomaceous earth, and will start the precipitation of $CaCO_3$ once a crack occurs. Through this process the bacterial cell will be coated with a layer of calcium carbonate, resulting in death of the micro-organism, but in the meantime the crack faces may be bond together.

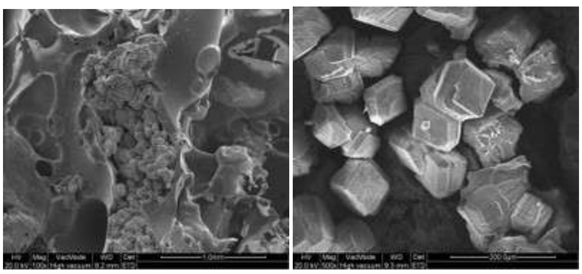

Fig. 4.3 Bacterial immobilization

4.3 Methodology Involved in Bacterial Beam Specimen for Crack Healing.

4.3.1 Preparation Of Concrete Beam Specimen

- Concrete beam specimen size of 500x100x100 mm were prepared using 53 grade ordinary Portland cement ,fine aggregate,coarse aggregate and bacterial solution.
- Control concrete beam specimen and bacterial beam specimen were casted according to the concrete mix proportions.

4.3.2 Creation Of Cracks

- Crack was created in the concrete specimen by introducing a thin copper plate of 0.3mm thickness in the fresh concrete paste upto a depth of 10mm
- The plate will be removed during demoulding after 24hrs resulting in beam with a narrow groove on the upper surface with a depth of 10mm and a width of 0.3mm

Fig 4.1 Artificial Crack Created In Conventional Concrete beam Using thin copper plate.

Fig 4.2 Artificial Crack Created In bacterial Concrete beam Using Thin Copper Plate

4.3.4Self-Healing Incubation Conditions

The two cracked concrete specimens (one control and one bacteria beam specimen) were featuring a narrow groove (crack) were immersed horizontally curing tank which has kept open to the atmosphere during the whole incubation period period to allow free diffusion of oxygen and carbon dioxide over the water air interface. Specimen were removed from water weekly for inspection and for quantification of crack-healing with time. This process is to be prepared for 90 days.

Extensive and partly crack protruding precipitates, which will be formed at crack surface of bacteria –based specimens,are to be manually removed for further analysis with the aid of pincers and a stereomicroscopes (SEM) energy dispersive X-ray (EDAX) element analyzing system , and then examined by X-ray diffraction.

5.0 Quantification of Crack Healing by Bacteria

5.1 General

The weekly inspection of crack healing in beam specimens is carried out.The result of the weekly inspection of bacterial beam is shown in figures.

Fig 5.1 to 5.7 shows the photographs of cracks healing in bacterial beam specimen after 50 days ,white precipates were observedin the cracks of bacterial concrete specimens..at the end of 90 day, complete healing of cracks was observed in bacterial beam specimen cast with bacillus licheniformi

Week 1 -NO CHANGE

Week 2 -NO CHANGE

Week 3 –NO CHANGE

Week 4 SLIGHTLY CHANGE OCCURS

Week 5 – SLIGHTLY 30% HEALED

Week 6 - SLIGHLTY 50% HEALED

Week 7 - ALMOST 70% HEALED

6.0 Conclusion

- The bacterial concrete specimen resulted in increase of compressive Strength split tensile strength,flexural strength when compared to control concrete.
- It was observed that 15% addition of bacterial solution with water in bacterial concrete has attained 33% increase in compressive strength,23.83% of split tensile strength and 20.4% of flexural strength.
- From this result bacteria cullture in ground water is proved to be economical and cost effective .
- Almost 70% healing of cracks was observed in concrete specimen casted with bacillus licheniformis bacteria and it is concluded that bacterial solution in concrete resulted in increased strength and complete healing of cracks in bacterial beam specimens.
- A lower permeability due to healing of cracks would also result in a decreased ingress rate of the aggressive chemicals
- Finally,bacterial culture prepared in ground water, which is used for bacterial concrete beam specimen is also suitable in crack healing than conventional concrete beam specimen and it can be used for building structures

7.0 References

1. Arunachalam, K. D., Sathyanarayanan, K. S., Darshan, B. S., & Raja, R. B. (2010). Studies on the characterisation of Biosealant properties of Bacillus sphaericus. International Journal of Engineering Science and Technology, 2(3), 270-277.
2. Afifudin, H., Nadzarah, W., Hamidah, M. S., & Hana, H. N. (2011). Microbial participation in the formation of calcium silicate hydrated (CSH) from Bacillus subtilis. Procedia Engineering, 20, 159-165.
3. Chahal, N., Siddique, R., &Rajor, A. (2012). Influence of bacteria on the compressive strength, water absorption and rapid chloride permeability of fly ash concrete. Construction and Building Materials, 28(1), 351-356.
4. Chahal, N., Siddique, R., &Rajor, A. (2012). Influence of bacteria on the compressive strength, water absorption and rapid chloride permeability of fly ash concrete. Construction and Building Materials, 28(1), 351-356.
5. C.S Maneesh Kumar, S.Anthoniraj & E.Karthikeyan (2015) "An Experimental study on strengthening of concrete by using Bacterial Mineral Precipitation" International Journal of Core Engineering & Management.
6. De Muynck, W., Cox, K., De Belie, N., &Verstraete, W. (2008). Bacterial carbonate precipitation as an alternative surface treatment for concrete. Construction and Building Materials, 22(5), 875-885
7. Ghosh, P., Mandal, S., Pal, S., Bandyopadhyaya, G., &Chattopadhyay, B. D. (2006). Development of bioconcrete material using an enrichment culture of novel thermophilic anaerobic bacteria

*****