International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-11, September 2019

Self Healing of Microcracks in linings of Irrigation Canal Using Coir Fibre Reinforced Bio-Concrete

S. Prabhath Ranjan Kumar, R. Vighnesh, G. Karthikeyan, S. Maiyuri

Abstract*— Development of cracks in the concrete leads to mitigation of the strength and durability of the concrete structures. This paper deals with the application of self-healing concrete for an irrigation canal in a village near Erode. The self-healing of concrete is a result of calcite precipitation by bacteria (Bacillus Megaterium MTCC 3353) mixed with natural fibres. Here, the compressed soil made irrigation canal which has been used by the farmers for agricultural purpose over a century was lined with the self-healing concrete in order to reduce the evaporation and infiltration of water into the soil thereby improving and increasing the functionality yield of the canal. A controlled crack width is assured by means of the fibres used which substantially increase the tensile capacity of the concrete. The properties of the fibre reinforced bio-concrete was evaluated by conducting flexural and compression tests along with study of amount of crack-healing in concrete with and without the use of bacteria.

***Keywords:* Bacillus Megaterium MTCC 3353, Compressive Strength, Flexural Strength, Alkaliphilic, XRD.**

I. INTRODUCTION

Concrete is an essential component of construction materials used in most of the buildings. Also Concrete is a material which possesses micro cracks within its matrix due to a variety of reasons, one being shrinkage. This creates an opportunity for the hostile materials gases to go through its pore structure and severely dent its durability. In order to reduce such an access, bio concrete may perhaps be used as one of the solution. It is a unique category of concrete in which the calcite precipitating bacteria is used along with the typical ingredients of concrete. Calcite precipitation will augment the density of concrete, thereby increasing the strength in addition to the durability of concrete. Due to microbial activities of the bacteria, microbiologically induced calcite precipitation (MICP), a highly impermeable calcite layer is formed which increases the performance of concrete structures. This microbial concrete presents a potentially enormous lengthening in service-life of infrastructure, substantially reducing the maintenance costs and also considerably increases the safety of structures. The Bacterial Concrete can be made by embedding bacteria into the concrete that are able to constantly precipitate calcite. This phenomenon is called Microbiologically Induced Calcite Precipitation (MICP). The study is conducted on investigation of the usage of two component bio chemical healing agent which involved impregnation of clay pellets with calcium lactate and microorganisms under vacuum. The oxygen measurements within the concrete showed that the bacteria remain feasible and functional for several months. The bio concrete healed a crack of 0.46 mm width in comparison to 0.18 mm autogenously healing of normal concrete. [5]. The experiments were conducted on the compression strength and water permeability of self-healing concrete (Bacillus species). The results showed an enhancement in the compression strength and reduction in water permeability of the self-healing concrete when compared to that of the typical concrete [6]. Various tests conducted on concrete mixed with different bacterial stains (4 types of bacillus species) to check its capacity to improve compression strength as well as the self-healing capacity showed that the Bacillus Megaterium bought from MTCC gave the highest strength as well as healed the crack efficiently. [8]. The examination on the ability of the bacteria to stay alive at elevated temperatures showed that the bacteria, extracted from soil sustained up to 90ºC. The maximum temperature recorded inside concrete was 70ºC. [10] This study emphasizes on the self- healing concrete which can be preferred in construction of the lining of the canal. This special concrete has the capacity of healing cracks up to width of 0.4 mm which prevents the loss of water from the canal. This healing capacity of the concrete is provided by the Bacillus Megaterium. The bacterial concrete must be cured in a separate curing medium which contain calcium chloride and urea mixed in normal water to improve the calcite precipitation of bacteria.

II. MATERIALS AND METHODOLOGY

A. Materials

1. Cement

Ordinary Pozzolano Cement (OPC) of 53 Grade conforming to IS: 12269-1987 was used throughout the project.

Manuscript published on 30 September 2019.
***Correspondence Author(s)**
S. Prabhath Ranjan Kumar, Assistant professor Department of Civil Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, Tamil Nadu, India.
(E-mail: prabathranjankumar@gmail.com)
R. Vighnesh, Assistant Professor, Department of Civil Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, Tamil Nadu,India.
(E-mail: f92vighnesh@gmail.com)
G. Karthikeyan, UG Student, Department of Civil Engineering, Amirta school of Engineering, Amirta Vishwa Vidhyapeedham, Coimbatore, Tamil Nadu, India.
(E-mail: cie13031@gmail.com)
S. Maiyuri, UG Student, Department of Civil Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, Tamil Nadu, India
(E-mail: maiyuriskannan067@gmail.com)

Cement was stored in air tight bags to prevent lumping due to the presence of moisture. The preliminary tests of cement were performed and results were obtained to design a workable concrete mix. Results are presented inTable I

Table I Properties Of Cement

Specific Gravity	3.1
Normal Consistency	33%

2. Coconut coir

Natural coir fibres are used as reinforcement in soil for the entire project work. The aspect ratio was taken as 125. Diameter of the coir fibre was found to be 0.01224cm by using screw gauge. The length of the fiber used in this study was 2.8cm.

3. Fine aggregates

Fine aggregate of Zone II grade conforming to IS: 383-1970 was used for the cement concrete. Uniformly graded sand was used to obtain minimum void ratio. The various tests done on the fine aggregate include water absorption test, specific gravity test and fineness test. The results are presented in Table II.

Table - II Properties Of Fine Aggregate

Specific Gravity	2.6
Water absorption	2%

4. Coarse aggregates

Ordinary blue granite crushed stone aggregate conforming to IS: 383- 1970 was used as a coarse aggregate in the concrete. Coarse aggregate of size 20mm was adopted throughout the project. The properties and the results of the preliminary tests are shown in Table III.

Table – III Properties Of Coarse Aggregate

Specific Gravity	2.5
Water absorption	0.85

5. Wooden mould

The mould of cross section of 30 x 30 cm of 10cm thickness was made using 12mm plywood. The Surface of the mould is cleaned, dried and it is covered with polyester sheet for easy removal of formwork.

6. Nutrients

Calcium chloride ($CaCl_2$) and Urea were added as nutrients in water. Since Calcium chloride ($CaCl_2$) has the ability to accelerate cement hydration. Research has shown that there is increase in strength for every addition of Calcium chloride ($CaCl_2$) in water this is because of Calcium chloride ($CaCl_2$) which has equivalent cure strength at 50°F as plain concrete at 70°F. The quantity of nutrients taken were Tabulated in IV.

Table – IV Quantity Of Nutrient

Calcium chloride ($CaCl_2$)	50 g/L
Urea	20 g/L

B. Methodology

1. Material Preparations

Batching of the materials was performed in room temperature. The cement samples were dry mixed either by hand or in a mixer to ensure proper blending and uniformity in the material. A surface dry aggregate of desirable grade was used for making the concrete. The aggregates were separated into fine and coarse fractions and recombined for each concrete batch to produce desired grading and IS sieve of size 4.8mm was used for separating the fine and coarse fractions.

2. Batching and mixing

The required weight of cement, fine aggregate, coarse aggregate and water for each batch was determined to an accuracy of 0.1 percent of the total weight of the batch mixing concrete. The concrete was mixed in a laboratory batch mixer, in such a manner that the loss of water and other materials were minimal. The materials were batched 10 percent in excess to that of the required weight of materials to compensate the loss during the process of mixing.

3. Curing of Concrete

The test specimens were stored in a place, at a temperature of 27°C ± 2°C. Normal concrete specimen were cured in normal water and Bacterial concrete specimen, Fibre concrete specimen and Bacteria cum fibre concrete specimen were cured in a separate deposition media containing Calcium chloride ($CaCl_2$) + Urea.

C. Tests on Specimen

1. Compressive Test

A suitable mix proportions concrete for a desired strength of concrete was obtained and test was conducted on specimens at 7,14 and 28 days. The test procedure was conformed to IS 516 (1959): Method of test for strength of concrete.

2. Flexural Strength

The flexural strength of concrete was determined as per the procedure conforming to IS 516(1959): Method of test for strength of concrete.

3. Rapid Chloride Penetration test

According to ASTM C1202 Rapid Chloride Penetration Test was conducted with 50mm thick, 100mm diameter concrete specimen was subjected to 60V of applied DC Voltage for 6 hours. The permeability cell, which was made of glass and consists of two parts each with a reservoir being capable of holding 250ml of chemical solution and copper mesh of 100mm diameter to act as an electrode The upstream reservoir contains 3.0% of NaCl solution of 24N while 0.3M NaOH is present in the other reservoir. These concentrations give the equal electrical conductivity of both the solutions. An external voltage cell is used to apply a voltage difference of 60V between the electrodes. This results in the migration of chloride ions from sodium chloride solution to sodium hydroxide solution through the pores in the concrete specimen.

Ratings for RCPT are presented in Table V.

Table – V Ratings For Rcpt

Charge Passing (Coulombs)	Chloride Ion Permeability
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very Low

3. Water absorption test

The water absorption checks the durability of the concrete specimens with and without bacteria. Bacterial concrete with and without fibers was also used in the same concentrations. Cubes of dimensions 100*100*100 mm were casted and cured for 28

% water absorption = $[(W_2 - W_1) / W_1] \times 100$

Where,

W_1 = Oven dry weight of cube, grams

W_2 = weight after 24 hours of soaking in water, grams

III. RESULTS AND DISCUSSION

A. Compressive strength

Compressive strength tests were carried out for all the four cases. The results are compared and presented.

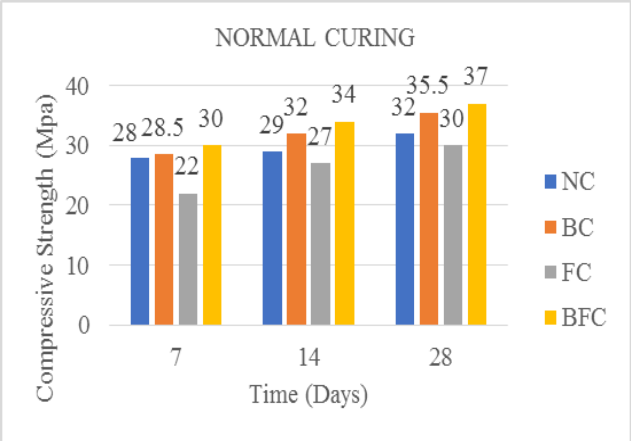

Fig. 1 Compressive strength of normal curing specimen

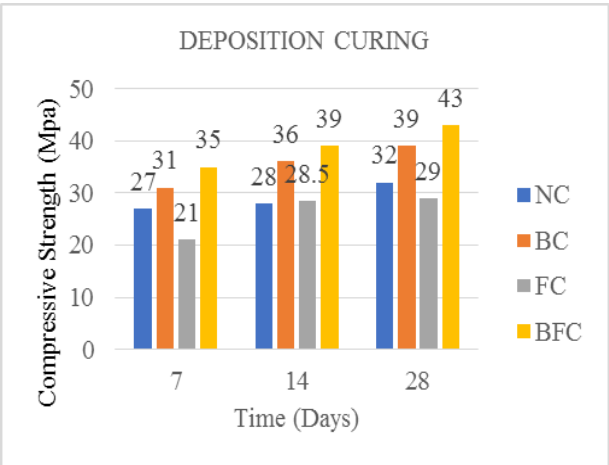

Fig. 2 Compressive strength of specimen cured in deposition medium

Compressive Strength achieved from a period of 7, 14 and 28 days are presented Fig. 1 shows there is a rise in compression strength with 0.5% of fibres. Bacterial specimens with 0.5% of coir fibres offered an improved strength of 38 % (47 MPa) at 28 days, 32% (45MPa) at 14 days & 21% (41MPa) at 7 days respectively when compared with the ordinary concrete (34 MPa) at 28days.

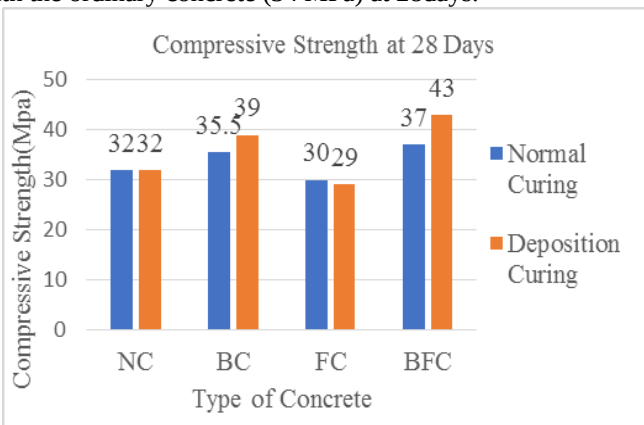

Fig. 3 Compressive Strength at 28 day

Increase in strength is due to biological calcite precipitation process within the cement matrix. Thus, the bacteria fibre concrete showed better results than that of normal concrete. Specimens cured in a medium containing 50 g/l of $CaCl_2$ + 20 g/l of urea. BC (Bacterial concrete specimens) and BFC (Bacterial Fibre concrete specimens) cured in deposition medium had higher strength than that of the normal concrete cured in the same medium. It was observed that the increase in the strength was due to the Ureolytic reaction of bacteria in the presence of urea and calcium chloride. This reaction produced limestone as the end product which was the responsible for increase in strength.

B. Flexural Strength

Flexural strength of the different cases were compared:

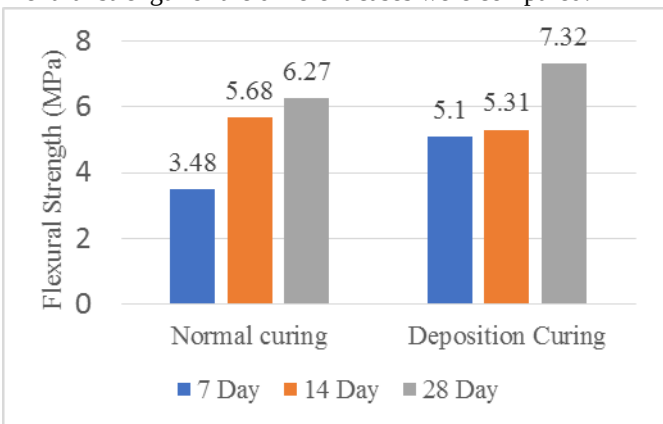

Fig. 4 Flexural Strength of Normal concrete

Flexural Strength achieved from a period of 7, 14 and 28 days is presented in the fig.5 it was clear that nutrients added specimens shows an increase in the strength of 19% (7.48MPa) rise in strength at 28 days. The specimens cured

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

in a medium containing $CaCl_2$ + urea shows 16.7% (7.32MPa) rise in strength respectively at 28 days when compared to normal concrete cured in normal water (6.27MPa).

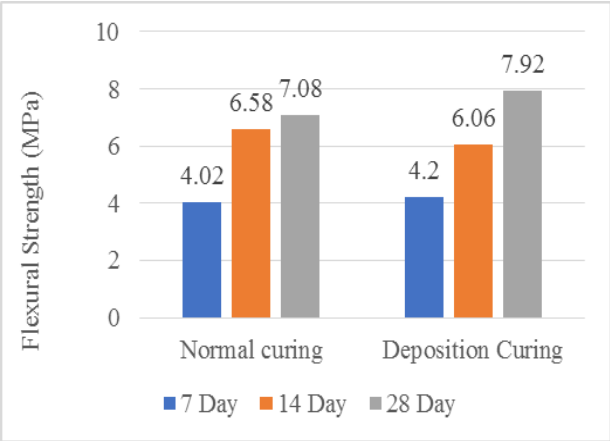

Fig. 5 Flexural Strength of Bacterial concrete

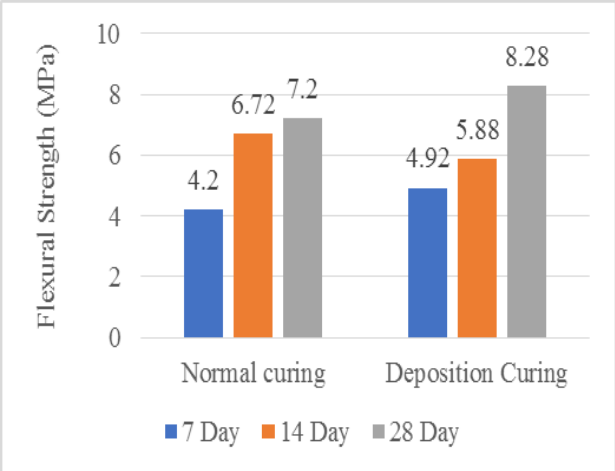

Fig. 6 Flexural Strength of Fibre concrete

Flexural Strength achieved from a period of 7, 14 and 28 days are presented in the fig 6 the nutrients added specimen shows an increase in strength of 34% (8.41MPa) rise strength at 28 days. The specimens cured in a medium containing $CaCl_2$ + urea shows32% (8.28 MPa) increase in strength respectively at 28 days when compared to normal concrete cured in normal water(6.27MPa).

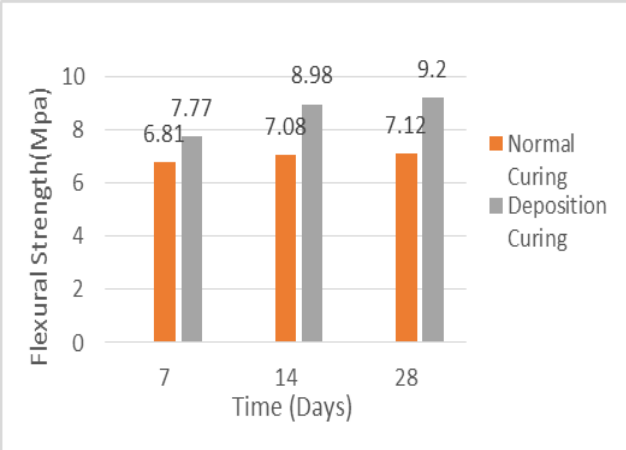

Fig. 7 Flexural Strength of Bacteria with Fibre concrete

Flexural Strength achieved from a period of 7, 14 and 28 days are presented in the Fig. 8 the nutrients added specimen's shows an increase in the strength of 48% (9.2MPa) rise in strength at 28 days. The specimens cured in a medium containing $CaCl_2$ + urea shows 45% (9.12MPa) increase in strength respectively at 28 days when compared to concrete cured in normal water (6.27MPa).

C. Rapid Chloride Penetration test

The capability of a concrete to allow chloride to pass by diffusion through its matrix depends on the internal strucure of the concrete. Generally Bacterial concrete specimens will have closely compacted microstructure by calcite precipitation in the pores of the concrete. From the Fig 8 it was clear that the penetration of chloride ions in bacterial concrete decreases with increase in compressive strength when compared to normal concrete. With introduction of bacteria and 0.5% of coir fibre into concrete the chloride migrated through the concrete surface further decreases.

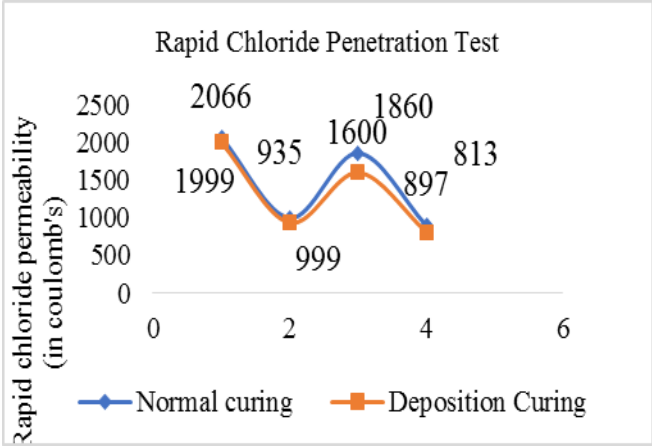

Fig. 8 Rapid Chloride Penetration Tests for different medium

D. Water absorption Test

Water absorption in the concrete depends upon the micro void formation in the concrete matrix. It was clear from the results that the fibre reinforced concrete absorbs more water when compared to other concrete specimens in normal curing conditions as well as medium curing containing $CaCl_2$ + Urea. This was due to the fibres which are hydrophilic in nature, when exposed to moisture the fibres swells thereby causing swelling stresses. These swelling stresses lead to cause damages to the structures which results in the formation of cracks. Due to these cracks the matrix becomes accessible to the surrounding environment which results in de-bonding the fibres and becomes major cause for deterioration in fibre reinforced buildings and structures. But from Fig 9 it is clear that there was a reduction in water absorption when the Bacteria with fibres (BFC) specimens were cured in deposition medium ($CaCl_2$ + Urea).

Retrieval Number: K25340981119/19©BEIESP
DOI: 10.35940/ijitee.K2534.0981119
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

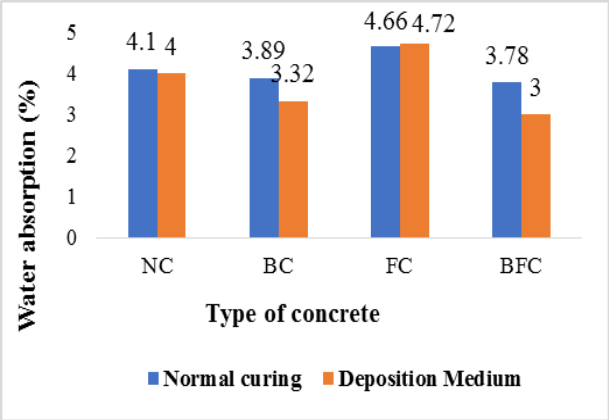

Fig. 9 Water absorption in Different medium of curing

E. X-Ray Diffraction

The calcium precipitation by bacteria was confirmed by getting the chemical composition of the sample from the XRD. This test was done on samples prepared as crystalline powder which was kept inside the sample holder and placed at an angle of 45 degrees.

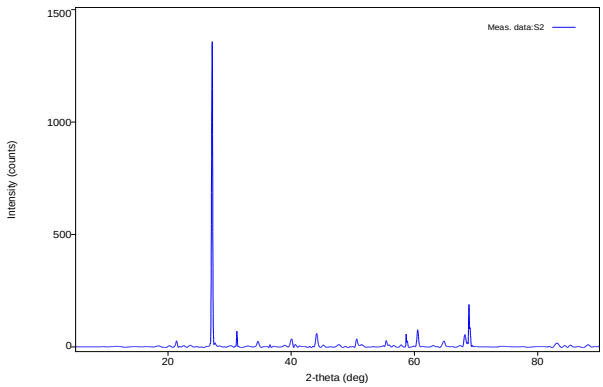

Fig. 10 XRD for Normal concrete at 28 Days

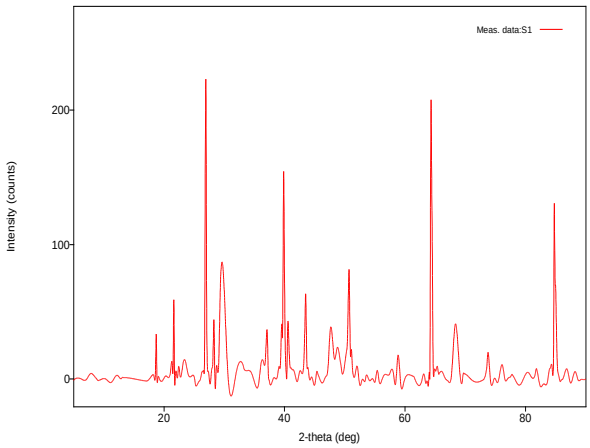

Fig. 11 XRD for Bacterial concrete at 28 Days

The XRD results for Control and Bacterial concrete specimen were presented in Fig. 10 and Fig 11., The peaks in the graph for bacterial specimen shows higher peaks that represents presence of calcium carbonate in the bacterial concrete sample is more than that of normal concrete. This shows that bacterial based concrete are producing the expected calcium carbonate thus bacterial reactions takes place inside the concrete are verified.

F. Field Application

The local economy in the Bhavani region, India is mainly depends on agriculture and local consumption. There is a need of continuous supply of water for the crops. To supply water from well to agricultural land a irrigation canal was built before hundred years. Due to permeability of soil and evaoperation loss from decades the water carrying capacity of canal decreased up to 30%. To increase the capacity, we casted concrete linings in the canal made trenches with fibre as a steel reinforcement. By construction of fibre reinforced bio concrete the performance of this irrigation system improved significantly.

During concreting the water flow in the canals deviated for site clearance work. After site clearance the section of canal that was chosen for casting, the wood formwork was placed. The cross section of canal was 30 x 30 cm and thickness of bottom surface is 10 cm. Three linear meters of concrete linings with bacteria were casted. The ingredients for concrete were measured per one meter cube volume. Prior to mixing and casting, the solution of bacteria and the food source were kept prepared and mixed. The coir fibres were cut to a length of 2cm.

Fig. 12 1.5 mm manually created cracks

Fig. 13 Cracks observed after 3 weeks of 28 days hardening

IV. CONCLUSION

The mechanical properties and the durability properties of Bacterial concrete with various curing condition were experimentally investigated and the following conclusions were made:

1. A significant increase in compressive strength and flexural strength was achieved by using Bacillus Megaterium, MTCC 3353 in concrete of grade M25 compared to normal concrete. Strength tests show that there

was a improvement in strength in both compression as well as flexure. All the bacterial specimens were found to be stronger than the specimens with and without fibres.

2. The water absorption capacity on Bacterial Fibre Concrete was considerably less compared to normal concrete. There was a reduction in water absorption when the Bacteria with fibres (BFC) specimens were supplemented with nutrients ($CaCl_2$ + Urea) during the time of mixing the concrete. Results shows that the Bacteria with Fibre Concrete (BFC) supplemented with nutrients yielded 71% reduction in water absorption when compared to normal concrete.

3. While curing the Normal concrete, Fibre concrete in deposition medium containing 50 g/l of $CaCl_2$ + 20 g/l of urea there was increase in strength since the Ureolytic reaction does not takes place to produce calcium carbonate. When curing the bacterial concrete in a medium containing 50 g/l of $CaCl_2$ + 20 g/l of urea the ureolytic reactions takes place to produce calcium carbonate. Consequently the strength increases as density increases. Use of coir fibers at 0.5% (weight of the cement) shows decrease in compressive strength when compared to normal concrete. The strength increases when the bacterial concrete are reinforced with 0.5% of coir fibres.

4. Fibre reinforced concrete shows less penetration of chlorides into the concrete when compared to normal concrete.The use of bacteria with coir fibres in concrete reduces the cracks which minimize the voids to a maximum extent thus results in decrease in chloride permeability of concrete.

5. By comparing the XRD results, the calcite precipitation was confirmed by verifying the chemical composition.

REFERENCES

1. M.V. Seshagiri Rao, V. Srinivasa Reddy, M. Hafsa, P. Veena and P. Anusha , "Bioengineered Concrete - A Sustainable Self-Healing Construction Material", *Research Journal of Engineering Sciences*, ISSN 2278 – 9472 Vol. 2(6), pp.45-51, June (2013).
2. VarenyamAchal, Xiangliang Pan, NilüferÖzyurt "Improved strength and durability of fly ash-amended concrete by microbial calcite precipitation", *Ecological Engineering* 37 (2011) pp. 554–559.
3. M.G. Sierra Beltrán, H.M. Jonkers, W. Mera Ortiz, "Concrete with Abaca fibres and bacteria to improve sustainability and performance of irrigation Canals in Ecuador", in *Proc. First International Conference on natural fibres, Guimaraes*, 2013.
4. Mahendra Kumar Trivedi, Rama Mohan Tallapragada, Alice Branton, Dahryn Trivedi, Gopal Nayak, Omprakash Latiyal, Rakesh Kumar Mishra, Snehasis Jana. "Physicochemical Characterization of Biofield Energy Treated Calcium Carbonate Powder". *American Journal of Health Research*. Volume 3, No. 6, 2015, pp. 368-375.
5. VirginieWiktor, Henk M. Jonkers "Quantification of crack-healing in novel bacteria-based self-healing concrete", *Cement & Concrete Composites* 33 (2011), pp. 763–770.
6. Syed Intikhab Zia, "Use of coconut fiber concrete" *International Research Journal of Engineering and Technology (IRJET)* Vol. 02 Issue: 06 (2015).
7. RajanShikha, Saxena A.K., Jha A.K." Evaluation of Compressive Strength of Concrete Using Coconut Coir Fibre" *International Journal for Research in Applied Science & Engineering Technology*, Vol. 3 Issue IX (2015).
8. S. Krishnapriya, D.L.VenkateshBabu, Prince Arul raj G, "Isolation and identification of bacteria to improve the strength of Concrete", *Microbiological Research*, 174 (2015), pp. 48–55.
9. Kim Van Tittelboom , "Use of bacteria to repair cracks in concrete" *Cement and Concrete Research*, 40 (2010), pp. 157–166.
10. A. T. Manikandan, A.Padmavathi "An Experimental Investigation on Improvement of Concrete Serviceability by using Bacterial Mineral Precipitation", *IJRSI*, Vol. II, Issue III, March 2015.
11. Mahendra Kumar Trivedi, Rama Mohan Tallapragada, Alice Branton, Dahryn Trivedi, Gopal Nayak, Omprakash Latiyal, Rakesh Kumar Mishra, Snehasis Jana. "Physicochemical Characterization of Biofield Energy Treated Calcium Carbonate Powder". *American Journal of Health Research*. Volume 3, No. 6, 2015, pp. 368-375.
12. Jagadeesha kumar b g. "Bio mineralization of calcium carbonate by different bacterial strains and their application in concrete crack remediation" *International Journal of Advances in Engineering & Technology*, Mar. 2013, ISSN: 2231-1963.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)