International Journal of Engineering & Technology, 7 (2.1) (2018) 11-14

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research Paper

Study on strength and durability properties of bio-concrete

B Ashok Varma [1] *, G Chandra Sekhar [1]

[1] *Assistant Professor QIS College of Engineering and Technology Ongole, Andhrapradhesh, India*
**Corresponding author E-mail: ashokvarma53@gmail.com*

Abstract

Concrete is very vulnerable to cracking which allows chemicals, salts and water which initiates the corrosion and reduces the life of concrete structures. So it is better to adopt a self-repairing technique which can reduce the fissures and cracks. Bio-concrete is one of the remedial techniques. In this project Bio-concrete is prepared under the grade of concrete M20 by using various amounts of bacteria (Bacillus subtilis) to enhance the strength and durability properties of concrete. The compressive strength and tensile strength of concrete were found .The durability studies are also carried out by using concentered H_2SO_4 for both conventional and bio-concrete specimens exposure to 28 days and it showed that bio-concrete gave better Improvement comparatively.

Keywords: *Bio-Concrete; Beef Extract; Tensile Strength; Durability and Conc H_2SO.*

1. Introduction

Cement mortar and concrete are the major construction material in various types of industries due to the easy availability of cementing materials. It is one of the materials where strength, durability and Impermeability are required. Cement concrete is one of the seemingly simple but actually complex materials. The behavior of concrete with respect to long-term drying shrinkage, creep, fatigue, cracks and fissures. Here the bio-concrete is the technique which heals the cracks and enhances the strengthening properties. It was a novel based technique which was given Ramakrishnan etc al many of concrete structures face immature degradation problems like carbonation, chloride attack problems and leads to repair or retrofitting of the structures. The usage of these cementitious materials in or combinations of the above is being researched for its variable characteristics are studied. Bacillus subtilis, which is rich in soil, has been used to generate CaCO3 precipitation. The "Bio-Concrete" is a concrete in which cultured bacteria is mixed to concrete. Impeachment of calcium carbonate in concrete enhances properties of concrete. [1] The bacterial concrete can be made by embedding bacteria in the concrete that are able to constantly precipitate calcite. This called microbiologically induced calcite precipitation (MICP).Bacillus subtilis, which can successfully remediate cracks in concrete. Bacteria are the most abundant and metabolically diverse forms of life on earth. Bio-concrete are also called as bacterial concrete. Various researches were conducted in the past on bacterial concrete. Microscopic techniques in combination with permeability tests revealed that complete healing of cracks occurred in bacterial concrete and only partly in control concrete (Jonkers H.M,2011).Microbial 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 (MayurShantilal and Jayeshkumar,2013). Water be the finest way for bio self-healing concrete (MianLuo et al, 2015).

2. Scope of study

The main Scope of the project is to

i) Governing and comparing the mechanical behavior of conventional concrete with Bio-concrete.
ii) Study the bio-concrete performance by using acid tests under $H_2SO_4$and comparing it with conventional concrete.
iii) To find the optimum content of bacteria based on the durability and strength properties obtained

3. Classification of bacteria

3.1. Various types of bacteria used in concrete

Bacterial concrete or self- healing concrete seals the cracks developed in structures by the help of bacterial reaction in the concrete after hardening. [2] Types of bacteria, its mechanism and preparation of bacterial concrete is

Various types of bacteria used in construction area are as follows.

1) Bacillus pasteurii.
2) Bacillnesphaericus.
3) Escherichia Colli.
4) Bacillus Sabtilis.
5) B. Cohnii.
6) B. Pseodofirrius.

4. Chemical process of self-healing or bacterial concrete

When the water reacts with the unhydrated calcium in the concrete, calcium hydroxide is produced by the help of bacteria which act as catalyst. This calcium hydroxide reacts with atmospheric carbon dioxide and forms limestone and water. This extra water molecule keeps the reaction going [11].

$Cao+H_2O$---→ Ca (oH) $_2$

Ca (oH) $_2$---→ $CaCo_3+H_2O$

5. Preparation of bacteria

Bacteria are relatively simple, single celled organisms. The bacteria used were Bacillus subtilis. It is a bacterium with the ability to precipitate calcium carbonate in the presence of any carbonate source. The microbes are a bacillus species and are completely not harmful to human beings. They precipitate inorganic crystals hence the healing of the cracks takes place in the concrete and it can withstand any temperature conditions. The peptone, beef extract are the ingredients for the growth of Bacteria bacillus subtilis. The procedure for bacterial concrete is used for evaluating the concentration of bacteria cells present in the culture.
The sub culture is maintained constantly on nutrient agar slants. It forms irregular dry white colonies on nutrient agar. Whenever required a single colony of the culture is inoculated into nutrient both of 200ml in 500ml conical flask and the growth conditions are maintained at 37 degree temperature and placed in 125rpm orbital shaker. The medium composition required for growth of cultures Peptone, NaCl, beef extract. Primarily 12.5g of Nutrient broth (media) is added to a 1000ml conical flask containing distilled water. [3], [5] 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 colour before the addition of the bacteria Later the flasks are opened up and an exactly 1ml of the bacterium is added to the sterilized flask and is kept in a shaker at a speed of 150-200 rpm overnight. After 24 hours the bacterial solution was found to be whitish yellow turbid solution. After the completion of presence of bacillus subtilis the prepared liquid media shown in Fig.1 should be mixed into the concrete.

Fig. 1: Cultured Bacteria (Bacillus Subtilis).

6. Test data for materials of concrete

The various ingredients of the concrete such as cement, Fine aggregate, coarse aggregate were tested for their properties and compared with Indian standards before mixing of concrete.

6.1. Cement

Ordinary Portland cement of 53 grade of ACC brand used for experimental purpose. Physical properties of cement were determined as per IS 12269 (1987) and tabulated in

Table 1: Properties of Cement

Property	Experimental Result	IS Code requirement
Specific gravity	3.12	3.10-3.15
Initial Setting Time	60 min	>30 min
Final Setting Time	350min	<600 min
Fineness (%)	1.70%	<10%

6.2. Fine aggregate

The various types of aggregate tests were conducted to determine the physical properties of aggregate. It was found that all the properties shown in Table.2 are within the limits and useful in preparation of concrete.

Table 2: Properties of Fine Aggregate

S. No.	Property	Value Obtained
1.	Specific gravity	2.61
2.	Fineness modulus	2.51
3.	Water absorption	0.50%
4.	Grading Zone	Zone II

The fineness modulus of the aggregate is found to be 2.51 and based on IS383:1970 it was found that the fine aggregate belongs to zone II shown in Table.3. Based on this the proportion of fine and coarse aggregate were decided in mix design.

Table 3: Fineness Modulus of Fine Aggregate

S. No	Sieve size (mm)	Mass retained on sieve (g)	% mass retained	Cumulative percentage mass retained (%)	Cumulative fine (%)
1.	4.75	3.9	0.39	0.39	99.61
2.	2.36	8.1	0.81	1.20	98.80
3.	1.18	86.5	8.65	9.85	90.15
4.	0.6	493.3	49.33	59.18	40.82
5.	300 µ	274.0	27.40	86.58	13.42
6.	150 µ	79.0	7.90	94.48	5.52
Fine aggregate belongs to Zone II (IS383:1970)					

6.3. Coarse aggregate

Coarse aggregate is crushed type and tested for its specific gravity, fineness modulus and water absorption. It was found that all the properties shown in Table.4 are within the limits and useful in preparation of concrete.

Table.4: Properties of Coarse Aggregate

S. No.	Property	Result
1.	Type	Crushed
2.	Specific gravity	2.76
3.	Fineness modulus	7.56
4.	Water absorption	0.5%

The max size of aggregate used is 20mm retained shown in Table.5 and for manufacturing of concrete aggregate 20mm retained and 10mm retained are used in 60% and 40% respectively.

Fig. 2: Compressive Strength of Concrete.

Table 5: Sieve Analysis of Coarse Aggregate\

S. No	Sieve size (mm)	Mass retained on sieve(g)	% mass retained	Cumulative percentage mass retained (%)	Cumulative fine (%)
1	80	0.00	0.00	0.0	100.00
2	40	0.00	0.00	0.0	100.00
3	20	8.52	56.82	56.82	43.18
4	10	6.42	42.84	99.66	0.34
5	4.75	0.05	0.34	100.00	0.00
6	2.36	0.00	0.00	100.00	0.00
7	1.18	0.00	0.00	100.00	0.00
8	0.6	0.00	0.00	100.00	0.00
9	0.3	0.00	0.00	100.00	0.00
10	0.15	0.00	0.00	100.0	0.00

7. Mixing of concrete and specimen preparation

For the concrete mix, OPC of 53 grade is used.The fine aggregate used is confined to Zone-II and maximum size of coarse aggregate is 20mm. [8] The workability tests are carried out immediately after mixing of concrete using the compaction factor testing apparatus in accordance with IS: 10510-1983. 5ml, 10ml, 15ml and 20ml reference of bacteria (Bacillus subtilis) was added to every 500 ml of water while mixing concrete, so the total amount of bacteria was added to required liters of water used for mixing cement in concrete. The mixing process is carried out in electrically operated mixer. The materials are laid in Uniform layers, one on the other in the order coarse aggregate, fine aggregate and cement. Dry mixing is done to obtain a uniform colour.
Mix design has been done based on IS10262:2009 is followed and the water cement ratio considered as 0.50. [9] The water content is taken as 186liters. Based on this the mix proportion obtained is as shown in Table.6.

Table 6: Mix Proportion

S. No	Material	Weight of material (Kg/m^3)	Mix ratio with respect to cement
1	Cement	372.00	1
2	Fine Aggregate	706.1	1.89
3	Coarse Aggregate	1238.4	3.32
4	Water	186.0	0.50

The below table represents various mix trials casted during this research and throughout the process the same convention used to represent the mix. Concrete specimens were prepared to test the mechanical properties.

Table 7: Mix Designation

Mix Designation	Amount of Bacteria added for every 500 ml water
M1	--
M2	5ml
M3	10ml
M4	15ml
M5	20ml

8. Results and analysis

Bio-concrete Concrete has been tested for fresh properties like workability and strength properties like Compressive strength, split tensile strength and flexural strength.The durability has been tested.

8.1. Workability

Workability of concrete is tested for each mix when it was casted as per IS1199-1959.[8]For mix design the slump value of 25mm to 50mm is adopted and all the mixes gave the slump Values in the given range. In all the mixes, the type of slump was true. The slump values are as shown in Table.8.

Table.8: Slump values

Mix designation	Slump value (mm)	Type of slump
M1	36	True
M2	38	True
M3	41	True
M4	40	True
M5	39	True

8.2. Compressive strength

Compression test has been carried out on concrete cubes with standards confirming to size of 150mm cube IS516-1999.All the samples were tested in a 2000KN capacity Compression testing machine. After 4 weeks of curing, the cubes were permitted to turn in to dry condition before testing. Plane surfaces of the specimen were between platens of compression testing machine and subjective to loading. The compressive strength of the concrete cubes is given in Fig.2. The greatest improvement in compressive strength occurs at Culture of 10ml at 28 days. [12] This improvement in compressive strength is due to deposition on the microorganism cell surfaces and within the pores of cement sand matrix, which plug the pores within the mortar. The extra cellular growth produced by the microorganism is expected to contribute more to the strength of cement mortar with a longer incubation period and thus the strength improvement is found to be more at 28 days.

Table 9: Percentage Increase with Mix1for 7-Days

Cell concentration/ ml of mixing bacteria	% increase Compressive strength comparing with Mix1 for 7 days
M1	--
M2	25.61
M3	30.55
M4	15.53
M5	11.03

Table 10: Percentage Increase with Mix1for 28-Days

Cell Concentration/ml of mixing bacteria	Increase comparing with 28 Days Mix1%
M1	-
M2	12.25
M3	17.26
M4	10.39
M5	5.41

8.3. Flexural strength

Flexural strength test has been conducted on beam of size 500x100x100 mm specimen with three point loading test. For all the specimens the crack has occurred very closer to mid span.

Fig. 3: Showing Prism Testing.

Table 11: Percentage Increase with Mix1for 28-Days Flexural Strength

Cell Concentration/ml of mixing bacteria	% increase comparing with 28 Days Mix1
M1	---
M2	6.61
M3	19.81
M4	15.8
M5	8.82

8.4. Split tensile strength

Split tensile strength test has been conducted on cylinder of 150mm diameter and 300mm height as shown in the fig.4 the results are mentioned in table12.

Fig. 4: Showing Cylinder Testing.

Table 12: Percentage Increase with Mix1for 28-Days Split Tensile Strength

Cell concentration/ ml of mixing bacteria	%increase comparing with Mix1
M1	--
M2	9.50
M3	16.11
M4	12.39
M5	5.76

References

[1] Bachmeier KL, Williams AE, Warmington JR, Bang SS., "Urease activity in microbiologically-induced calcite precipitation." Journal of Biotechnology 93, 2002, pp. 171- 181. https://doi.org/10.1016/S0168-1656(01)00393-5.

[2] Bang, S.S., Galinat, J.K., and Ramakrishnan, "Cal- cite Precipitation Induced by Polyurethane

[3] De Muynck W., Cox K., De Belie N. and Verstraete W"Bacterial carbonate precipitation as an alternative surface treatment for concrete", Constr Build Mater, 22, 875-885 (2008). https://doi.org/10.1016/j.conbuildmat.2006.12.011.

[4] F. Hammes, N. Boon, J. De Villiers, W. Verstraete, S. D. Siciliano, and J. De Villiers, "Strain-Specific Ureolytic Microbial Calcium Carbonate Precipitation," Applied And Environmental Microbiology, vol.69, no.8, 2003, pp. 4901– 4909. https://doi.org/10.1128/AEM.69.8.4901-4909.2003.

[5] Ghosh P, Mandal S, Chattopadhyay BD, Pal S., "Use of microorganism to improve the strength of cement mortar." Cement and Concrete Research 35, 2005, pp.1980-1983. https://doi.org/10.1016/j.cemconres.2005.03.005.

[6] Jonkers H.M, and Schlangen E, "A two component bacteria-based self-healing concrete," Concrete Repair, Rehabilitation and Retrofitting II, 2009, pp. 215–220.

[7] Immobilized Bacillus) Pasteurii," Enzyme and Microbial Technology, vol.28, 2001, pp. 404–409.

[8] IS 10262, Recommended Guideline ForConcrete Mix Design".

[9] IS 456:2000, Plain and Reinforced Concrete-Code of Practice".

[10] IS 12269-1987 Specification for 53 grade Portland cement' Bureau of Indian Standards, New Delhi, India.

[11] MayurShantilal V, and Jayeshkumar P., "Bacterial Concrete: New Era For Construction Industry", International Journal of Engineering Trends and Technology (IJETT) – Volume 4 Issue

[1] Ramachandran, S.K., Ramakrishnan, V., and Bang, S.S. "Remediation of concrete using micro-organisms". ACI Materials Journal, 2009 98(1):3-9.