An Experimental Study on Strength And Durability Properties of Bacterial Concrete

K.H.N.S.D.Ragini[1],A.Naga sai[2], A S Kumar[3]
[1] Dept of Civil Engineering
[2, 3]Asst. Professor, Dept of Civil Engineering
[1, 2, 3] Aditya Engineering College, Surampalem.

Abstract- *Concrete is the worldwide accepted construction material for its adverse strength and durability properties. It has very high compressive strength and very weak in tension, because of which reinforcement is used in concrete to take the tension. As the concrete is brittle, it always results in the formation of cracks in the tension zones upon loading and leads to the durability issues by decreasing the life time of the structures. To counter such durability problems conventional repair methods like crack filling with epoxy injections and use of additional reinforcement for decreasing the crack width were in practice which involves a lot of economy. This lead to the development of self-healing concrete concept using some bacteria mixing in the concrete and the crack developed will be self-healed by bacteria as a result of reproduction of the bacteria. In the present work, it was investigated to identify the strength and durability properties of the M30 grade concrete by mixing bacteria named Bacillus Subtilis as at varying percentages like 5ml, 10ml, 15ml and 20ml for 500ml of water to be mixed in concrete. It was found that at 10ml of bacteria for 500ml of water yields enhanced strength properties when compared with the conventional concrete. As part of durability studies, when the cubes are immersed in 5% H2SO4, at 10ml of bacteria it showing the better performance than the conventional concrete.*

Keywords- Concrete, Bacteria, Cracks, Self-healing, Durability.

I. INTRODUCTION

Bacteria concrete is said to be the new formulation of the concrete with bacteria. In the biosphere, bacteria can function as geo-chemical agents promoting the dispersion, fractionation and concentration of materials. Microbial mineral precipitation is resulted from metabolic activities of microorganisms. Based on this, bio-mineralogy concept, an attempt has been made to develop bacteria concrete material incorporating of an enrichment culture of thermophilic and alkaliphilic bacteria within cement sand mortar/concrete. The results showed a significant increase in compressive strength. The astonishing advantage of this bacteria concrete is its self-healing capacity. Self healing concrete is a product that will biologically produce

limestone to heal itself the cracks that appear on the surface of concrete structures. However it is as durable and strong as conventional concrete and can be used as a better replacement for the normal concrete. So it is more beneficial if we used the bacteria concrete in such cases where the repair is tedious such as large dams. Bacteria concrete works better with its autonomous self-healing capacity. Bio mineralization is a biologically induced process which some bacteria, has been investigated due to its wide range of scientific and technological implications. Bacteria spores can with stand extreme mechanical and chemical stresses are remain dormant for years but viable bacteria spores immobilized in the concrete matrix will become metabolically active when they get contact with water entering freshly into the concrete. So by the metabolic action of the bacteria spores these cracks will subsequently sealed by a mechanism known as calcium carbonate precipitation. The alkaline environment of concrete with pH around 12 is the major hindering factor for the growth of bacteria, so that more research has been focused on alkaliphic microorganisms.

II. OBJECTIVES OF THE STUDY

In the present work, it was investigated to identify the mechanical properties of the M30 grade concrete by mixing bacteria named Bacillus Subtilis as at varying percentages like 5ml, 10ml, 15ml and 20ml for 500ml of water to be mixed in concrete to study the durability of self healing concrete at 5% H2SO4 dilution.

III. MATERIALS USED

- Ordinary Portland cement 53 grade (KCP cement) with specific gravity of 3.15
- Locally available river sand with bulk density of 1712 kg/m^3 and specific gravity of 2.613 and confirming to zone-2 of IS:383
- Coarse aggregate with bulk density of 1682 kg/m^3 and specific gravity of 2.822
- Baccillus subtilis Bacteria

IV. METHODOLOGY

The Compressive strength, split tensile strength and flexural strength are the main properties for determining the concrete strength. In this, the strength properties are calculated by 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 and compared to conventional concrete.

For this the following number of cubes, beams and cylinders were casted and tested for the same.

Cubes – 9 (for each trail), tested for **7, 28 & 90** days.
Cylinders – 3 (for each trail), tested for **28** days.
Beams – 3 (for each trail), tested for **28** days.

Then, they are tested for durability but curing them in 5% H2SO4 solution and the percentage weight loss and strength loss are calculated for 14 and 28 days. The acid durability factor is also found out.

V. EXPERIMENTAL INVESTIGATION

The experimental investigation consists of casting of 9 cubes, 3 cylinders and 3 beams for each trail to determine compressive, tensile and flexural strengths respectively by taking different amount of bacteria for every 500ml of water. Cube specimen dimension is of 15 cm x 15 cm x 15 cm, cylinder specimen dimension is 15 cm x 30 cm and beam specimen is 50 cm x 10 cm x 10 cm.

The moulds are applied with a lubricant before placing the concrete. After a day of casting, the moulds are removed. The cubes, cylinders and beams are removed to the curing tank carefully.

Mix Designation	Amount of Bacteria added for every 500 ml water
M0	0 ml
M1	5ml
M2	10ml
M3	15ml
M4	20ml

VI. MECHANICAL PROPERTIES

Mechanical properties of concrete are mainly related to the calculation of its strength. The calculation of mechanical properties includes the testing of concrete and its performance in Compressive strength, Split tensile strength and modulus of rupture. The procedures and calculations of these three tests are confirmed by the standard specification IS 516 –1959.

CompressiveStrength

Compressive strength or crushing strength is the main property observed in testing the cubes .Cubes are tested to find Compressive strength by applying gradual loading in Compression Testing Machine. The reading of the failure load is occurred on the top of the machine in the indicator.

After 28 days curing, cubical specimens are placed on compression strength machine having a maximum capacity of 3000KN. Ultimate load at which cubical specimen fails is noted down the dial gauge reading. Compressive strength is obtained by applying crushing load on the cube surface The test results are presented here for the Compressive strength of 7 days, 28 days and 90 days of testing

Compressive strength = P/A N/mm$^{2.}$

Split Tensile Strength

After 28 days curing, cylinder specimens are placed on tension strength machine having a maximum capacity of 1000kN, by placing two steel plates below and above the cylinder in horizontal direction. Ultimate load at which cylinder specimen fails is noted down the dial gauge reading.The cylindrical specimens are also tested in compression testing machine. The cylinders are placed in axial direction by facing cylindrical face to the loading surface.

Split tensile strength = 2P/ □LD

Flexural Strength

After 28 days curing, prismatic specimens are placed on flexure strength machine having a maximum capacity of 100 kN by a placing in such a way that the two point loading be placed at a distance of 13.3cm from both the ends.

Flexural Strength f_{cr}= PL/bd^2

The modulus of rupture is denoted by “f_{cr}“.
The „f‟ value is mainly based on the shortest distance of line fracture „a‟ If 110mm < a < 133mm, f_{cr} = 3PL/bd^2
If a > 133mm, f_{cr}= PL/bd^2
If a < 110mm, the test shall be discarded

VII. TABLES AND GRAPHS

Table 7.1 Compressive strength of cubes

Grade	Mix Designation	Compressive strength of Concrete in MPa					
		7 days	% increase	28 days	% increase	90 days	% increase
M30	M0	24.32	-	39.26	-	41.23	-
	M1	29.72	22.20	45.26	15.28	45.27	7.60
	M2	32.16	32.16	46.39	18.16	49.54	20.15
	M3	30.16	24.01	43.26	10.10	45.86	11.22
	M4	28.65	17.80	41.33	5.20	43.14	4.63

Compressive strength variation for M30 grade at 7, 28 & 90 days

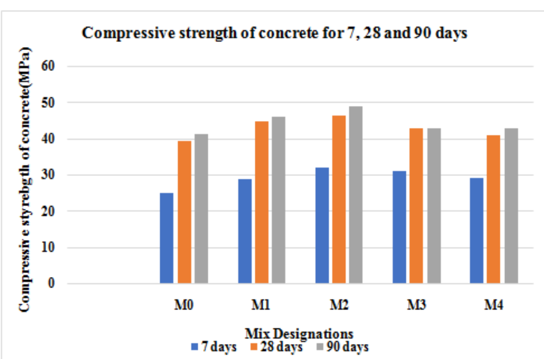


Table7.2Split tensile strength results M30 Grade

Grade of Concrete	Mix Designation	Tensile strength of Concrete in MPa	
		28 days	% Increase
M30	M0	3.42	--
	M1	3.79	11.80
	M2	3.91	15.34
	M3	3.81	12.39
	M4	3.69	8.85

7.3 Split tensile strength variation for M30 grade at 28 days

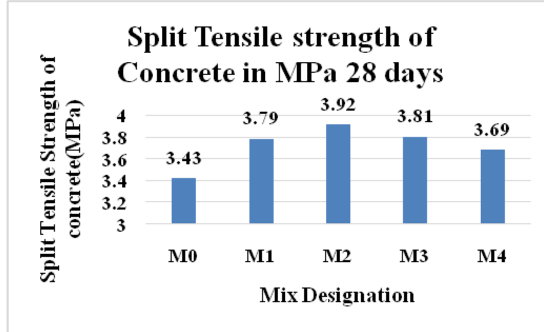
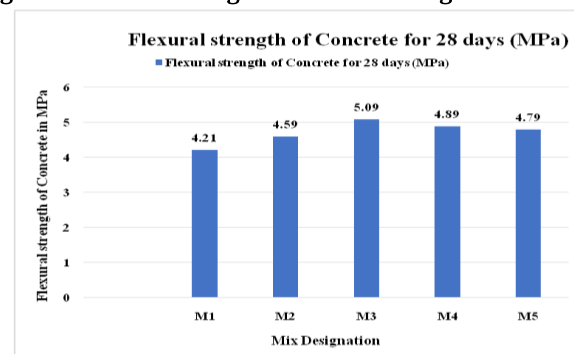


Table 7.4 Flexural strength results M30 Grade at 28 days

Grade of Concrete	Mix Designation	Flexural strength of Concrete in MPa	
		28 days	% Increase
M30	M1	4.21	--
	M2	4.59	5.28
	M3	5.09	16.74
	M4	4.89	12.16
	M5	4.79	9.86

Fig 7.5. Flexural strength variation M30 grade at 28 days



VIII. DURABILITY TEST

To check the Acid resistance of concrete Sulphuric Acid (H2SO4) is selected. The concentrations of acids in water are taken as 5%. The standard specifications for this study are IS 516-1959 and ASTM C666-1997.

The aim of the project is to study the strength behaviour of plain concrete and the bacteria concrete for each 500 ml of water with 5ml, 10ml, 15ml and 20ml proportions in Sulphuric acid of 5% concentration at different periods of immersion14and28day.Plastictray(500mm*360mm*160mm)a reused to immerse the concrete cubes in the sulphuric acid and for required time of immersion. Five trays are used for each designation of M0, M1, M2, M3,M4 one for conventional and remaining four are used for bacteria concretecubes.1sttray contains conventional tray, 2ndtray contains 5ml bacteria concrete for each 500 ml of water cubes, 3rdtray contains 10ml bacteria concrete for each 500 ml of water cubes, 4thtray contains 15ml bacteria concrete for each 500 ml of water cubes and 5thtray contains 20ml bacteria concrete for each 500 ml of water cubes.

The cube, meant for a particular time of immersion, is first tested for weight loss and then same cube is used for testing strength loss, immediately after the completion of the same period of immersion. The cubes are placed staggered in trays to maximize the exposed surface. The trays are covered to prevent any evaporation. The cubes are tested till 28 days of immersion/exposure in H2SO4.Before weighting or testing, the cubes are lightly brushed under water to remove the loose surface debris

8.1 Summary of brief details for durability study

Acids used	H_2SO_4
Concentrations for trails	5% in water
Number of days of testing	14 days and 28 days
Termination period	28 days
Properties comparing	Acid Durability Factor % of weight loss % strength loss

Table 8.1 Results after 14 and 28 days:

Tray no.	Mix Designation	Acid consumption After 14 days	Acid consumption after 28 days
1	M1	323.80 ml	76.1
2	M2	318.00 ml	38.42ml
3	M3	306.50 ml	26.40ml
4	M4	300.01ml	19.60ml
5	M5	228.00ml	2.56ml

IX. DURABILITY RESULTS

Percentage weight loss = [(Initial weight-Final weight)/Initial weight]*100

Percentage strength loss = [(Initial strength-Final strength)/Initial strength]*100

Percentage weight loss and percentage strength loss of cubes in 5% H2SO4

Table 9.1 % Weight loss & % strength loss in H2SO4 for M30 Grade

MIX	Curing Under 5% H_2SO_4			
	% weight loss after 14 days	% weight loss after 28 days	% strength loss after 14 days	% strength loss after 28 days
M0	3.58	5.78	9.54	59.58
M1	2.99	4.59	8.96	54.98
M2	2.81	4.54	8.32	55.78
M3	2.96	4.68	8.66	56.18
M4	3.12	4.89	9.04	58.21

Fig 9.1 Percentage of weight loss in 5% H2SO4 for M30 grade

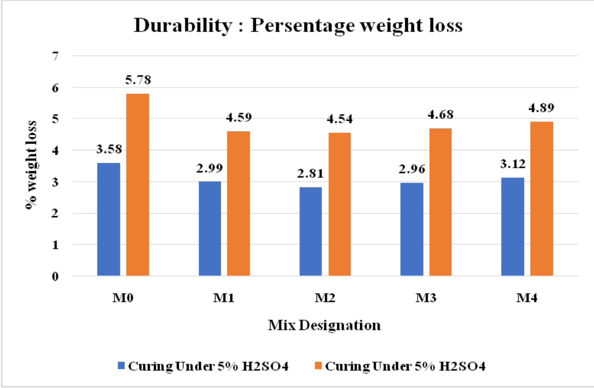


Fig 9.2 Percentage of strength loss in 5% H2SO4 for M30 grade

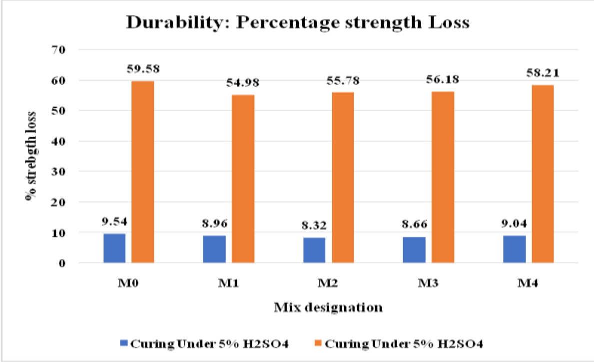
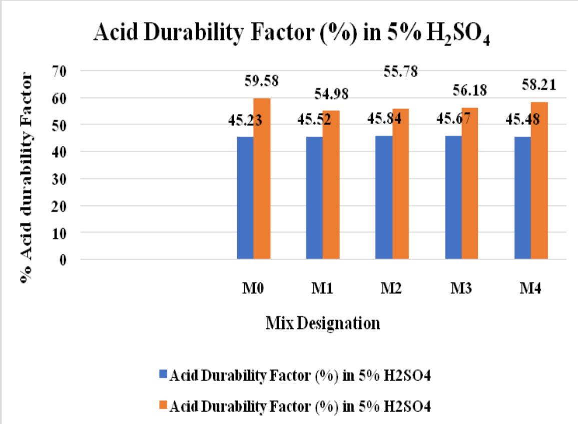


Table 9.2 Acid durability factor for M30 Grade in 5%H2SO4

Mix	Acid Durability Factor (%) in 5%H_2SO_4					
	ADF for 14 Days			ADF for 28 Days		
	%loss in strength	Relative strength S_r (%)	ADF	%loss in strength	Relative strength S_r (%)	ADF
M1	9.54	90.46	45.23	60.36	59.58	59.58
M2	8.96	91.04	45.52	55.52	54.98	54.98
M3	8.32	91.68	45.84	54.26	55.78	55.78
M4	8.66	91.34	45.67	56.98	56.18	56.18
M5	9.04	90.96	45.48	58.17	58.21	58.21

Fig 9.3 Acid durability factor in 5% H2SO4 forM30



X. CONCLUSIONS

Based on the results from experimental investigation, the following points can be concluded:

- Addition of bacteria has improved the strength and durability characteristics of the concrete.
- At 10ml optimum percentage of bacteria for 500ml of water, the enhancement if the compressive strength at early ages is very high finally resulting in 18%, split tensile strength as 15.34% and flexural strength as 16.74%.
- As part of durability studies, the acid consumed by the bacterial concrete is less compared to the conventional concrete.
- Under 5% H_2SO_4 acid curing at 28 days the percentage weight loss is 6% and the percentage strength loss is 3.8% which has less weight and strength losses than the conventional concrete
- From the above it can be concluded that bacillus subtilis can be easily cultured and safely used in improving the performance characteristics of concrete

REFRENCES

[1] **A**.T.Manikandan, A.Padmavathi, "An experimental investigation on improvement of concrete serviceability by using bacterial mineral precipitation", IJRSI, Volume II, Issue III, March 2015, (PP:46-49)

[2] Amudhavalli.N.K., Keerthana.K., Ranjani.A, "Experimental study on bacterial concrete", ISSN: 2395-3470, International Journal of Scientific Engineering and Applied Science (IJSEAS) - Volume-1, Issue-8, November 2015, (PP:456-458)

[3] Deepika.B, C.Savinth Kumar, "Study on strength of bacterial concrete in bacillus megaterium", ISSN: 2277-9655, International Journal of Engineering Sciences & Research Technology, Deepikaet al., 5 (5): May, 2016 , (PP: -780-785)

[4] Dr. M. Mageswari1, Akash Sharma, P.Hemnath, "Study on concrete durability by bacterial precipitation", International Journal of Engineering Science and Computing, March 2016, Volume 6 Issue No. 3, (PP: 3152-3158)

[5] G.T. Suthar, Dr. K.B.Parikh, "A Study of microorganism (bacteria) on concrete strength and durability", International Journal of Innovations in Engineering and Technology (IJIET), Volume 6 Issue 4 April 2016 ISSN: 2319 –1058, (PP: 594- 599)

[6] Harshali J, Mitali S., Neha A., Pragati B, "Bio concrete and bacteria based self- healing concrete", IJRET: International Journal of Research in Engineering and Technology, Volume: 05 Issue: 05 May-2016, (PP:95-99)

[7] Krishna Priya Kota*, Rohini Krishna Kota, John Babu Dulla, Abraham Peele Karlapud "Bioconcrete enhancement from biofilm producing marine bacterium", Mar – Apr 2014; Article No. 52. (PP:276-279)

[8] Kunal. R. Patil, B. P. Waghere, R. R. Salve, B. K. Ahire, K. S. Patel. Professor: P H Bhoir, AkshayThakare,"Effect of bacteria calcite precipitation on compressive strength of general concrete cubes", ISSN 2348 – 7968, IJISET - International JournalofInnovativeScience,Engineering&Technology,Vol.3Issue2,February 2016,(PP: -423-429)

[9] L.Soundari,C.S.ManeeshKumar,S.Anthoniraj,E.Karthikeyan,"Anexperimental study on strengthening of concrete by using bacterial mineral precipitation", International Journal of Core Engineering & Management (IJCEM) ,Volume 2, Issue 9, December 2015, (PP:92-100)

[10] Leena Chaurasia, Rajesh K Verma and Vishakha Bisht, "Microbial carbonate precipitation by urease producing bacteria in cementitious materials",International Journal of Advanced Biotechnology and Research(IJBR) ISSN 0976-2612, Received 15/09/2014, Accepted-15/10/2014, (PP: - 672-679)

[11] Mayur Shantilal Vekariya1, Prof. Jayeshkumar Pitroda, "Bacterial concrete new era for construction industry", International Journal of Engineering Trends and Technology (IJETT) – Volume 4 Issue 9- Sep 2013(PP:4128-4136)

[12] Mohit Goyal, P. Krishna Chaitany,:-" Behaviour of bacterial concrete as self-healing materiaL", International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 5, Issue 1, January 2015,(PP:100-103)

[13] P Ghosh & S Mandal, S Pal, G Bandyopadhyaya& B D Chattopadhyay, "Development of bioconcrete material using an enrichment culture of novel thermophilic

anaerobic bacteria", Indian Journal of Experimental Biology Vol. 44, April 2006, (PP:336-339)

[14] Pradeep Kumar. A, M.plan, MBA. Assistant professor &Akila Devi , M.E, Assistant professor " An experimental work on concrete by adding bacillus subtilis", International Journal of Emerging Technologies and Engineering(IJETE) Volume 2 Issue 4, April 2015, ISSN 2348 – 8050 :- (PP: -69-73)

[15] S.Soundharya&Dr.K.Nirmalkuma," Study on the effect of calcite - precipitating bacteria on self-healing mechanism of concrete", ISSN: 2348-4039, International Journal Of Engineering Research & Management Technology, ,July-2014 Volume 1, Issue-4, (PP: -202-207).

[16] Shaik Nasreen, Dr. T. Suresh, "Effect of bacteria on 28days split tensile strength of concrete and its stress-strain curves", ISSN 2348-7607, International Journal of Civil and Structural Engineering Research, Vol. 3, Issue 2, (PP:33-38).

[17] IS 10262,"Recommended Guideline For Concrete MixDesign".

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

[19] IS 456:2000,"Plain and Reinforced Concrete-Code ofPractice".