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Study on Strength and Durability Properties of Bacteria Concrete

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***Abstract:*— Cracks in concrete are unavoidable and it is one of the inherent weaknesses of concrete. Sometimes water and other salts seep through these cracks because of which corrosion initiates, and thus reduce the life of concrete. So there was a need to develop a self-repairing material which can remediate the cracks and fissures in concrete and bacterial concrete is one of them. In this research, M40 grade of concrete is prepared by adding various amount of bacteria (Bacillus subtilis) to improve strength and durability properties.The bacterial concrete specimens and conventional concrete specimens were immersed in 5% H2So4for 28 days and it was found that bacterial concrete shows better performance comparatively.**

***Keywords:*-- Bacterial concrete, compressive strength, flexural strength, Durability and H2So4.**

I. INTRODUCTION

Cement mortar and concrete are the most widely used building material in the construction field.It is difficult to point out another material of construction which is versatile as concrete. It is the material of choice where strength,durability andImpermeability are required. Cement concrete is one of the seemingly simple but actually complex materials.. The behaviour of concrete with respect to long-term drying shrinkage, creep, fatigue,cracks and fissures. Here the bacterial concrete is the technique which heals the cracks and enhances the strengthening properties. 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 $CaCO_3$ 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. 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.

It has been early tested and approved that dynamic guiding forces cause an increase of wear index, of both the wheel and the rail, especially when the vehicle crosses curved rail section. Moreover the stronger the curve, the higher the dynamic guiding (MICP). Bacillus subtilis, which can successfully remediate cracks in 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 (H. M. Jonkers,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 andJayeshkumar, 2013). Water curing was exposed to be the finest way for bio self-healing concrete (Mian Luo et al, 2015).

II.OBJECTIVE OF STUDY

The main objective of the project is to

i) Determine and compare the mechanical properties such as compressive strength, flexural strength and split tensile strengthof Bacterial concrete with conventional concrete.

ii) Study the bacterial concrete performance 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.

III. 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

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any temperature conditions. Thepeptone, beef extract are the ingredients for the growth of Bacteria bacillus subtilis.

The pure 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 in500ml 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. 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)

IV. TEST DATA FOR MATERIALS OF CONCRETE

The materials like cement, Fine aggregate, coarse aggregate were tested for their properties and compared with Indian standards before mixing of concrete.

4.1. Cement

Ordinary Portland cement of 43 grade of ACC brand used for experimental purpose. Physical properties of cement were determined as per IS 12269 (1987)and tabulated in Table 1.

Table.1 properties of cement

Property	Experimental Result	IS Code requirement
Specific gravity	3.13	3.10-3.15
Initial Setting Time	70 min	>30 min
Final Setting Time	350min	<600 min
Fineness (%)	1.70%	<10%

4.2. Fine Aggregate

Fine aggregate is tested for its specific gravity, fineness modulusand water absorption. 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 aggragate

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 thatthe 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)					

4.3. 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 Tble.4 are within the limits and useful in preparation of concrete.

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Table.4 Properties of Course 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.

Table. 5 sieve analysis of Course 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	56.8	56.82	43.18
4	10	6.42	42.8	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

V. 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. 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 inUniform 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 0.40. The water content is taken as 170liters. 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	425.00	1
2	Fine Aggregate	701.25	1.65
3	Coarse Aggregate	1232.50	2.90
4	Water	170.00	0.40

Following table represents various mix trials casted during this research and throughout the paper the same convention used to represent the mix.

Table.7 Mix Designation

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

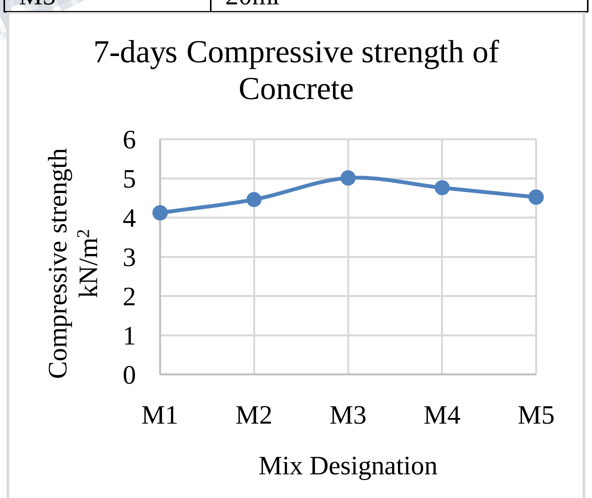

Fig. 2 Compressive strength of Concrete for 7-days

Table.8Percentage increase with Mix1for 7-days

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Concrete specimens were prepared to test the mechanical properties. Cubes of size

VI. RESULTS AND ANALYSIS

Bacterial Concrete has been tested for fresh properties like workability and mechanical properties like Compressive strength, split tensile strength and flexural strength. The durability has been

6.1. Workability

Workability of concrete is tested for each mix when it was casted as per IS1199-1959.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.9.

Table.9 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

6.2. Compressive strength

Compression test has been carried out on concrete cubes with standards confirming toIS516-1999.All the samples were tested in a 2000KN capacity Compression testing machine. After 28 days 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 are given in Fig.3.

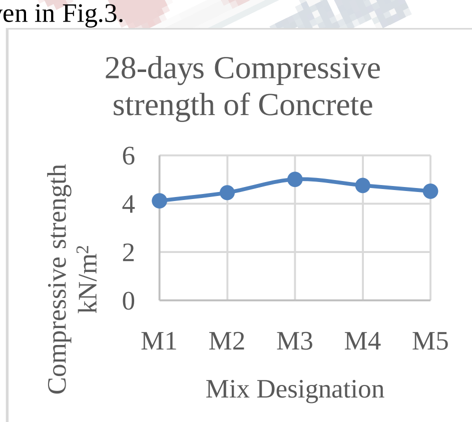

Fig.3 Compressive strength of Concrete for 28days

Table.10 Percentage increase with Mix1for 28-days

Cell Concentration/ml of mixing bacteria	**%increase comparing with Mix1**
M1	--
M2	5.90
M3	16.22
M4	11.59
M5	9.60

The greatest improvement in compressive strength occurs at Culture of 10ml at 28 days. 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.

6.3. Flexural Strength

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

Fig.4 showing Prism testing

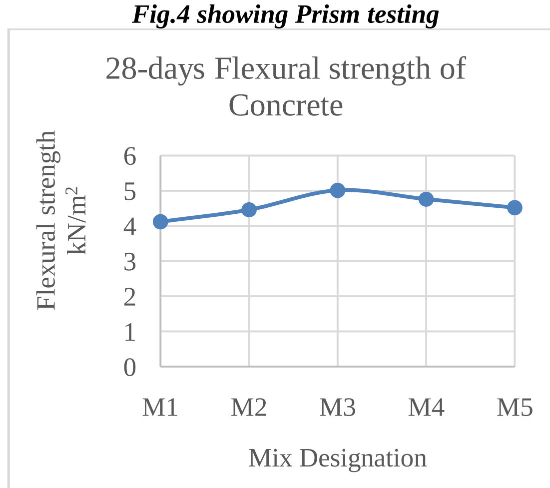

Fig.5 Flexural strength of Concrete for 28-days

Table.11 Percentage increase with Mix1for 28-days Flexural strength

Cell concentration/ ml of mixing bacteria	**%increase comparing with Mix1**
M1	--
M2	9.68
M3	24.61
M4	19.18
M5	14.34

6.4. Split tensile strength

Split tensile strength test has been conducted on cylinder of 150mm diameter and 300mm heightas shown in the fig. the results are mentioned in table.

Fig.6 showing cylinder testing

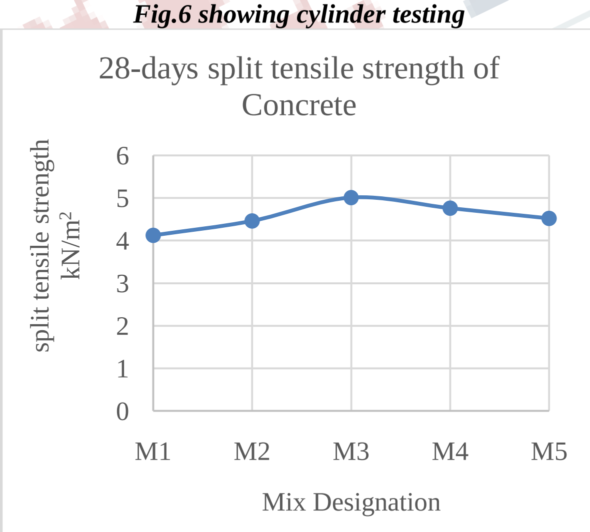

Fig.7 Split tensile strength of Concrete for 28-days

Table.12 Percentage increase with Mix1for 28-days Split tensile strength

Cell concentration/ ml of mixing bacteria	**%increase comparing with Mix1**
M1	--
M2	8.25
M3	21.60
M4	15.53
M5	9.70

6.5. Durability Studies

To study durability characteristics, the specimens are subjected to 5% solution of H_2SO_4 for 14 and 28 days. In this investigation, the weight loss and strength loss of concrete is compared with the concrete specimens cured under water. It is found that the bacterial concrete made with 10mml addition of bacteria lost less weight and strength when compared with other mixes. So based on the durability test, the M3 is found to give optimum results. The results are mentioned in Table13. From the table it can be observed that M3 lost only 1.26%& 2.29% for 14 days and 28 days respectively. Coming to the strength it lost 6.26%&41.23% for 14 days and 28 days.

Fig. 8 Curing of Cubes in H_2SO_4

Table. 13 percentage of weight and strength loss for 14 and 28 days

Mix	14-Days		28- Days	
	Loss in Weight (%)	Loss in Strength (%)	Loss in Weight (%)	Loss in Strength (%)
M1	1.83	8.25	3.12	56.42
M2	0.98	7.09	2.07	47.26
M3	1.26	6.26	2.29	41.23
M4	1.42	7.30	2.44	50.55
M5	1.74	8.03	2.30	45.40

VII. CONCLUSION

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

i) Addition of bacteria to the concrete doesn't impact the workability of the concrete.

ii) Addition of bacteria at any content improves the strength of the concrete. But the optimum content of bacteria can be added is determined as 10ml in strength aspects.

iii) When bacteria is added to the concrete, its performance is increased in the presence of H_2So_4compared with conventional concrete and the best performance found at 10ml of bacteria.

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