EXPERIMENTAL STUDY ON PERFORMANCE OF BACTERIA IN HIGH STRENGTH CONCRETE

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Abstract: This paper deal with a study to determine the performance ofthe concrete by the microbiologically induced special growth. One such has led to the development of a very special concrete known as bacterial concrete wherebacteria is induced in the mortars and concrete to heal up the faults. Researchers with different bacteria proposed different concretes. Here an attempt was made by using the bacteria "Bacillus subtilis". The aim is to examine the physical properties of normal M50 concrete in addition of bacteria "Bacillus subtilis".This study showed a significant increase in the compressive strength due to the addition of bacteria. There for it is decided to carry out an investigation of determining optimum dosage of bacterial solution required of concrete by forming various concrete cube samples having variations of bacterial solution viz, 20 ml, 40ml, 60ml, and 80ml, further these various samples are tested under various laboratory method and there by an optimum dosage required is computed.

Keywords: Bacteria, crack repair, sealing, Bacillus subtilis

I. INTRODUCTION

Bacterial concrete: Cracking of concrete is a common phenomenon. Without immediate and proper treatment, cracks in concrete structures tend to expand further and eventually require costly repairs. Even though it is possible to reduce the extent of cracking by available modern technology, remediation of cracks in concrete has been the subject of research for many years. There are a large number of products available commercially for repairing cracks in concrete: structures epoxy, resins, epoxy mortar and other synthetic mixtures. Cracks and fissures are a common problem in building structures, pavements, and historic monuments. We have introduced a novel technique in fixing cracks with environmentally friendly biological processes that is a continuous self-remediating process. In the study, Bacillus pasteurii that is abundant in soil has been used to induce $CaCO_3$ precipitation. It is therefore vital to understand the fundamentals of microbial participation in crack remediation.

Definition: The "Bacterial Concrete" is a concrete which can be made by embedding bacteria in the concrete that are able to constantly precipitate calcite. This phenomenon is called microbiologically induced calcite precipitation. It has been shown that under favorable conditions for instance Bacillus Pasteruii, a common soil bacterium, can continuously precipitate a new highly impermeable calcite layer over the surface of an already existing concrete layer. The favorable conditions do not directly exist in a concrete but have to be created.

Mechanism of bacterial concrete: Self-healing concrete is a result of biological reaction of non-reacted limestone and a calcium based nutrient with the help of bacteria to heal the cracks appeared on the building. Special type of bacteria's known as **Bacillus** are used along with calcium nutrient known as **Calcium Lactate.** While preparation of concrete, this products are added in the wet concrete when the mixing is done. This bacteria's can be in dormant stage for around 200 years. When the cracks appear in the concrete, the water seeps in the cracks. The spores of the bacteria germinate and starts feeding on the calcium lactate consuming oxygen. The soluble calcium lactate is converted to insoluble limestone. The insoluble limestone starts to harden. The other advantage of this process is, as the oxygen is consumed by the bacteria to convert calcium into limestone, it helps in the prevention of corrosion of steel due to cracks. This improves the durability of steel reinforced concrete construction.

II. MATERIAL PROPERTY

Bacteria: Bacterial have been effectively used for improving the strengths of concrete beams and other structures, which have air gaps and micro cracks. The bacterial Bacillus subtilis in the concentration of 8.6*108 cells/ml can improve the strength of the concrete by forming a calcite layer in the crack. Thus, the strength of the beams has improved back to 81.97% of the original strength. Reddy et al have reported the addition of B.subtilis bacteria increase the compressive strength of standard grade concrete up to about 15% at 28 days, and also show a significant in split tensile strength compared to conventional Concrete**.** There are various types of bacteria were used in bacterial concrete construction are:

- Bacillus pasteurizing
- Bacillus sphaericus
- Escherichia coli
- Bacillus subtilis
- Bacillus cohnii
- Bacillus balodurans
- Bacillus pseudofirmu

Fig.1 Bacterial solution

III. EXPERIMENTAL METHODS & TEST

Tests for cement

Fineness test: 100 grams of cement is taken in a standard IS sieve no 90µ. The air which get lump is broken down and the material is sieved continuously for 15 minutes using sieve shaker. The residue left on the sieve is weighed.

Table I- Fineness Test

SI.NO	OBSERVATION	TRIAL 1	TRIAL 2	TRIAL 3
1	Weight of sample taken(gm)	100	100	100
2	Weight of residue retained after sieving(gm)	2	2	2
3	% of residue left on the sieve on 90 μ	2	2	2

Fineness modulus of cement = 2%

Normal consistency: 300g of cement is taken and a paste with a weight quantity of water (say 24%) is prepared. The paste is filled in the mould within 3 to 5 minutes. The mould is well is shake to exist air. A standard plunger if 10mm diameter and 50mm long attached to the Vicat apparatus and brought down to touch the surface of the past in the test block and is quickly released to sink into the paste by its own weight. The depth of penetration of the plunger is noted. The second trail is conducted by adding 25% of water and the depth of penetration is noted. Similarly, numbers of trials were conducted, till the plunger penetrates to a depth of 33mm to 35mm is the percentage of water required to produce the cement paste of standard consistency (P). Needle used: - Plunger size 10mm diameter and 50mm long Grade of cement : 53 grade Name of cement : Ordinary Portland Cement

Table II- Normal consistency

S.No	Sample Taken in gm	Water Added		Penetration of Needle from Bottom
		Percentage	In ml	
1.	300	24.0	72	44
2.	300	26.0	78	40
3.	300	28.0	84	38
4.	300	30.0	90	35

Consistency of cement = 30%

Initial setting time: A net cement paste with 0.85 times of water required is prepared to give standard consistency. The time at which the water is added is noted. Then the vicar mould is filled with cement paste in 3-5 minutes. The surface of the paste is smoothened making it level with top of the mould. The needle is gently lowered to the surface of the paste and is quickly released allowing it to sink into the paste by its own weight. The procedure is repeated until the needle fails to pierce the block for about 5mm to 7mm measured from bottom and the is noted using stop watch. The difference between the timing will give the initial setting time.

Grade of cement: 53 grade

Name of cement: Ordinary Portland Cement

Initial setting time of cement = 50 minutes

Table III- Initial setting time

Sl.NO	TIME IN MINUTES	PENETRATION
1	0	0
2	5	0
3	10	0
4	15	1
5	20	1
6	25	2
7	30	2
8	35	2
9	40	2
10	45	2
11	50	4 (3 to 5)

Final settiing time: This procedure is similar to initial setting time. In this procedure needle with annular collar is inserted in the vicat apparatus. Time for penetration is noted at every 30 minutes. The procedure is repeated until the attachment fails to make an impression on the test block.

Needle used: 1mm square

Amount of water added: 0.85P = 105.4ml

Fineness by dry sieving of cement

Grade of cement : 53 grade

Name of cement : Ordinary Portland cement

Table IV- Final setting time

Sl.NO	TIME IN MINUTES	PENETRATION
1	0	0
2	30	7
3	60	10
4	90	15
5	120	12
6	150	18
7	180	17
8	210	16
9	240	14
10	270	13
11	300	10

Final setting time of cement = 300 minutes

Specific gravity test: The dry specific gravity bottle is weighed as W_1 grams. The bottle is filled with distilled cement and weighed as W_2 grams. The specific gravity bottle is dried and filled with kerosene and is weighed as W_3 grams. Some of the kerosene is poured out and introduced with and weight quantity of cement and the weight is measured as W_4 grams. 100 grams weight of cement is taken as W_5 grams.

Table V-Specific gravity of cement

S.NO	DESCRIPTION	Trail 1	Trail 2	Trail 3
1	Weight of empty bottle(w1)	46	46	46
2	Weight of bottle + cement (w2)	106	108	105
3	Weight of bottle + cement+ kerosene (w3)	173	175	174
4	Weight of bottle + kerosene(w4)	122	122	122
5	Specific gravity	3.04	3.07	3.29

Specific gravity of cement = 3.13

Test for fine aggregate

Fineness test: The sample brought to an air- dry condition before weighing and sieving this may be achieved either by drying at room temperature, the air - dry sample shall be weighed and sieved successively on the appropriate sieves starting with the largest size sieve. If sieving is carried out with rest of sieves on and machine not less than minutes sieving will be required for each test. Weight of sample taken: 1kg.

Table VI – Fineness modulus of fine aggregate

S.NO	IS Sieve(m)	Weight retained(g)	% of weight retained(g)	% of weight passing	Cumulative % weight retained
1	4.75	28	2.8	97.2	2.8
2	2.36	36	3.6	93.6	6.4
3	1.18	216	21.6	72	28
4	600μ	192	19.2	52.8	47.2
5	300μ	378	37.8	15	85
6	150μ	132	13.2	1.8	98.2
7	Pan	18	1.8	0	100

Fineness modulus = 3.324

Specific gravit: The pycnometer is dried thoroughly and it is weighted it as W_1 g. Take 200 gram of the soil sand in the pycnometer, weighed it as W_2. The pycnometer is filled with water up to the top. Then it is shook well and stirred thoroughly with the glass rod to remove the entrapped air. After the air has been removed, the pycnometer is completely filled with water up to the mark. Then outside of the pycnometer is dried with and clean cloth and it's weighed as W_3 g. The pycnometer is cleaned thoroughly. The pycnometer is completely filled with up to the top. Then outside of the pycnometer is dried with and clean cloth and its weighed as W_4 g.

Table VII –Specific gravity of Fine Aggregate

S.NO	DESCRIPTION	Trial 1	Trial 2	Trial 3
1	Weight of pycnometer (w1)	0.622	0.622	0.622
2	Weight of pycnometer + sand (w2)	1.092	1.066	1.104
3	Weight of pycnometer + sand + water (w3)	1.812	1.796	1.816
4	Weight of pycnometer + water (w4)	1.525	1.527	1.518
5	Specific gravity of sand(G)	2.568	2.537	2.619

Average Specific gravity of fine aggregate = 2.575

Test for coarse aggregate

Fineness test: The sample is brought to an air dry condition before weighing and sieving this may be achieved either by drying at room temperature or heating at and temperature of 100̊ c to 110̊ c. The air dry sample shall be weighed and sieved successively on the appropriate sieves starting with the largest size sieve. If sieving is carried out with, rest of sieves on and machine not less than 10 minutes sieving will bending required for each test.

Table VIII – Fineness modulus of coarse aggregate

S.NO	IS Sieve (mm)	Weight retained (kg)	% of weight retained	% of weight passing	Cumulative retained
1	20	1.693	33.86	66.14	33.86
2	10	3.237	64.74	35.26	98.6
3	4.76	0.063	1.26	98.74	99.86
4	2.36	-	-	-	100
5	1.18	-	-	-	100
6	600µ	-	-	-	100
7	300µ	-	-	-	100
8	150µ	-	-	-	100
9	Pan	-	-	-	100

Fineness modulus = 8.32

Specific gravity test: The container is dried thoroughly and its weighed W_1 g. Take 200g of the coarse aggregate and it's weighed again with container W_2 g. The sufficient water is added to cover the coarse aggregate half full and is screwed on the top.It is shaking well and stirred thoroughly with the glass rod to remove the entrapped air. After the air has been removed container is completely filled with water up to mark. The outside of the container filled with water up to mark is dried with and cloth and its weighed W_3 g. The container is completely filled with water up to the top. The outside of the container is a dried with a clean cloth and its weighed W_4 g.

Table IX - Specific gravity of coarse aggregate

S.NO	OBSERVATION	Trial 1	Trial 2	Trial 3
1	Weight of container(w_1) kg	2.568	2.568	2.568
2	Weight of container + coarse aggregate (w_2) kg	4.398	4.576	4.604
3	Weight of container + coarse aggregate + water (w_3) kg	6.652	6.714	6.772
4	Weight of container + water (w_4)	5.520	5.482	5.490
5	Specific gravity of coarse aggregate	2.62	2.58	2.70

Specific gravity of coarse aggregate = 2.6

Table – X Water absorption of coarse aggregate

S.NO	OBSERVATION	Trial 1	Trial 2	Trial 3
1	Weight of container(w_1) kg	1.253	1.253	1.253
2	Weight of container + coarse aggregate (w_2) kg	2.135	2.142	2.162
3	Weight of container + coarse aggregate + water (w_3) kg	3.442	3.451	3.472
4	Weight of container + water (w_4)	2.880	2.878	2.879
5	Weight of container + wet aggregate (w_5)	2.140	2.161	2.180
6	% of absorption	0.56	2.1	1.98

Water absorption of coarse aggregate = 1.6

EXPERIMENTAL TEST ON BACTERIAL CONCRETE

Various test are performed on bacterial concrete in order to get the results in various forms these experimental methods are summarized below-

Slump cone test: The slump test is the most commonly used method. Consistency is a term very closely related to workability. It is a term which describes the state of fresh concrete. It is used for the determination of the consistency of freshly mixed concrete, where the maximum size of the aggregate does not exceed 38 mm. The slump test is suitable for slumps of medium to high workability, slump in the range of 25 – 125 mm; the test fails to determine the difference in workability in stiff mixes which have zero slumps, or for wet mixes that give a collapse slump. It refers to the ease with which the concrete flows. It is used to indicate the degree of wetness.

Workability of concrete is mainly affected by consistency i.e. wetter mixes will be more workable than drier mixes but concrete of the same consistency may vary in workability.

Ultra sonic pulse velocity: This method consists of producing an ultrasonic longitudinal pulse by an electro acoustical transducer which is held in contact with one surface of the freshly placed concrete member under test. After traversing a known distance in the concrete, the pulse to be measured from which the pulse velocity timing circuit enables the transit time of the pulse to be measured from which the pulse velocity is calculated. This procedure is called the "Ultrasonic method."

IV. MIX DESIGN:

Mix Design M-50 Grade

The mix design M-50 grade (Using Admixture – Sika visconcrete 5201 ns) provided here is for reference purpose only. Actual site conditions vary and thus this should be adjusted as per the location and other factors.

Parameters for mix design m5:
GradeDesignation=M-50
Type of cement = O.P.C-53 grade Brand of cement = Ultratech cement
Admixture = Sika [Visconcrete 5201 ns]
Fine Aggregate = Zone-II

Specific gravity
Cement = 3.15
Fine Aggregate = 2.61
Coarse Aggregate (20mm) = 2.65
Coarse Aggregate (10mm) = 2.66
Minimum Cement (As per contract) =400 kg / m^3
Maximum water cement ratio (As per contract) = 0.45

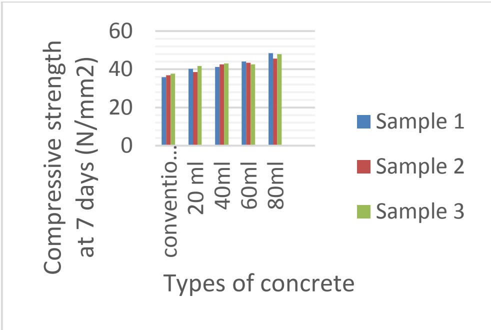
IV. RESULT & DISCUSSION

Compresive strength tests:

The cubes are tested as per IS: 516-1979.The tests are done on an electro-hydraulically operated compression-testing machine. The specimen is placed in bearing surface of the compression-testing machine and compressive load is applied on opposite faces axially, slowly at the rate of 140MPa/min. The compressive load is noted for the ultimate failure Standard dimension of cube specimen =150mmx150mmx150 mm

Table -XI Compressive strength at 7 days

Types of concrete	Compressive strength at 7 days (N/mm^2)				
	Sample 1	Sample 2	Sample 3	Avg.value	% Increase in strength
conventional	35.9	36.8	37.7	36.80	-
20 ml	40.2	38.5	41.8	40.17	9.16
40ml	41.2	42.5	43.0	42.23	14.75
60ml	44.1	43.4	42.6	43.37	17.85
80ml	48.5	45.6	47.9	47.33	28.60



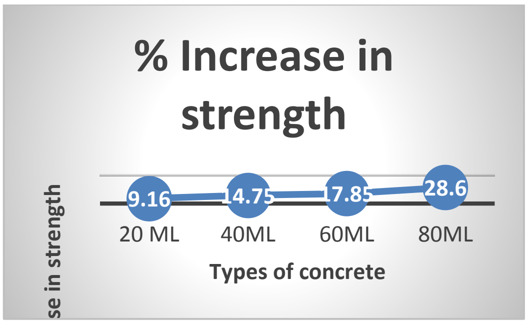
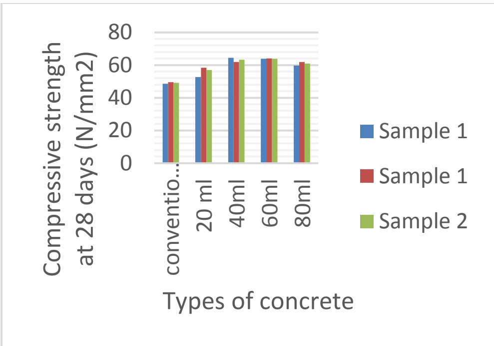


Fig.2 Compressive strength at 7 days

Table -XII Compressive strength at 28 days

Types of concrete	Compressive strength at 28 days (N/mm^2)				
	Sample 1	Sample 2	Sample 3	Avg.value	% Increase in strength
conventional	48.6	49.5	49.1	49.06	-
20 ml	52.6	58.3	56.9	55.93	14.00
40ml	64.5	61.9	63.2	63.20	28.82
60ml	63.8	64.1	63.9	63.90	30.25
80ml	59.7	61.9	61.0	60.87	24.07



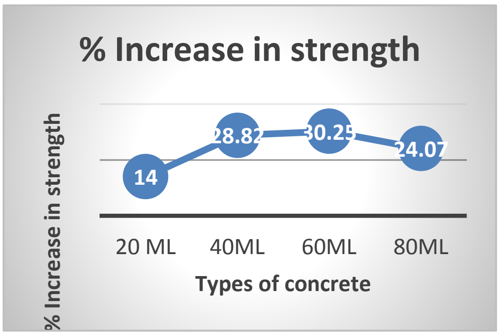


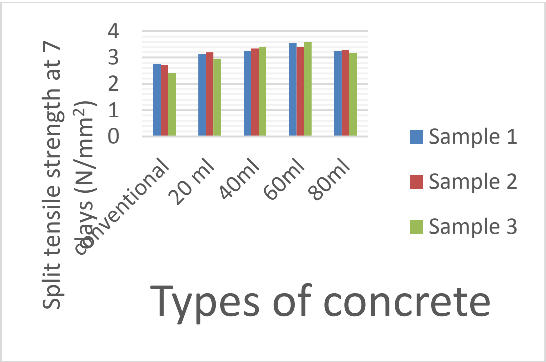
Fig.3 compressive strength at 28 days

The compressive strength test is conducted both conventional and bacterial concrete samples for 7 and 28 days. For 7 days increase in strength gradually then it is maximum at 80ml bacteria added sample. There have 28.6% strength is obtain at 80ml sample consider to conventional samples. For the 28 days the strength is increased gradually and maximum at 60ml sample then it is reduced at 80ml sample. There have 30.25% strength is obtain at 60ml sample considering to conventional sample.

Split tensile test: The concrete cylinder is tested according to IS 5816-1976, procedure for the split tensile test. The specimen is placed horizontally between the loading surface of the compression-testing machine and load is applied till the specimen fails. The load is noted for ultimate failure

Table -XIII Split tensile strength at 7 days

Types of concrete	Split tensile strength at 7 days (N/mm^2)				
	Sample 1	Sample 2	Sample 3	Avg.value	% Increase in strength
conventional	2.76	2.72	2.42	2.63	-
20 ml	3.12	3.20	2.95	3.09	17.49
40ml	3.26	3.35	3.40	3.34	27.00
60ml	3.55	3.40	3.60	3.52	33.84
80ml	3.26	3.30	3.18	3.25	23.57



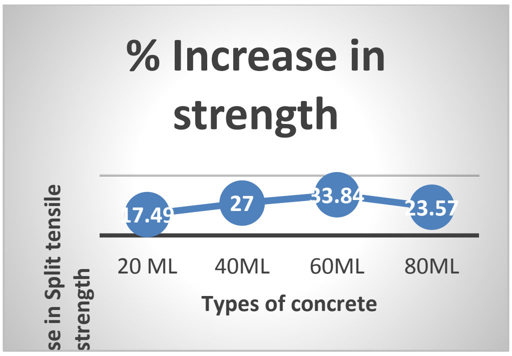
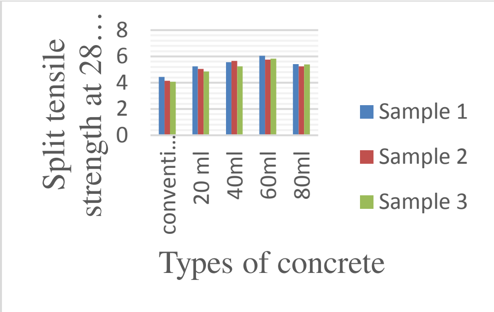


Fig.4 Split tensile strength at 7 days

Table -XIV Split tensile strength at 28 days

Types of concrete	Split tensile strength at 7 days (N/mm^2)				
	Sample 1	Sample 2	Sample 3	Avg.value	% Increase in strength
conventional	4.45	4.15	4.08	4.23	-
20 ml	5.25	5.06	4.86	5.05	19.39
40ml	5.55	5.65	5.25	5.48	29.55
60ml	6.05	5.75	5.84	5.88	39.00
80ml	5.42	5.25	5.40	5.36	26.71



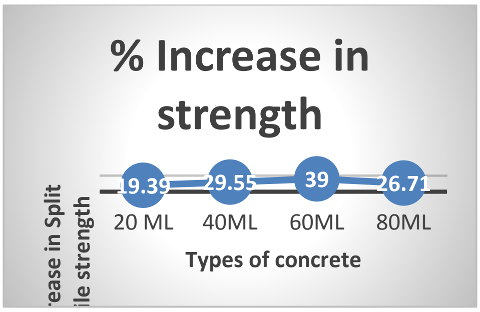
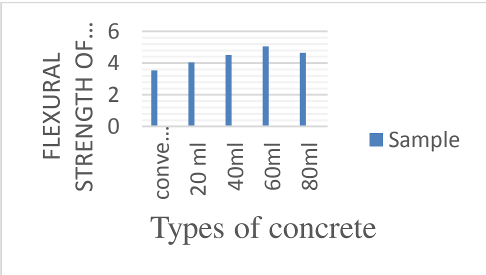


Fig.5 split tensile strength at 28 days

For 7 days increase in strength gradually then it is maximum at 60ml bacteria added sample then it is reduced at 80ml sample. For the 28 days the strength is increased gradually and maximum at 60ml sample then it is reduced at 80ml sample.

Table No. XV Flexural strength of concrete at 7 days

Types of concrete	FLEXURAL STRENGTH OF CONCRETE (N/mm^2)	
	Sample	% Increase in strength
conventional	3.55	-
20 ml	4.05	14.08
40ml	4.52	27.32
60ml	5.05	42.25
80ml	4.65	30.98



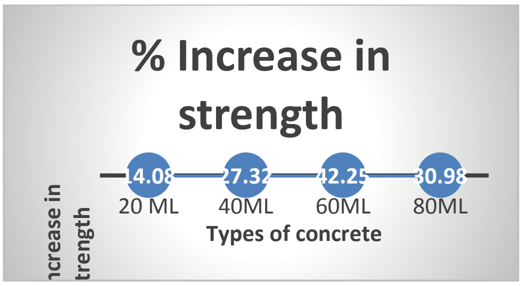


Fig.6 Flexural strength at 7 days

Table no XVI. Flexural strength of concrete at 28 days

Types of concrete	FLEXURAL STRENGTH OF CONCRETE (N/mm^2)	
	Sample	% Increase in strength
conventional	6.36	-
20 ml	7.80	22.64
40ml	8.52	33.96
60ml	9.96	56.60
80ml	8.65	36.00

Fig.7 Flexural strength of concrete at 28day

For 7 days increase in strength gradually then it is maximum at 60ml bacteria added samplethen it is reduced at 80ml sample. There have 42.25% strength is obtain at 60ml sample consider to conventional samples. For the 28 days the strength is increased gradually and maximum at 60ml sample then it is reduced at 80ml sample. There have 56.60% strength is obtain at 60ml sample considering to conventional sample.

V. CONCLUSION

In this paper work there have found that strength of the hardened concrete is increased by adding of bacillus bacterial solution. The strength is maximum at the 60ml bacterial sample compare to others. The compressive strength test the strength is increased gradually and maximum at 60ml sample then it is reduced at 80ml sample. There have 30.25% strength is obtain at 60ml sample considering to conventional sample. The split tensile strength test the strength is increased gradually and maximum at 60ml sample then it is reduced at 80ml sample. There have 39.00% strength is obtain at 60ml sample considering to conventional sample. The split flexural strength test strength is increased gradually and maximum at 60ml sample then it is reduced at 80ml sample. There have 56.60% strength is obtain at 60ml sample considering to conventional sample. Normally the bacillus bacterial concrete have high in strength compare to normal concrete. The self-healing concrete is so useful that to reduce the crack in the concrete by the action of bacteria.

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