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A STUDY AND ANALYSIS ON PROPERTIES OF HIGH STRENGTH BACTERIAL CONCRETE

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Abstract- High-strength concrete is indeed a new progression in concrete technology. It groups compressive strength of 40 MPa or above. Since HSC is another kind of solid, it has not been broadly utilized by the designers. Because of absence of research, it has just been utilized as a part of some reinforced concrete members and few large and precise structures. In our study, we will try to discover the ideal extent of mineral admixture with cement to accomplish most extreme packing density and make a mix design based on the obtained results. We will be utilized five mineral admixtures as a pozzolanic material in cement. The mineral admixtures utilized were Quartz powder, Fly ash, Metakaolin, Ultra-fine slag and Rice-husk ash. A third-generation superplasticizer will also be additionally used to set up the mix design with a specific end goal to minimize the water necessity for cement hydration. In this study we will also like to address two challenges that are commonly faced with concrete. One is the negative impact produced on environment due to huge Carbon Dioxide emission during cement manufacturing. We will try to in cooperate some greener materials partially replacing the cement in order to reduce harsh effect on environment.

Crack development is also another bigger challenge that is faced by concrete. Crack development in high strength concrete is not a common phenomenon due to higher pore refinement and interface refinement. But with later ages if cracks developed it will deteriorate the structure. We can also do its reaping by filling those cracks, but it is not a sustainable technique. In this study we will try to make a concrete that will be able to heal its crack with the help of calcite precipitating bacteria. So that it can provide us a more sustainable structure.

Keywords: Bacteria, Self-healing concrete, High strength concrete, Crack, Mineral precipitation, Biomineralization.

I. INTRODUCTION

1.1 General

Nowadays, Self-healing concrete has come out as the material of choice as a repair construction material which makes concrete more durable. In this report, self-healing is done through biological processes as a repair material is completely reviewed. This report represents a new research in the field for repair of unexpected cracking of concrete. In this study we attempted to make a High Strength Concrete which will also have self-healing properties, which will give this concrete some extra durability.

1.2 Biomineralization in High Strength Concrete

In recent times concrete has become the second most consumes material on the planet after water. In past concrete mixes of low grades or strength were enough to meet our requirements. But due to recent innovations and big structures it was found that past methodologies were not enough. So, researchers decided to find new methods and materials that can meet our requirements. In this series researches came up with a new term known as High Strength Concrete. High Strength cement is a rising innovation that gives another measurement to the expression "High performance concrete".[1–4] It has a lot of potential in construction development industry. It has great mechanical properties and durability properties when contrasted with the traditional cement. It can likewise substitute basic steel in a few applications by joining fiber support. It can also substitute structural steel in some

applications by combining fiber reinforcement. Standards like packing density, micro structural improvement can be used to accomplish HSC. The advantage like water resistance and strength are likewise given by HSC. Different examination of the HSC has been performed for assurance of mechanical and durability properties. The outcomes demonstrate that HSC have more prominent compressive and flexural strength and a decreased water penetrability. The most extreme compressive strength is between 120-150 MPa. [5-7] Occasionally strength may likewise reach up to 200MPa.[8] At such a high compressive strength the coarse aggregates are the weakest part in concrete. The concrete is liable to fail from coarse aggregates.

1.3 Bacteria

Bacteria are the single cell microbes. There is no nucleus and any other membrane in them therefore, they have simple cell structure. DNA contains generic information of bacteria in a single loop., all this present in the control centre of the bacteria. Plasmid is also one of many circles of different genetic materials. It contains genes, which give advantages to bacterium over bacteria.[17], [21], [24]

1.4 Classifications of Bacteria

Classification based on shapes: According to their basic shapes, bacteria can be classified into 5 groups.

i) Spherical (Cocci) ii) Comma (vibrios) iii) Spiral (spirilla) iv) Rod (Bacilli) &
v) Corkscrew (spirochaetes).

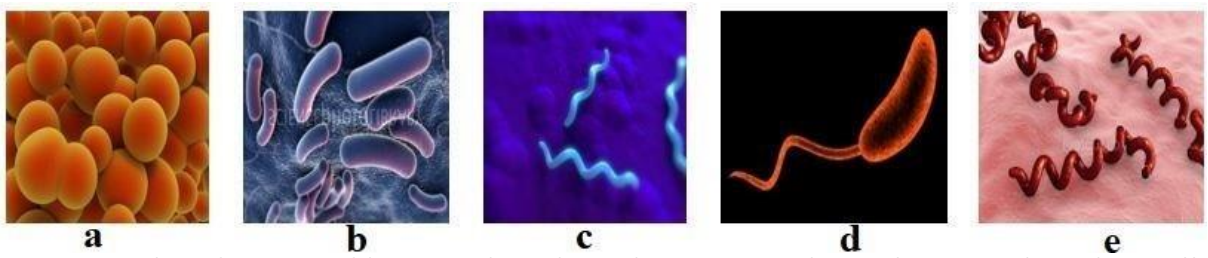

Figure 1 Classification of bacteria based on shapes. (a. Spherical (Cocci); b Rod (Bacilli); c. Spiral (Spirilla); d Comma (Vibrios); e Corkscrew (Spirochaetes).

1.5 Classification based on Gram strain

According to gram strain, bacteria can be classified into2 groups.

i) Gram Positive (gives positive results in gram strain test) &
ii) Gram Negative (gives negative results in gram strain test).

1.6 Classification based on Oxygen requirement

According to oxygen, required by bacteria can be classified into 2 groups.

i) Aerobic (tomic oxygen is required as terminal electron acceptor) &
ii) Anaerobic (does not require atomic oxygen as terminal electron acceptor).

1.7 Bacteria Used in Concrete

Concrete is extremely alkaline; its pH is about 11 to 13 and it mixed under high mechanical stresses. Therefore, immobilized bacteria must be alkaliphilic (alkali-resistant) and must have propensity to endure against the mechanical stresses. The key point against crack repairing is that the bacteria must precipitate with calcite ($CaCO_3$) to form crystalline layer over cracked surface. Bacillus spores show this kind of properties. The crack-filling phenomenon is due to the urease activities due to the alkaliphilic bacteria, which form calcite.[17], [21], [25], [26]

In bio-concrete following *Bacillus* species can be used:

i) Bacillus pasteurii.
ii) Bacillus subtilis.
iii) Bacillus megaterium.
iv) Bacillus cohnii.
v) Bacillus halodurans.

vi) Bacillus pseudofirmus. And other similar species.

1.8 Reproduction and Growth of Bacteria

Practically all microorganisms multiply by two-fold split technique. A solitary cell of bacteria, the "parent," copies its own DNA and becomes larger in size by expanding the contents of cell by multiple times. This multiplied substance is sent to each divided body of the cell. At that point, little opening rise in focal point of parent cell, at last parting it into two comparable "girl" cells which appeared in Figure 1.2 couple of bacterial animal groups like firmicutes and cyanobacteria increase through maturing. At maturing stage, little girl cell develops a posterity as the posterity of its parent. It begins as minuscule stub, develops till the size of its parent lastly separates.

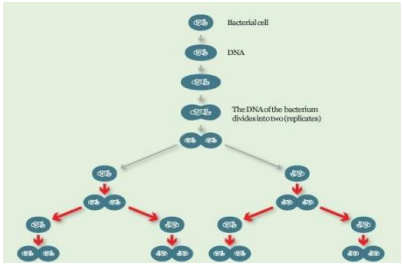

Figure 2 Bacteria Reproduction through Binary Fission

2 METHODOLOGY

In order to complete the study, we need to go through various steps in a systematic manner. These steps include the procurement of raw materials and then determining their properties.

We need to carry out the Optimum packing density optimization of the materials in Binary, Tertiary, quaternary models in order to achieve Highest packing density. Side by side we will get the samples for Bacteria isolation and to all the necessary steps to isolate and screen Calcium precipitating bacteria for our Study. Once the samples are made, they will further be tested for their mechanical properties as well as water absorbing capacity, The voids within the Concrete Cubes. In order to get the idea of crack healing capacity of concrete we also need to do continuous Microscopic and SEM Analysis. The step by Step Flow methodology adopted for the study is given below.

2.1 Experimental programme

In the First stage we will isolate the Bacteria from the samples and side by side we will do the optimization process. Meanwhile, we will test the materials for their properties. In the second stage after isolation of bacteria, we will prepare a mix design. The mix of concrete will be based on the results obtained from Puntke Method. In stage 3 we will test the concrete specimens for compressive strength, Flexural Strength and Tensile Strength. Crack quantification will also be done in stage 3

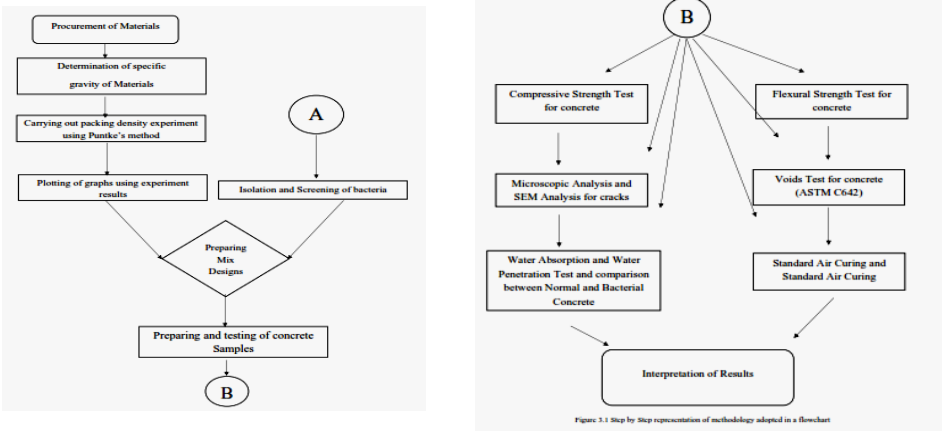

Figure 3 Step by Step representation of methodology adopted in a flowchart

2.2 Experimental Work

Determination of material specific gravity

Table 1 Material required for Specific Gravity test

Le-Chatelier Flask	250ml, the neck graduated 0-1ml and 15-24ml
Dispersing medium	Kerosene
Wash bottle	Plastic having250 ml capacity
Spatula	150 mm blade length
Funnel	Glass, narrow mouth
Thermometer	Glass having range 0-50°C
Pipette	Glass having 10ml capacity

The specific gravity of materials described as proportion of the mass of a volume of solids to water. Specific Gravity relies on the chemical composition of the material. The distinction between the initial and final value speaks about the volume of liquid displaced by the mass of concrete utilized in the test.

Procedure: Firstly, fill up the flask with kerosene up to the mark below the bulb. Now, Take 55-65 grams of the material. The material is gradually poured into the flask through funnel as the kerosene rise the lowest point of graduation, material is cautiously poured. As the first gradation if achieved, stop the material to be poured. Note down the volume of the material. Calculate the weight of material used

3 RESULTS

In this Chapter results of all the experimental work conducted till date are given in respective tables. In this discussion of the results obtained after conducting various tests is donechapter all the results obtained from various tests are discussed Results obtained during identification and isolating bacteria with calcite precipitating properties of calcite precipitating bacteria The data of the size of colonies obtained, and time for obtaining those colonies are given in Table 2

Table 2 Time taken for colonies appearance along with their size

Isolate No.	Sample No.	Colony Size	Shape	Colour
1	1	Small	Round	Greyish white
2	1	Small	Perfectly Round	Greyish white
3	1	Small	Round	White
4	1	Very Small	Round	White
5	1	Small	Round	Pale White
6	1	Small	Irregular Round	Pale White
7	1	Small	Round	White
8	1	Small	Round	Pale White
9	1	Very Small	Perfectly Round	Greyish White
10	1	Very Small	Round	White turned safranin
11	1	Small	Irregular Round	White turned green

From these outcomes, sub culturing was done of some selected isolates with purpose to get the best bacterial isolate of all..11 particular isolates of bacteria, including the isolate obtained from MTCC located in Chandigarh were acquired on petri dishes subsequent to developing urea stock cylinders. The morphology of chosen isolates is shown in Table 3

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Table 3 Morphology of Selected Isolates.

Sample No.	Colonies Size	Time taken to obtain colonies
1	Small	3 days
2	Medium	4 days
3	Small	4 days
4	Very Small	4 days
5	Medium – Large	4 days
6	Very Small	5 days
7	Small	3 days
8	Small	5 days
9	No colony	-
10	Medium	5 days

3.1 Calcite Precipitation Results

From the test it was concluded that the isolated 1, 3, 4, 5, 6, are heavy calcite precipitating bacteria. Table 4 shows the difference in the weight isolates on dry filter paper having calcite and empty filter paper.

Table 4 Calcite Precipitation Results

Isolate No.	Weight of Calcite Precipitated (mg)	Isolate No.	Weight of Calcite Precipitated (mg)
1	79.6	7	45.1
2	68.9	8	39
3	117.5	9	16
4	86.4	10	47.6
5	68.9	11	51.1
6	92		

3.2 Urease Assay Results

Isolates 5 & 9 showed negative urease activity. It means that when the test was conducted the isolates did not show any colour change towards the test.

Table 5 Results of urease activity.

Isolate No.	Colour Change	Urease Activity	Isolate No.	Colour Change	Urease Activity
1	Yes	+	7	Yes	+
2	Yes	+	8	Yes	+
3	Yes	+	9	Yes	-
4	Yes	+	10	Yes	+
5	Yes	-	11	Yes	+
6	Yes	+			

3.3 Materials Testing Results

The results obtained from conducting various test on materials like cement, sand, aggregate were compared with the standard values specified in Indian Standards. It was concluded that all the materials satisfy the conditions given in Indian Standards and hence can be used in our study. Table 6 gives the data of the test performed along with the value obtained from the tests.

Table 6 Material Testing Results

S. No.	Test performed	Value Obtained
1	Standard consistency of cement	30%
2	Initial Setting Time of cement	40 min
3	Final Setting Time of cement	230 min
4	Soundness of cement	2.43 mm
5	Fineness of cement	2.18%
6	Specific Gravity of cement	3.15
7	Fineness Modulus of Fine Aggregate	Conforming to Zone 1 of Table 4 IS 383
8	Specific Gravity of Fine Aggregate	2.70
9	Specific Gravity of Coarse Aggregate	2.80
10	Specific Gravity of Fly Ash	2.2
11	Specific Gravity of Silica Fume	2.2
12	Specific Gravity of HRWRA	1.1, Solid, Content 42%

3.4 Compressive Strength Test Results

Compressive strength test results performed on concrete specimen at interval of 7, 14 and 27 days respectively are shown in Figure 2

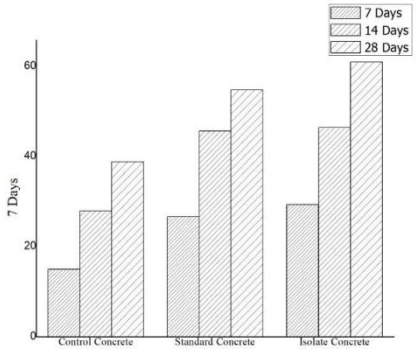

Figure 4 Compressive strength of control, isolate and standard concrete at 7, 14, 28 days respectively

4 CONCLUSION

Results from this investigation revealed that, in concrete microbial cells can be utilized for purpose of crack healing of both Macro and Micro sizes. From the isolation stage, 11 bacterial cultures having potential are isolated, and when the further screening proceeded, the number reduced to just 2. It is because of the concrete's high alkaline harsh environment. The survival of major group of bacterial genus becomes difficult in such a high pH environment. In this way it can be said that only those isolates which can survive in high pH environment needs to be isolate, separated for use in concrete. Test conducted on concrete revealed that the performance of concrete with microorganisms in it showed higher strength and better characteristics when compared to control concrete (without bacteria). This happened due to the presence of calcite precipitating bacteria in concrete which filled the pores inside matrix and the cracks appeared on the surface with thin calcium carbonate crystals. Bacteria is only able to precipitate Calcium carbonate when it gets nutrition i.e rich calcium course and moisture. However the moisture requirement and food requirement of the colony of bacteria is so less that it can be fulfilled with the moisture present in air and minute food particles travelling in air .Whitish-yellow colored crystals were observed near the crack surfaces when visual inspection of the crack was done at 7 days of concrete casted. As the investigation further continued for 28 days it was observed that the highest crack healed in comparison to both isolate and control concrete was found in Standard concrete system. According from this investigation following conclusion were drawn.

I. It is better to use soil which is rich in lime and magnesia in order to obtain calcite precipitating bacteria. As the chances of getting one in such soil is quite higher
II. For developing bacterial cells, it was observed that rather than using direct plate technique we should use enrichment culture technique. With the help of this technique we can limit the growth of other bacteria which are not required
III. The concrete with Standard culture of bacteria showed highest compressive strength 60.92 (MPa) when compared to compressive strength of Isolate concrete 54.74 (MPa) and control concrete specimen 38.80 (MPa).
IV. Only those bacterial isolates can be used in crack healing of concrete which show positive urease activity and endospore formation. It is a fact that the microscopic organisms which are unable to frame endospore can't survive in an exceptionally highly alkaline environment of new concrete.

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