Analysis of Strength Parameters of Bacterial Concrete

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Abstract: The objective of the present investigation is to obtain the performance of the concrete by the microbiologically induced special growth. One such thought has lead to the development of a very special concrete known as Bacterial Concrete where bacteria is induced in concrete used to mix the ingredients to make concrete. Here an introducing attempt was made by using the bacteria "Bacillus flexus"

Concrete cubes were casted with and without addition of bacteria and it is observed that there is an improvement in the compressive strength for the cubes with the addition of bacteria. Concrete cylinders with and without addition of bacteria was cast and it is observed that there is an improvement in the Split tensile strength for the cylinders with the addition of bacteria and Concrete beams are casted with and without bacteria, we observed that increasing flexural strength of beams casted with bacteria. The maximum strength in all cases occurred at bacterial concentration of 10^5 cells/ml.

Key words: bacillus flexu, bacterial concrete, compressive strength, concrete, slump cone test, split tensile test, Vee-bee consistency test.

I. INTRODUCTION:

1.1 General:

Concrete is an artificial material in which the aggregates both fine and coarse are bonded together by the cement when mixed with water. The concrete has become so popular and indispensable because of its inherent in concrete brought a revolution in applications of concrete. Concrete has unlimited opportunities for innovative applications, design and construction techniques. Its great versatility and relative economy in filling wide range of needs has made it is very competitive building material.

Many researchers have recorded the benefits of microbial concrete which includes the enhancement of compressive strength, reduction of maintenance cost and reinforced corrosion in construction materials. The use of microbial concrete in civil Engineering has become increasingly popular. Microbial concrete technology has proved to be better than many conventional technologies because of its eco- friendly nature, self-healing abilities and very convenient for usage. This novel and innovative concrete technology will soon provide the basis for an alternative and high quality structures that will be cost effective and environmentally safe but, more work is required to improve the feasibility of this technology from both an economical and practical viewpoints.

The application of microbial concrete to construction may also simplify some of the existing construction processes and revolutionize the ways of new construction processes. The process can occur inside or outside the microbial cell or even some distance away within the concrete. Often bacterial activities simply trigger a change in solution chemistry that leads to over saturation and mineral precipitation. Use of these Bio mineralogy concepts in concrete leads to potential invention of new material called Bacterial Concrete.

1.2 Bacterial Concrete:

The concept of bacterial concrete was first introduced in by H..Jonkers et al. Building with concrete that is able to heal itself. It might seem like a far cry, but if microbiologist and inventor Henk Jonkers from the TU Delft has anything to do with it, this will soon be reality. This Dutch researcher has developed the bio-concrete of the future, inspired by nature: concrete with bacteria embedded in it. Jonkers: What makes these limestone-producing bacteria so special is that they are able to survive in concrete for more than 200 years and come into play when the concrete is damaged. For example, if cracks appear as a result of pressure on the concrete, the concrete will heal these cracks itself. Numerous applications are possible for this invention and it has currently been translated.

A novel technique is adopted in remediating cracks and fissures in concrete by utilizing microbiologically induced calcite ($CaCO_3$) precipitation. Microbiologically induced calcite precipitation (MICP) is a technique that comes under a broader category of science called biomineralization. *Bacillus all mixture* , a common mix of six bacterias it can induce the precipitation of calcite. As a microbial sealant, $CaCO_3$ exhibited its positive potential in selectively consolidating simulated fractures. Microbiologically induced calcite precipitation is highly desirable because the calcite precipitation induced as a result of microbial activities, it is pollution free and natural. The technique can be used to improve the compressive strength and stiffness of cracked concrete specimens. The bacteria concrete makes use of calcite precipitation by bacteria. The phenomenon is called microbiologically induced calcite precipitation (MICP). The pioneering work on repairing concrete with MICP is reported by the research group of Ramakrishna V and others the South Dakota School of Mines & Technology, USA. The MICP is a technique that comes under a broader category of science called biomineralization. It is a process by which living organisms or bacteria form inorganic solids. *Bacillus all mixture,* a common bacterium, can induce the precipitation of calcite.

Under favorable conditions, when used in concrete, can continuously precipitate a new highly impermeable calcite layer over the surface of the already existing concrete layer better than other bacterial group. The precipitated calcite has a coarse crystalline structure that readily adheres to the concrete surface in the form of scales. In addition to the ability to continuously grow upon itself, it is highly insoluble in water. It resists the penetration of harmful agents (chlorides, sulphates, carbon dioxide) into the concrete thereby decreasing the deleterious effects they cause. Due to its inherent ability to precipitate calcite continuously, bacterial concrete can be called a Smart Bio Material‖ for repairing concrete. The MICP comprises a series of complex biochemical reactions. It is selective and its efficiency is affected by the porosity of the medium, the number of cells present and the total volume of nutrient added. The phosphate buffer or urea-$CaCl_2$ has been found effective as nutrients. The bacteria precipitate calcite in the presence of nutrients. The optimum pH for growth of *Bacillus* bacteria is around 13.

The alkaline environment of concrete with pH around 12 is the major hindering factor for the growth of bacteria. However the microbial modified concrete has become an important area of research for high-performance construction materials. The effects of incorporating a facultative anaerobic hot spring bacterium on the microstructure of a concrete. Environmental scanning electron microscopic (ESEM) views and image analysis (IA) of the bacteria modified mortar (thin-section) showed significant textural differences with respect to the control (without bacteria) samples.

II. Scope and Objective of Study:

Bacterial concrete is the new innovative technique, in which the bacteria are added to the concrete mix to enhance the strength and also it act as a excellent self-healing agent. If a method could be developed to automatically repair cracks in concrete this would save an enormous amount of money, both on the costs of injection fluids for cracks and also on the extra steel that is put in structures only to limit crack widths. A reliable self-healing method for concrete would lead to a new way of designing durable concrete structures which is beneficial for national and global economy. The Bacterial Concrete‖ can be made by embedding bacteria in the concrete that are able to constantly precipitate calcite. This phenomenon is called microbiologically induced calcite precipitation. As per the present investigation it has been shown that under favorable conditions for instance *Bacillus all mixture*, a common mixture bacterium, can continuously precipitate a new highly impermeable calcite layer over the surface of an already existing concrete layer. Furthermore the bacteria should be suspended in a certain concentration in a certain medium before they are mixed through the concrete ingredients. Optimization is needed here, which involves experimental investigation.

Detailed investigations carried out by V. Ramakrishna have shown that *Bacillus pasteurii* bacteria can be used for improving the strength and durability of concrete. However, not much investigation is carried out in India for producing bacterial concrete. Keeping this in view, the present experimental investigations are taken up to study the strength in Ordinary grade(M_{20}) concrete before and after cracking of concrete with and without addition of bacteria *Bacillus all mixture, group* of bacterias.

The main **objective** of the present experimental investigation is to study the strength of before and after cracking of concrete on ordinary grade concrete. The present work is divided into three phases, they are

Phase-1: Culture and growth of Bacterias.

Phase-2: To study the compressive strength, split tensile strength and flexural strength of concrete.

Phase-3: To study the compressive strength, split tensile strength and flexural strength of concrete.

III.MATERIALS AND METHODS

3.1 General:

The main objective of the present experimental investigations is to obtain specific experimental data, which helps to understand the Bacterial concrete and its characteristics (Strength and Durability). In the present experimental investigation, studies have been carried out on the behavior of fresh and hardened properties of ordinary grade concrete with and without addition of Bacteria. The hardened properties like compressive strength of cement mortar, compressive strength and split tensile strength of concrete, are determined by conducting suitable laboratory tests on concrete in hardened state.

3.2 Ingredients:

For this experimental study, the following materials were used:

1. **Coarse Aggregate**: Crushed angular granite from local quarry is used as coarse aggregate. The cleaned coarse aggregate is chosen and tested for various properties such as specific gravity, fineness modulus, bulk modulus etc. The physical characteristics are tested in accordance with IS : 2386 – 1963.
2. **Fine aggregate:** The locally available river sand is used as fine aggregate in the present investigation. The cleaned fine aggregate is chosen and tested for various properties such as specific gravity, fineness modulus, bulk modulus etc. in accordance with IS : 2386-1963.
3. **Water:** Water used for mixing and curing is fresh potable water, conforming to IS:3025-1964 part 22,part 23 and IS: 456-2000.
4. **Calcium lactate:** The calcium lactate was needed for bacteria to severing purpose to add the 10 gms per kg of cement.
5. **Bacteria:** *Bacillus flexu*, a laboratory cultured bacterium is used.

3.3 Mix Design:

Ordinary grade concrete (M20)

Mix proportion:

W/c ratio	=	0.50
Cement	=	383kg/m^3
Fine Aggregate	=	538.67 kg/m^3
Coarse Aggregate	=	1189.57kg/m^3

3.4 Casting of Test Specimens:

For estimating the compressive strength, split tensile strength and flexural strength on hardened concrete, we have prepared cubes, cylinders and beams as test specimens respectively. The cubes of 150mmX150mmX150mm size, the cylinders of150mm diameter and 300mm length and the beams of 150mmX150mmX450mm size were prepared. And cured for 7days and 28 days.

3.5 Tests Conducted:

The following tests were conducted on the casted specimens:

Workability tests:

- Slump cone test
- Compaction factor test

- Vee-bee consistency test

Strength tests:

- Compressive strength test for 7 days and 28 days on cubes
- Split tensile strength test for 7 days and 28 days on cylinders
- Flexural strength test for 7 days and 28 days on beams

IV. Results

The results of the above mentioned tests are projected as follows.

4.1 Workability Tests

- **Slump cone test**

Table-4.1
Results of Slump cone test

Description	Water cement ratio	Initial height	Final height	Slump of concrete in "mm"
without *Bacillus flexus* bacteria	0.50	300	178	122
With *Bacillus flexus* bacteria	0.50	300	180	120

- **Compaction factor test**

Table-4.1
Results of Slump cone test

S.NO	Description	without *Bacillus flexus* bacteria	With *Bacillus flexus* bacteria
1	Water cement ratio	0.50	0.50
2	Empty wt of cylinder W_1	4.310	4.310
3	Wt. of cylinder + partially compacted concreteW_2	16.5	16.9
4	Wt. of cylinder + fully compacted concreteW_3	17.3	18.1
5	Compacting factor of concrete	0.938	0.912

- **Vee-Bee consistency test**
  - The Vee-Bee consist meter for concrete is 5.2 sec for W/C Ratio of 0.50 without Bacillus Flexus bacteria.
  - The Vee-Bee consist meter for concrete is 4.9 sec for W/C Ratio of 0.50 with Bacillus flexus bacteria.

4.2 Strength Analysis

- **Compressive strength**

Table-4.3
Results of 7 days compressive strength test

S.NO	Bacillus flexus bacteria concentration	Load in KN	Strength in N/mm^2	Average Strength N/mm^2	Percentage of Increase %
1	Nil (control)	432	19.20	19.37	0.00
2		436	19.37		
3		440	19.55		
4	10^4	756	33.60	33.40	72.43
5		754	33.51		
6		745	33.11		
7	10^5	810	36.00	35.93	85.49
8		814	36.17		
9		802	35.64		
10	10^6	652	28.97	28.94	49.40
11		647	28.75		
12		655	29.11		
13	10^7	602	26.75	27.00	39.40
14		612	27.20		
15		609	27.06		

Table-4.4
Results of 28 days compressive strength test

S.NO	Bacillus flexus bacteria concentration	Load in KN	Strength in N/mm^2	Average Strength N/mm^2	Percentage of Increase
1	Nil (control)	726	32.26	32.32	0.00
2		731	32.48		
3		725	32.22		
4	10^4	946	42.04	42.05	30.11
5		951	42.26		
6		942	41.86		
7	10^5	1010	44.88	44.75	38.45
8		1002	44.53		
9		1009	44.84		
10	10^6	862	38.31	38.48	19.05
11		871	38.71		
12		865	38.44		
13	10^7	796	35.37	35.84	10.89
14		815	36.22		
15		809	35.95		

- **Split tensile strength**

Table-4.5
Results of 7 days split tensile strength test

S.NO	Bacillus flexus bacteria concentration	Load in KN	Strength in N/mm^2	Average Strength N/mm^2	Percentage of Increase
1	Nil (control)	202	11.43	11.74 N/mm^2	0.00%
2		212	11.99		
3		209	11.82		
4	10^4	231	13.07	13.16 N/mm^2	12.09%
5		238	13.46		
6		229	12.95		
7	10^5	251	14.20	14.16 N/mm^2	20.61%
8		247	13.97		
9		253	14.31		
10	10^6	227	12.84	13.04 N/mm^2	11.07%
11		233	13.18		
12		232	13.12		
13	10^7	215	12.16	12.52 N/mm^2	6.64%
14		222	12.56		
15		227	12.84		

Table-4.6
Results of 7 days split tensile strength test

S.NO	Bacillus flexus bacteria concentration	Load in KN	Strength in N/mm^2	Average Strength N/mm^2	Percentage of Increase
1	Nil (control)	236	13.35	13.08	0.00
2		228	12.91		
3		230	13.01		
4	10^4	268	15.16	14.80	13.14
5		257	14.54		
6		260	14.71		
7	10^5	278	15.73	15.71	20.10
8		281	15.90		
9		274	15.50		
10	10^6	247	13.97	14.27	9.09
11		253	14.31		
12		257	14.54		
13	10^7	252	14.26	13.82	5.65
14		239	13.52		
15		242	13.69		

- **Flexural strength**

Table-4.7
Results of 7 days Flexural strength test

S.No.	Bacterial concentration(cells/ml)	Flexural stress (N/mm^2)	Avg. stress (N/mm^2)	Percentage of increase %
1	-----	1.60	1.60	0
2		1.55		
3		1.70		
4	10^4	1.85	1.72	6.97
5		1.96		
6		2.10		
7	10^5	1.84	2.23	28.25
8		1.69		
9		1.72		
10	10^6	1.99	1.97	18.78
11		2.12		
12		2.05		
13	10^7	1.64	1.76	9.09
14		1.78		
15		1.72		

Table-4.8
Results of 28 days split tensile strength test

S.No.	Bacterial concentration(cells/ml)	Flexural stress (N/mm^2)	Avg. stress (N/mm^2)	Percentage of increase %
1	-----	3.10	3.15	0
2		3.15		
3		3.45		
4	10^4	2.65	3.56	11.51
5		3.00		
6		3.45		
7	10^5	3.15	4.01	21.44
8		3.21		
9		3.12		
10	10^6	3.98	3.79	16.88
11		4.25		
12		4.12		
13	10^7	3.17	3.65	13.69
14		3.15		
15		3.10		

V. Conclusion

The *addition* of *bacillus flexure bacteria* increases the compressive strength of concrete. In standard grade concrete the compressive strength is increased up to 38.45% at 28 days, split tensile strength up to 20.10% at 28 days and flexural strength up to 21.44% at 28 days by addition of *bacillus flexure* bacteria when compared to Conventional concrete. The addition of *bacillus flexure bacteria* showed significant improvement in the split tensile strength than the conventional concrete. Compared to conventional concrete, bacterial concrete is best in economical.

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