COMPARATIVE STUDY OF MECHANICAL PROPERTIES OF SHC WITH AND WITHOUT PARTIAL REPLACEMENT OF FLY ASH IN EXTREME CONDITIONS

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Abstract : Now a day's concrete is used as the basic materials for the construction works. The concrete is good in compression but weak in the tensile strength. And it has a high tendency to form cracks due to less tensile strength. These cracks lead to significant reduction in concrete service life and high replacement costs. Although it is not possible to prevent crack formation, various types of techniques are in place to heal the cracks. It has been shown that some of the current concrete treatment methods such as the application of chemicals and polymers are a source of health and environmental risks, and more importantly, they are effective only in the short term. Thus, treatment methods that are environmentally friendly and long-lasting are in high demand. A microbial self-healing approach is distinguished by its potential for long-lasting, rapid and active crack repair, while also being environmentally friendly. Furthermore, the microbial self-healing approach prevails the other treatment techniques due to the efficient bonding capacity and compatibility with concrete compositions. This study provides an overview of the microbial approaches to produce calcium carbonate (CaCO3). Initial results show that the addition of specific organic mineral precursor compounds plus spore-forming alkaliphilic bacteria as self-healing agents produces up to 100- μm

This project is mainly focuses on variation of strength characteristics with respect to change in proportion and comparison of the same with traditional concrete along with determining mechanical properties of bio-concrete and bacterial fly ash concrete. The bacteria added for bio-concrete is 7% by the weight of cement and for the bacterial fly ash concrete the cement was replaced 20% by the weight of cement and the bacteria added in the form of liquid and having without its food, for bacillus Subtilis the food calcium lactate was added 10% by the weight of bacteria. The flexural test, split tensile test and compression test were performed on traditional concrete and with & without partial replacement of fly ash concrete, the total 3 beams of 100x100x500mm, 12 cylinders of 150mm diameter, 300mm length and 9 cubes of 150mmX150mmX150mm were casted using design mix M30 and mix proportion of 1: 1.64:3.0 as per IS code. These beams included one of traditional concrete, one of without fly ash, and one of partial replacement of fly ash The results obtained accrue the advantage obtained by the composite members when compared to standard reinforced concrete and plain concrete.

***IndexTerms* - Self Healing ConcreteAlkaliphilic, Compressive Strength, Bacillus Subtilis, Microbial, Flexural Strength, Quality**

I. INTRODUCTION

Cracks in concrete are the major problems in this era. Cracks can occur when changes to accommodate these factors are not implemented in the design and development. Other factors that can affect concrete and its lifespan include shrinkage, design flaws or poor quality of construction materials. Due to these factors in addition to several more it is inevitable that reinforced concrete eventually develop cracks. When cracks originate in concrete structures, a sequence of serious events begins to occur within those structures. Not only do these cracks affect the functionality of the structure, but they also affect the durability and strength of the structure.

In order to enhance concrete resistance to these defects and degradations, the innovation of bio concrete is promising. Bio concrete can be defined as concrete that possesses self-healing agents, which will 'automatically heal' concrete structures, used " Bacillus Subtilis " bacteria having food "calcium lactate" when cracks occur during their life cycle. Self-healing agents may be transferred through strong core microcapsules, hollow reinforced fibers and even by forms of organic matter. All of these methods are currently undergoing testing and analysis in order to test their durability and long evitable.

The bio concrete is one that senses its cracks formation and reacts to cure itself without human intervention. This phenomenon is same like the human bones are naturally healed by Osteo Blast Cells that mineralize to re-form the bone.

It is popularly known as "Self-Healing Concrete. This is because of its ability to rectify the crack by its internal activity and to extend the service life of any concrete structure

1.1 Introduction to Bacillus Subtilis Bacteria

Bacillus subtilis was originally named as Vibrio subtilis and renamed in 1872, this organism has other names as Bacillus uniflagellatus, Bacillus globigii, and Bacillus natto. Bacillus subtilis bacteria were one of the first bacteria to be studied. Bacillus subtilisis also known as hay bacillus or grass bacillus. Bacillus subtilis cells are rod-shaped, Gram-positive bacteria that are naturally found in soil and vegetation. Bacillus subtilis grow in the mesophilic temperature range. The optimal temperature is 25-35 degrees Celsius (Entrez Genome Project). Stress and starvation are common in this environment, therefore, Bacillus subtilis has evolved a set of strategies that allow survival under these harsh conditions. One strategy, for example, is the formation of stress-resistant endospores. Bacillus subtilis has historically been classified as an obligate aerobe, though evidence exists that it is a facultative aerobe. Bacillus subtilis is considered the best studied Gram-positive bacterium and a model organism to study bacterial chromosome replication and cell differentiation.

A bacteria called Subtilis belongs to Bacillus family has the capacity to heal the crack. The bacteria can survive in extreme conditions for 200 years. It consumes its food calcium lactate and secrete calcite which seals up the crack.

1.2 Objective of the Study

The main objectives of the project is, to test the properties of bacterial concrete with and without partial replacement of fly ash with conventional concrete which creates self-healing in the concrete. An important aim of the research is to test the mechanical properties of the concrete when cured in unclean and extreme conditions, despite of the ability of bacteria to sustain in extreme conditions up to about 2 centuries.

After completion, the concrete quality is checked by non-destructive tests like USPV and Rebound hammer test and later the compressive strength is determined using compressive testing equipment.

II. Materials

***Cement*:**

Cement is a fine, grey poweder, It is mixed with water and materials such as sand, gravel and crushed stone to make concrete. The cement and water form a paste that binds the other materials together as the concrete hardness. The ordinary cement contains two basic ingredients namely argillaceous and calcareous. In the present work 53 grade ACC cement was used rfor casting cubes and beams for all the concrete mixes. The cement was of uniform color i.e. grey with a light greenish shade and was free from any hard lumps and fulfilling the requirements as per IS 12269-1989

Fine Aggregate:

The sand used for the experimental works was locally procured and conformed to grading zone II. Sieve analysis of the Fine aggregate was Carried out in the laboratory as per IS 383-1970. The sp. Gravity of the fine aggregate is 2.64.

Coarse Aggregate:

Crushed Basalt stones obtained from local quarries were used as coarse aggregate. The maximum size of coarse aggregate used was passed through 25mm and retained on 20mm. The properties of coarse aggregate were determined by conducting tests as per IS:2386 (Part-III). The specific gravity of Coarse aggregate is 2.75

Water:

As Bacteria is used it may react with water so the water used in the concrete work should be free from injurious of acids, alkalis or other organic or inorganic impurities. Water which is being used should possess all the drinking water standards. But the water used here is tap water in order to check the consequences experimentally

Bacteria:

A Bacteria called Subtilis belongs to Bacillus family has the capacity to heal the crack. The bacteria can survive in extreme conditions for 200 years. It consumes its food Calcium lactate and secrete Calcite which seals up the crack. The bacteria is used in both powdered and liquid form

Calcium Lactete:

This Calcium Lactate is mixed with bacillus subtilis Bacteria. It acts as food for bacteria on consumption of which releases calcite helps in filling the crack.

III. Mix Design & Methodology

3.1 Calculation for mix proportion of M30 grade :

3.1.1 Target mean strength of concrete:

$f_{ck} = f_{ck} + 1.65 \text{ x } S$

Where,

f_{ck}= target average compressive strength at 28 days

f_{ck} = characteristic compressive strength at 28 days

S = Standard deviation

f_{ck}= 30+1.65x5.0

f_{ck} = 38.25 MPa

for S refer IS 10262:2009 Cl 3.2.1.2 Table No.1 page no.2 and In old IS 10262:1982 t value was taken from tableNo.2 of same IS page no. 6

3.1.2. Selection of water cement ratio:

Referring IS 10262:2009 Cl. 4.1 page no.2
The maximum water cement shall be taken from table No.5 of IS 456:2009 page no.20
From Table 5 of IS 456,
max. water cement ratio = 0.45

Adopt w/c ratio 0.42

0.42<0.45, hence Ok

3.1.3 Selection of water content:

Referring IS 10262:2009 Cl. 4.2 table No.2 page no.3

For 20mm nominal max. size of aggregate water content is 186 lit. for 25 to 50 mm slum range. Estimated water content for 25-50mm slump is 186 litre.

3.1.4 Calculation of cementitious content:

Water cement ratio = 0.42
Water content = 186+(6/100)*186
=197 lit
w/c = 0.42

197/0.42 = 405 kg

Therefore provided cement = 405 kg/ m^3

Which is greater than the minimum cement content of 300 kg/m3 for moderate exposure condition as per table No.4 of IS 456-2009.

3.1.5 Proportion of volume of coarse & fine aggregate content:

From IS 10262:2009 Cl no. 4.4.1 & table no. 3, page no.3

Volume of C.A corresponding to 20mm size aggregate & sand conforming to zone II for w/c ratio of 0.5 is 0.62

In present case w/c ratio is 0.42. Therefore volume of C.A is required to be increased for degrease in F.A content

Correction to be made at the rate of ± 0.01 for every 0.05 change in w/c ratio.

Therefore the corrected proportion of volume of C.A for the w/c ratio 0.42 is +0.016

Volume of C.A **= 0.64**

Volume of F.A = 1-0.64= **0.36**

3.1.6 Mix calculation:

a) Volume of concrete = 1 m^3

b) Volume of cement = (Mass of cement/ Specific gravity of cement) x (1/1000)
= (405/3.10)x(1/1000)

= 0.130 m^3

c) Volume of water = (Mass of water/ Specific gravity of water) x(1/1000)

= (170/1)x(1/1000)

= 0.170 m^3

d) Volume of all aggregate = [a- (b + c)]

= [1-(0.130+0.70)]

= 0.699 m^3

e) Mass of C.A = [d] x vol of C.A. x specific gravity of C.A x 1000

= 0.699x0.64x2.72x1000

= 1219.81 kg

f) Mass of F.A = [d] x vol of F.A. x specific gravity of F.A x 1000

= 0.699x0.36x2.65x1000

= 666.846 kg

3.1.7 Mix proportions:

Cement = 405 kg/ m^3
Water = 170 kg/ m^3
F.A = 666.6 kg/ m^3
C.A = 1218.83 kg/ m^3

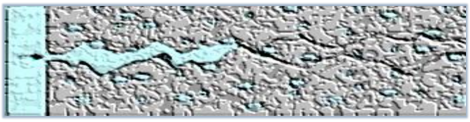
3.2. Mix design stipulation :

Grade designation	M 30
Type of cement	OPC 53 Grade
Grade Maximum nominal size of aggregate	20 mm
water-cement ratio	0.42
Workability	Medium
Exposure condition	Sever
Method of concrete placing	Manual
Degree of supervision	Good
Type of aggregate	Crushed angular aggregate
Proportion of Cement : Sand : Aggregate	1 : 1.64 : 3.0

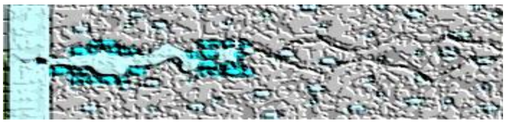
Table-1 : concrete mix design stipulation

Self-healing concrete is a product that will biologically produce limestone to heal cracks that appear on the surface of concrete structures. Specially selected types of the bacteria genus *Bacillus*, along with a calcium-based nutrient known as Calcium Lactate, and nitrogen and phosphorus, are added to the ingredients of the concrete 2% by volume when it is being mixed. These self-healing agents can lie dormant within the concrete for up to 200 years. However, when a concrete structure is damaged and water starts to seep through the cracks that appear in the concrete, the spores of the bacteria germinate on contact with the water and nutrients. Having been activated, the bacteria start to feed on the Calcium Lactate. As the bacteria feeds oxygen is consumed and the soluble Calcium Lactate is converted to insoluble limestone. The limestone solidifies on the cracked surface, there by sealing it up. It mimics the process by which bone fractures in the human body are naturally healed by osteoblast cells that mineralize to re-form the bone. The consumption of oxygen during the bacterial conversion of Calcium Lactate to limestone has an additional advantage.

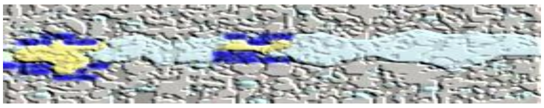
STAGE-1 : DEVELOPMENT OF CRACK



STAGE-2 : SPRINKLING OF WATER TO CRACK



STAGE-3: HEALING OF CRACK



IV. MATERIAL TESTING

The tests conducted on concrete elements were Compression Test on cubes by using CTM, flexural test (two-point load flexural test) on beams and split tensile test on cylinders. The number of specimens for each type of test is shown in Table2.

S.No.	Type of Testing	Specimens	Dimensions(in mm)
1	Compression Test	Cube	150X150X150
2	Split Tensile Test	Cylinder	150X300
3	Flexural Test	Beam	100X100X500

Table 2: Type of testing of specimens

4.1 Compressive Test :

For most of the works cubical moulds of size 15cm x 15cm x 15cm are commonly used.

This concrete is poured in the mould and tempered properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing.

These specimens are tested by compression testing machine after 7 days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm^2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

Fig.1: Test Setup to check compressive strength of cube

4.2 Flexural Strength Test

In order to check flexural strength of beam specimens are casted with dimension 100x100x500 mm. The different types of flexural beam specimen were:

- Traditional concrete
- Bacterial concrete with fly ash
- Bacterial concrete without fly ash

Fig.2: Test setup to check flexural strength of beam

4.3 Split Tensile Test :

For most of the works cylindrical moulds of size 15cm diameter and 30cm height are commonly used.
A method of determining the tensile strength of concrete using cylinders which splits across the vertical diameter. It is an indirect method of testing tensile strength of concrete.
Tensile strength formula :
Tensile strength = (2P/πLD)

Fig.3: Test Setup to check split tensile strength of cylinder

V. RESULTS & DISCUSSIONS

5.1. compressive strength test results :

Cubes	Traditional concrete	Bacterial concrete	Bacterial concrete with fly ash
7 Days	20.125 N/mm^2	4 N/mm^2	18.22 N/mm^2
14 Days	23.99 N/mm^2	6.66 N/mm^2	34.66 N/mm^2
28 Days	33.11 N/mm^2	27.55 N/mm^2	32.44N/mm^2

Table -3 : Compressive strength Results

5.2. Split tensile strength test results :

Cylinders	Traditional concrete	Bacterial concrete	Bacterial concrete with fly ash
7 Days	2.19 N/mm^2	1.48 N/mm^2	2.122 N/mm^2
14 Days	2.475 N/mm^2	1.626 N/mm^2	1.839 N/mm^2
28 Days	2.68 N/mm^2	2.475 N/mm^2	2.82 N/mm^2

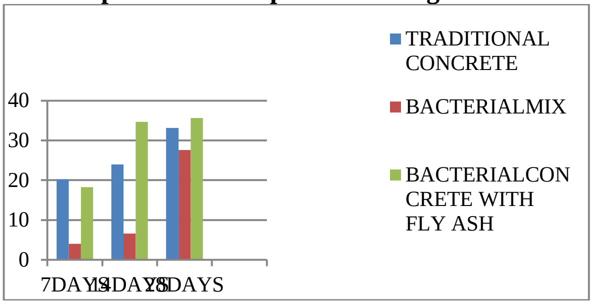
Table-4 : Split Tensile Strength Results

5.3. Flexural strength test results:

Beams	Traditional concrete	Bacterial concrete	Bacterial concrete with fly ash
28 Days	6.25 N/mm^2	7.5 N/mm^2	8.3 N/mm^2

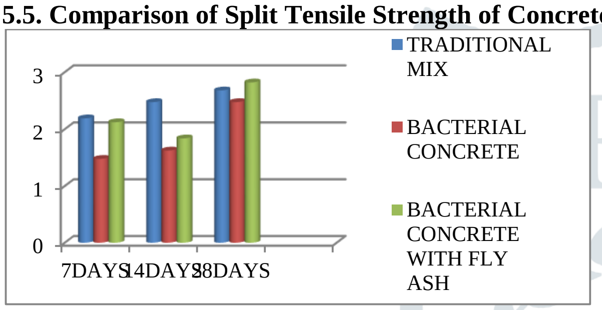
Table-5 : Flexural Strength Test Results

5.4. Comparison of compressive strength of concrete:



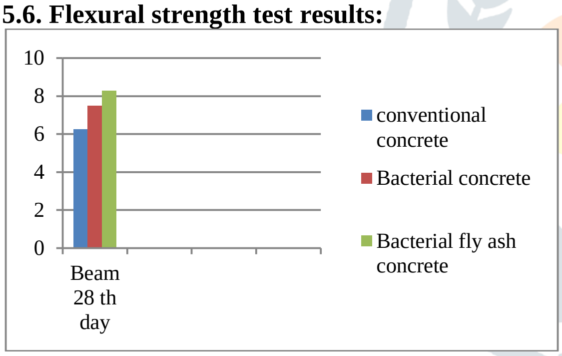
Graph-1 : Comparison of compressive strength

5.5. Comparison of Split Tensile Strength of Concrete



Graph-2 : Comparison of split tensile strength

5.6. Flexural strength test results:



Graph-3 : Comparison of Split tensile strength

There is lot of variation observed in strength when the Traditional concrete and Bacterial concrete were put under destructive tests.
To obtain the complete quality analysis, nondestructive tests like UPSV and rebound hammer tests were used.
The specimens prepared with bacteria with partial replacement of fly ash have given comparatively high strength than simple bacterial concrete. It is expected that the quality of concrete was good due to the reason, the fly ash particles were fine and filled up the pores.
From a research thesis, when the bacterial concrete mixed with distilled water and cured in potable water gave comparatively high results than the similar grade of concrete, mix proportion when mixed with regular water and cured in contaminated water.
Here the specimens are cured in unclean water to check the bacterial concrete properties in adverse conditions despite of property of bacteria that lives up to 200 years in extreme environmental conditions.
The cracks are expected to heal in 3 to 4 weeks.
The compressive strength of the cubes at 28th day for bacterial concrete is decreased about 16.79% and bacterial fly ash concrete is increased 19.11% as compared to the traditional concrete
The split tensile strength of the cylinder at 28th day for bacterial concrete is decreased about 7.64% and bacterial fly ash concrete is increased 8.2% as compared to the traditional concrete.
The Non-Destructive tests are done to check the quality of concrete like UPSV and Rebound hammer test and for both bacterial concrete and bacterial fly ash concrete got the results as good quality. But compare to the bacterial concrete the bacterial fly ash concrete have more quality and durability.

V. CONCLUSIONS & FUTURE RECOMMENDATIONS

Compressive strength trends of all bacterial mixes shows that incorporation of bacteria increases the strength as compared to the control mix. Concrete mix with B. megaterium and B. sphaericus exhibits maximum compressive strength which amount to be 16% and 15.95% respectively. The improvement in strength is mainly due to pores being filled with the microbial calcite precipitate produced by bacteria. In the visual quantification, images taken from the cracks surface of specimens confirmed the satisfactory performance of calcite precipitating bacteria 4 to 5 weeks are needed to get the crack sealed up. Due to its self-healing abilities, eco-friendly nature, increase in durability etc, it is better than the conventional technology. It is very effective in increasing the strength and durability of concrete. It also shows better resistance to drying shrinkage, resistance to acid attack, better sulphate resistance. Bacterial concrete prepared with admixtures like silica fume, fly ash etc, also gives better strength and durability. Thus, bacterial concrete can play a major role in modern construction, which requires precise technologies for producing high quality structures that will be cost effective and environmentally safe.

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