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Experimental Study on Strength of Bacterial Concrete with Bentonite as Partial Replacement of Cement in Concrete

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Abstract: The concrete is the composite material made by the combination of the cement, sand, coarse aggregate and water. It is versatile in nature and can be cast in diverse shape hence it is used in major part of the construction industry. But the major disadvantage of the concrete is the Co_2 emission, which will cause pollution to the environment. In order to control this emission to the environment the Bacillus bacteria is added to the concrete, which will absorb Co_2 and undergo Bio-mineralization of $Caco_3$. In this project an attempt is made to study the strength of bacterial concrete. To enhance the strength more, Bentonite powder is added as a replacement of 0%, 5% and 10% to the cement. Bentonite has strong colloidal property and which volume increases several times when coming in contact with water, creating a gelatinous and viscous fluid. The bacteria is added along with CaO which can precipitate calcite in crack and with that make the concrete structure water tight and enhance durability. This reduces the pores or cracks present in the concrete thus increasing the strength of the concrete.
Keywords: Bacillus Bacteria, bentonite, calcite formation, compressive strength.

1. Introduction:

Bacterial concrete is a special type of concrete it has the ability to repair the cracks in the concrete itself. This technique is highly desirable because the mineral precipitation induce as a result of microbial activities is pollution free and natural so the bacteria based self healing agent is believed to remain hibernated within the concrete for up to 200 years. When cracks appear in a concrete and water starts to seep in through the spores of the bacteria starts microbial activities on contact with water and oxygen. In this process of precipitating calcite crystal through nitrogen cycle the soluble nutrient are converted into insoluble $Caco_3$. The $Caco_3$ solidifies on the cracked surface, thereby sealing it up. The bacillus bacteria is mixed with Calcium oxide and then inserted into the clay pellets of size 4mm – 8mm and it is mixed with concrete.

Bentonite is absorbent aluminium phyllosilicate clay consisting mostly of montmorilliontie. The different types of bentonite are each named after the respective dominant element, such as Potassium (K), Aluminium (Al), Sodium (Na) and Calcium (Ca). Bentonite usually forms from weathering of volcanic ash from most often in the presence of water. It has 85% of clay minerals, montmorilliontie. It has excellent plasticity and lubricity, low permeability, low compressibility and high dry bonding strength.

2. Materials and Methods

Bacteria selection

A gram positive Bacillus bacterium is used along with CaO to precipitate $Caco_3$. Under stressful environmental conditions, the bacteria can produce oval endospores that are not true “spores”, but to which the bacteria can reduce themselves and remain in a dormant state for very long periods. Bacillus species can also occurs in extreme environment such as high pH, high temperature etc….

3. Properties of material

Ordinary Portland cement (OPC)

OPC 53 grade was used. It was examined as per Indian specifications and its properties are shown in table 1.

Table – 1: Physical properties of ordinary Portland cement

Fineness of Cement	3.5%
Standard consistency	31.6%
Initial setting time(min)	37 min
Final setting time(min)	216 min
Specific gravity	3.1

Properties of Bentonite:

- Bentonite presence strong colloidal properties
- Its volume increases several time when coming into contact with creating a gelatinous and viscous fluid
- The special property of bentonite are hydration, swelling, water absorption, viscosity and thixotropy
- The extent of hydration produces intercrystalline swelling.

Properties of Bentonite

CHEMICAL COMPOSITION	
Titanium oxide TiO_2	01.25
Ferric Oxide Fe_2O_3	10.91
Silica SiO_2	54.26
Aluminium Al_2O_3	18.34

PHYSICAL CHARACTERISTICS	
Specific Gravity	2.4
pH pH	8 to 8.8 8 to 8.8
Bulk Density gms/cc	0.6

Fine and coarse aggregate:

The aggregate which pass through 75mm IS sieve and retain on 4.75mm IS sieve are known as coarse aggregates. The coarse aggregate obtained from a local quarry has been used. The physical properties of coarse aggregate are fineness modulus, specific gravity are 2.31 and 2.89 respectively.

The aggregate which pass through 4.75mm IS sieve and retain on 75 micron IS sieve are known as fine aggregates. locally available river sand passing through 4.75mm IS sieve conforming to grade zone I of IS 383-1970 was used as fine aggregate. It was having a fineness modulus, specific gravity are 2.31, 2.89 respectively.

Concrete:

The size of the concrete cube is 100x100x100mm. The concrete mix design was carried out as per IS 10262-2009 FOR M4O grade of concrete. The ratio of mix is 1:1.38:2.41 with water-cement ratio of 0.40 were found out. Bentonite was added as partial replacement of cement at the concentrations of 0%, 5%, 10%. The concrete cubes are casted and cured for 28 days.

MIX PROPORTION IN Kg/m^3

Cement	Fine aggregate	Coarse aggregate	Water-cement ratio
450	623.63	1084.90	0.40
1	1.38	2.41	0.40

4. Literature Review

Meera C.M., Dr.Subha (2016) in this paper the experimental study shows that the addition of bacteria Bacillus Subtilis JC3 in concrete shows improvements in various properties of concrete in terms of compressive strength ,split tensile strength ,porosity ,acid resistance. As the bacteria can be produced in the laboratory, it could be proved to be safe and very cost effective. Bacterial concrete with a concentration of bacteria of 10^5 cells/ml was found to give best results out of the samples used. Hence it could be concluded that this particular concentration give optimum results which is proven by 42% increase in compressive strength and 63% increase in split tensile strength when compared to conventional concrete. Durability tests relieved that bacterial concrete have higher acid durability factor and higher acid attack factor from acid test results. Bacterial concrete exhibited lower rate of water absorption than conventional concrete. This is due to the bacteria induced formation of calcium carbonate in the porous present in concrete, leading to a lesser voids and hence a lesser permeability. Bacterial concrete is less vulnerable chloride attack also. The study accomplishes that the use of bacteria in concrete enhances its strength and durability hence using this type of bacteria for self-healing mechanism in concrete can produce cost effective strong or durable structures.

E.Schlangen, H.Jonkers, S.Qian & A.Garcia (2010) in this paper self healing techniques in three different materials are discussed. The first application is using bacteria to precipitate calcite in cracks in concrete. With this method relatively large cracks in reinforced concrete can be filled. The method does not lead to strength improvements of the structure, but by filling the cracks, the path to the reinforcement is blocked. Herewith the ingress of liquid and ions that start reinforcement corrosion is stopped and does the durability of the structure is enhancing. Furthermore this method is useful for water retaining structure. Cracks can be filled in this way and leakage can be stopped. Especially in underground structure were repair is difficult or impossible. Bacterial concrete has a big future. In the second application SHCC materials are studied, which have already a high potential for self-healing because of their small crack widths. New additions like microfibers and SAP's even promote this self healing capacity further. The third application is for asphalt concrete in which the self healing capacity is enlarged by using encapsulated oil micro-steel fibers. The later approach has been proven to work in the laboratory and will be applied in a real road in the Netherlands in 2010.

Chintalapudi Karthick , Rama Mohan Rao.P (2016) in this literature experiments have shown that the ability to heal the micro-cracks with the help of bacteria and healing agent was seen by SEM analysis and confirmed by XRD, that $CaCo_3$ precipitation helps in sealing the micro-cracks. The amount of bacteria added in concrete penetration results showed that high amount of bacteria added unsatisfied results. The compressive strength observed for 91 bases given satisfying results than compared to 28 day compressive strength observed for a bacterial concentration of 10^5 cells/ml. S.pasteurii formerly known as Bacillus pasteurii showed reduction in water absorption which increases the durability of concrete structures. The bacterial cells are potential admixtures in concrete helps in enhancing the mechanical performance of concrete. The SEM analysis and XRD analysis show the capability of producing calcite by S.pasteurii in the cement composites. Silica gel in concrete helps in protecting bacteria in high pH environment. This resulted in increase in ability to fill the cracks confirmed by ultra sonic pulse velocity tests and SEM images. The biological treatment of the cement composites result in the crack sealing and decrease in water permeability and the advantages of incorporating bio-based cement composites primarily reduce the maintenance costs, repair costs and hence results in increase of durability of the structures.

Shweta Puri , Manish Bhutani(2016) in this paper the investigation revealed that, as the partial replacement of cement by bentonite and coarse aggregates by recycled coarse aggregates in concrete mix increases, the workability of concrete mix decreases. The partial replacement of cement by bentonite at 10% and coarse aggregate by recycled coarse aggregates at 30% in concrete mix results in increase of compressive strength as compared to controlled mix whereas further replacement of cement with bentonite at 15% and coarse aggregates with recycled coarse aggregates at 45% decreases the compressive strength. The maximum increase in compressive strength was found when partial replacement of cement with bentonite at 10% and partial replacement of natural coarse aggregates with recycled coarse aggregates at 30% was 26.78Mpa for seven days 38.93Mpa for 28 days and 42.01Mpa for 56 days. Partial replacement of cement and coarse aggregates by bentonite and recycle coarse aggregate in concrete mix results in marginal increase of split tensile strength at 10% and 30% replacement as compared to control mix. The partial replacement of cement with bentonite at 10% and coarse aggregate with recycled coarse aggregate at 30% in concrete mix results in similar flexural strength as compared to control mix .from the SEM images of concrete containing 10% bentonite as partial replacement and 30% recycled aggregate as partial replacement of natural aggregate, very dense compact and continuous C-S-H gel formation over the entire image is observed resulting in the improved strength.

Results and Discussions

Test Results for Compressive Strength of Concrete Cube:

S.NO	W/C RATIO	PERCENTAGE OF CEMENT	PERCENTAGE OF BENTONITE	COMPRESSIVE STRENGTH at 28 days(N/mm^2)
1	0.40	100	0	38.4
2	0.40	95	5	40.9
3	0.40	90	10	42.1

Conclusion:

The Experimental study shows that the Concrete mixed with Bacillus Bacteria and Bentonite as partial replacement of cement increases the compressive strength of the concrete which is cast and cured for 28 days. The bacteria produced from laboratory are proved to be safe and economical and it is mixed with $CaCO_3$ .The use of bacteria in concrete enhances the strength of the concrete hence using this bacteria for self-healing mechanisms also. It has been found that the compressive strength of concrete with 10% partial replacement of bentonite shows better results when compared to cement with 0% and 5% partial replacement of bentonite.

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