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Experiment in Self-Healing Concrete by using FlyAsh as a Binder

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ABSTRACT:
Concrete is most widely used material in the construction work, but in some case the conventional concrete has lots of cracks in it, hence we can adopt the self-healing concrete. In our project we are using Bacillus subtilis along with the calcium lactate and fly ash for self-healing concrete. Here we are using M30 grade of concrete. We are using ordinary Portland cement of 53 grade and 20mm coarse aggregate. In the concrete we are mixing 35% of fly ash by replacing the fine aggregate. Adding 10, 10^1,10^2,10^3,10^4,10^5,10^6 and 10^7 cells/ml of bacillus subtilis and nutrient broth is added with it. We are testing compression strength test, tensile strength test by using compression testing machine and flexural strength test by using universal testing machine. The end result shows that the compressive strength of the bacteria mixed concrete is 25% greater than the conventional concrete, tensile strength of the bacterial mixed concrete is 15% greater than the conventional concrete and flexural strength of bacterial concrete is 25% greater than the conventional concrete.

Key Word: bacillus subtilis, calcium lactate, fly ash, compression testing machine, universal testing machine.

I. INTRODUCTION

Concrete is a strong and relatively cheap construction material and is therefore presentlythemostusedconstructionmaterialworldwide. Though concrete has a massive production, it exerts a negative effect on the environment. It is estimated that cement production alone contributes to about 7% of global anthropogenic CO2 emissions. In the construction sector, concrete is considered as one of the most important building materials around the world. Advancement in concrete technology is in its strength improvement and its enhancement in durability, using pollution-free and natural methods.

This needs to be taken care of at the design stage itself Autogenous rack-healing capacity of concrete has been recognized in several recent studies. Mainly micro cracks with widths typically in the range of 0.05 to 0.1 mm have been observed to become completely sealed particularly under repetitive dry/wet cycles. The mechanism of this autogenous healing is chiefly due to secondary hydration of non- or partially reacted cement particles present in the concrete matrix. The development of a self-healingmechanisminconcretethatisbasedonapotentially cheaper and more sustainable material then cement could thus be beneficial for both economy and environment. The main goal of the present research therefore was to develop a type of sustainable self-healing concrete using a sustainable self-healing agent. It was reported that the effect of bio -deposition improves the durability of cement mortar/concrete specimens.

Microbial Concrete

The microbial concrete makes use of calcite precipitation by favorable bacteria. In this technique Ureolytic bacteria (microorganism) are used hence the concrete is called Bacterial or Microbial concrete. The “Microbial concrete” can be prepared by adding spore forming bacteria in the concrete that are able to continuously precipitate calcite, this process of production of calcite precipitation is called Microbiologically Induced Calcite Precipitation (MICP). Recently, it is found that microbial calcite precipitation resulting from metabolic activities of favorable microorganisms in concrete improved the overall properties of concrete. Bacterial Cultures improves the strength of cement sand mortar and crack repair on surfaces of concrete structures.

The basic principle for this process is that the microbial urease hydrolyzes urea to produce ammonia and carbon dioxide and the ammonia released in surrounding subsequently increases pH, leading to accumulation of insoluble calcium carbonate [5]. Calcium carbonate precipitation, a metabolic process which occurs in some bacteria, has been investigated and proven its wide range of scientific and technological implications.

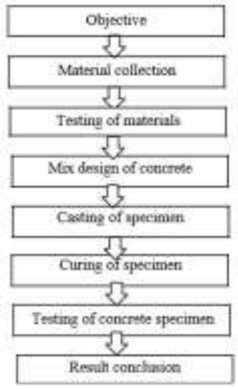
2. Performance of Bacteria in Concrete

Different types of bacteria, as well as abiotic factors (salinity and composition of the medium) contribute in a variety of ways to calcium carbonate precipitation. When bacteria are exposed to the air and the food, the bacteria grow through the bio chemical process that causes them to harden and fuse, strengthening the structure of concrete. This process extends the lifespan the concrete. When the concrete is mixed with bacteria, the bacteria go into a dormant state. When any cracks or minor damage occurred to concrete, it provides space for water and/or air entry within concrete and then spores of the bacteria initiate calcite precipitation process. Oxygen is an essential element for the corrosion of steel and when bacterial activity has consumed it then i t increases the durability of steel reinforced concrete constructions.

II. LITERATURE REVIEW

Ramakrishnan (2016) "Microbial Concrete with calcite" discussed about a novel technique in remediating cracks in concrete by utilizing microbiologically induced calcite ($CaCO_3$) precipitation (MICP), which is highly desirable chemical reaction because the calcite precipitation induced is a result of microbial activities. The technique can be used to improve compressive strength and stiffness of cracked concrete specimens. The effect of different concentrations of bacteria on the durability of concrete was also studied by him. It was found that all the specimens with bacteria performed better than the control specimens (without bacteria). The durability performance increased with increase in the concentration of bacteria up to optimum dosage.

III. METHODOLOGY



IV. MATERIALTESTING

Ordinary Portland Cement

Cement can be defined as the bonding material having cohesive & adhesive properties which makes it capable to unite the different construction material sand form the compacted assembly. Ordinary/Normal Portland cement is one of the most widely used type of Portland cement. The name Portland cement was given by Joseph Aspdin in 1824 due to its similarity in colour and its quality when it hardens like Portland stone. Portland stone is white grey limestone in island of Portland, Dorset.

1. PROPERTIES OF THE OPC

•Chemical properties
•Physical properties

1. Chemical properties

Portland cement consists of the following chemicalcompounds:
(a)Tricalciumsilicate$3CaO.SiO_2$ (C3S) 40%
(b) Dicalcium silicate$2CaO.SiO_2$ (C2S) 30%
(c)Tricalcium aluminate $3CaO.Al_2O_3$ (C_3A)11%
(d)Tetra calcium aluminate $4CaO.Al_2O_3.Fe_2O_3$ (C_3AF) 11%

There may be small quantities of impurities present such as calcium oxide (CaO) and magnesium oxide (MgO). When water is added to cement, C3A is the first to react and cause initial set. It generates greatamount of heat. C3S hydrates early and develops strength in the first 28 days. It also generates heat. C2S is the next to hydrate. It hydrates slowly and is responsible for increase in ultimate strength. C4AF is comparatively inactive compound.

2. Physical properties

The following physical properties should be checked before selecting aPortland cement for

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the civil engineering works. IS 269–1967 specifies the method of testing and prescribes the limits:
a)Fineness
b)Setting time
c)Soundness
d)Crushing strength.

(a)Fineness: It is measured in terms of percentage of weight retained after sieving the cement through 90-micron sieve or by surface area of cement in square centimeter per gram of cement. According to IS code specification weight retained on the sieve should not be more than 10 per cent. In Terms of specific surface should not be less than 2250 cm2/gm.

(b)Setting time: A period of 30 minutes as minimum setting time for initial setting and a maximum period of 600 minutes as maximum setting time is specified by IS code, provided the tests are conducted as per the procedure prescribed by IS 269-1967.

(c)Soundness: Once the concrete has hardened it is necessary to ensure that no volumetric changes takes place. The cement is said to beunsound, if it exhibits volumetric instability after hardening. IS code recommending test with Le Chatelier mould for testing this property. At the end of the test, the indicator of Le Chatelier mould should not expand by more than 10 mm.

BACILLUS SUBTILIS

We have selected Bacillus Subtilis, since it produces Calcium Carbonate and due to ease of availability. It is also known as Hay Bacillus or Grass Bacillus, is a gram-positive, Catalane-positive bacterium, found in soil and the gastrointestinal tract of ruminants and humans. A member of the genus Bacillus, B. Subtilis is rod-shaped, and can form a tough, protective endo-spores, allowing it to tolerate extreme environmental conditions. These bacteria are considered as the beststudied Gram-Positive bacterium and a model organism to study bacterial chromosome replication and cell differentiation.

Bacillus Subtilis is a Gram-Positive bacterium rod - shaped and catalase positive.it was originally named vibrio subtilis by Christian Gottfried Ehrenberg and renamed bacillus subtilis by Ferdinand Colm in 1872.Bacillussubtilisaretypicallyrodshapedandareab out4to10micrometer long and 0.25 to 1 micrometer in diameter with a cell volume of about 4.6 FL at stationary phase. As with other members of the genus bacillus, it can form an endospore to survive extreme environmental condition of temperature and desiccation.

Bacillus subtilis can divide symmetrically to make two daughter cells (Binary Fission), or symmetrically producing a single endospore thatcanremainviablefordecadesandisresistantto unfavourable environmental condition such as drought, salinity, extreme pH, radiation. It is found in soil, water, air decomposing plant matter.

CALCIUM LACTATE

Calcium lactate is a white crystalline salt with formula C6H10CaO6 consisting of two lactate anions for each calcium cation Ca2+. It forms several hydrates, the most common being the pent hydrate. Calcium lactate is used in medicine, mainly to treat calcium deficiencies; and asa food additive with E number of E327. Some cheese crystals consistof calcium lactate.

PROPERTIES OF CALCIUM LACTATE

Calcium lactate is a salt that consists of two lactate anions for each calcium cation (Ca2+). It is prepared commercially by the neutralization of lactic acid with calcium carbonate or calcium hydroxide. Addition of calcium lactate substantially increases the compressive strength andreduces water permeability of bio concrete.

Specially selected types of bacteria genus Bacillus, along with calcium-based nutrients known as calcium lactate & nitrogen phosphorus are added to the ingredients of the concrete when it is being mixed these self-healing agents can lie dormant within the concrete for up to 200 hundred years.

COURSE AGGREGATE

While the finished product is uniform and strong, concrete is made of many components, but is mostly made up of materials known as coarse aggregates. Coarse aggregates have a wide variety of construction applications because they resemble standard rock particles, as opposed to fine aggregate, which more closely resembles sand. Coarse aggregates are an integral part of many construction applications, sometimes used on their own, such as a granular base placed under a slab or pavement, or as a component in a mixture, such as asphalt orconcrete mixture.

PROPERTIES OF COARSE AGGREGATE

The properties of the coarse aggregate used in a concrete mixture affects the modulus for a few reasons. One property is the modulus of elasticity of the coarse aggregate. A higher aggregate modulus will result in aconcrete having a higher modulus. As expected, a lightweight aggregate will have a lower

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modulus than the mortar paste. Conversely, a strong aggregate produces a concrete that is stronger than the mortar paste (Zhou 180). In tests, concrete containing a higher percent of coarse aggregate resulted in a higher elastic modulus. As stated earlier, this is due to the aggregate being stronger than the mortar (Cetin andCarrasquillo 256).The particle shape of the aggregate contributes to theeffectiveness of producing a high-performance concrete. Crushed rock creates a much better bond between the paste and the aggregate than a gravel does. However, the aggregate -mortar bond may be more important in flexure tests than in compression tests. The mineral makeup of the aggregate also influences the modulus of elasticity of concrete. In a study by Aitcin and Mehta, they tested four different types of aggregates: diabase, limestone, gravel, and granite. Their test results showed that the limestone and diabase aggregates gave the highest values for the elastic modulus. The gravel performed poorly because of the weak bond between the aggregate and the cement paste. The granite aggregate, on the ot her hand, gave the worst results because of its mineral composition. In their granite sample, they found a mineral that is unstable in moist environments which is why the granite specimen's results were poor.

TEST FOR COARSE AGGREGATE

a)Specific gravity
b)Water absorption
c)Sieve analysis

(a) SPECIFIC GRAVITY

Specific gravity of coarse aggregate is the ratio of the weight of given volume of aggregates to the weight of equal volume of water The specific gravity of aggregates normally used in construction ranges from about 2.5 to 3.0 with an average value of about 2.68.

(b) WATER ABSORPTION

Water absorption is used to determine the amount of water absorbed under specified conditions. Factors affecting water absorption include: type of plastic, additives used, temperature and length of exposure. The data sheds light on the performance of the materials in water or humid environments.

(c) FINENESS MODULUS

Fineness modulus of coarse aggregates represents the average size of the particles in the coarse aggregate by an index number. It is calculated by performing sieve analysis with standard sieves. The cumulative percentage retained on each sieve is added and subtracted by 100 gives the value of fine aggregate.

USES OF COURSE AGGREGATE

1.They are easily available and they are economical as compared to cement
2.Aggregates provide additional strength to the concrete
3.Aggregates helps in binding the cement properly
4.If properly graded aggregates are used in concrete i.e. (fine + coarse) then the voids in the concrete will reduce and thus creating more strength
5.If the concrete is made only with cement it will shrink more and relatively more water is required for the cement to form workable paste so more amount of water means decrease in strength, and shrinkage causing c racks in the concrete

FINE AGGREGATE

Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 3\8-inch sieve used with a cement to produce either concrete or mortar.

1. PROPERTIES OF FINE AGGREGATE

Crushing strength, impact value abrasion resistance, and elastic modulus of aggregate are interrelated properties that are greatly influenced by porosity. Aggregates from natural sources that are commonly used for making normal-weight concrete, are generally dense and strong; therefore, they are seldom a limiting factor to strengthandelasticpropertiesofconcrete.

2. TEST FOR FINE AGGREGATE

a)Specific gravity
b)Water absorption
c)Sieve analysis

(a) SPECIFIC GRAVITY

Specific gravity of fine aggregate (sand) is the ratio of the weight of given volume of aggregates to the weight of equal volume of water. The specific gravity of sands is considered to be around 2.65.

(b) WATER ABSORPTION

It is calculated as the moisture content, which is equal to: (weight of the container with wet soil minus the weight of the container with dry soil)divided by (weight of the container with dry soil minus the weight ofthe container), then multiplied by 100 to express it as a percentage.

(c) FINENESS MODULUS

The Fineness Modulus (FM) is an empirical figure obtained by adding the total percentage of the sample of an aggregate retained on each of a specified series of sieves, and dividing the

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sum by 100. Fineness modulus offers a way to quantify the average size of the aggregateparticles in the concrete mix. The size of the particles, in turn, willgreatly affect how easily the concrete pours and spreads, as well as itsstrengthanddurabilityoncecured.

USES OF FINE AGGREGATE

1.Aggregates can be used for many different projects within the construction sector.
2.In concrete, an aggregate is used for its economy factor, to reduce any cracks and most importantly to provide strength to the structure.
3.In roads and railway ballast, it is used to help distribute the load and assist in ground water running off the road.

FLY ASH

Fly ash is a heterogeneous by-product material produced in the combustion process of coal used in power stations. It is a fine grey colored powder having spherical glassy particles that rise with the flue gases. As fly ash contains pozzolanic materials components which reach with lime to form cementations materials. Thus Fly ash is used in concrete, mines, landfills and dams.

PROPERTIES OF FLY ASH

1. Fineness of Fly Ash

As per ASTM, the fineness of the fly ash is to be checked in both dry n wet sieving. The fly ash sample is sieved in 45 micron sieve and the percentage of retained on the 45 micron sieve is calculated. Furtherfineness is also measured by LeChatelier method and Blaine Specific Surface method.

2. Specific Gravity of Fly Ash

The specific gravity of fly ash ranges from a low value of 1.90 for a sub-bituminous ash to a high value of 2.96 for an iron-rich bituminous ash.

3. Size and Shape of Fly Ash

As the flyash is a very fine material, the particle size ranges in between 10 to 100 micron. The shape of the fly ash is usually spherical glassy shaped.

Colour

The colour of the fly ash depends upon the chemical and mineral constituents. Lime content in the fly ash gives tan and light colours whereas brownish colour is imparted by the presence of iron content. A dark grey to black colour is typically attributed to an elevated un-burned content.

Uses of Fly Ash

1.Used in the manufacture of Portland cement.
2.Typically used for embankment construction.
3.Used as a soil stabilisation material.
4.Fly ash is also used as a component in the production of flowable fill.

VI. PROCEDURE:

1. Prepare the test specimen by filling the concrete into the mould in 3 layers of approximately equal thickness. Tamp each layer 35 times using the tamping bar as specified above.
2. Tamping should be distributed uniformly over the entire cross section of the beam mould and throughout the depth of each layer.
3. Clean the bearing surfaces of the supporting and loading rollers, and remove any loose sand or other material from the surfaces of the specimen where they are to make contact with the rollers.
4. Circular rollers manufactured out of steel having cross section with diameter 38 mm will be used for providing support and loading points to the specimens. The length of the rollers shall be at least 10 mm more than the width of the test specimen. A total of four rollers shall be used, three out of which shall be capable of rotating along their own axes. The distance between the outer rollers . shall be 3d and the distance between the inner rollers shall be d. The inner rollers shall be equally spaced between the outer rollers, such that the entire system is systematic.
5. The specimen stored in water shall be tested immediately on removal from water; whilst they are still wet. The test specimen shall be placed in the machine correctly centered with the longitudinal axis of the specimen at right angles to the rollers. For moulded specimens, the mould filling direction shall be normal to the direction of loading.
6. The load shall be applied at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0cm specimens.

2. CASTING OF SPECIMEN

Moulds used for casting specimens are well cleaned and its inner surface is oiled. Concrete is filled in to the cubes in two layers, cylinders in three layers and prism in 3 layers, compacting each layer 25 times by using tamping rod. Cubes of size 150 X 150 X 150 mm, Cylinders ofsize 150 mm diameter and 300 mm length and prism of size 150 x 150x 700 mm were casted.

3. CURING OF SPECIMEN

Curing of Concrete is a method by which the concrete is protected against loss of moisture required for hydration and kept within the recommended temperature range. Curing will increase the strength and decrease the permeability of hardened concrete.

CONCLUSION

Splittensilestrength,compressivestrengthalongwithflexuralstrength of concrete having Bacillus subtilis bacteria, show increment in comparison to control mix.

Compressive, split tensile along with flexural strength of concrete shows increment with increasing values of bacterial cells concentration (for 10, 102,103,104,105 cells/ml). Upto 105 cells/ml strength increases and at 106 cells/ml strength decreases.Strength increases with addition of bacteria upto certain cell concentration but after that level of cell concentration strength of the structure decreases.

The optimal value of cell concentration for achieving the highest compressive, split tensile and flexural strength is 105 cells/ml. Addition of Bacillus subtilis bacterium species shows increment in concrete strength due to its ability to form calcite precipitate. Calcium carbonate precipitate clogs the pores and heals the cracks of concrete resulting in better strength.

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