PROPERTIES OF BIO-CONCRETE

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Abstract : Concrete plays a major role in the construction industry. For a durable structure, good quality concrete must be used. A Self- Healing Concrete for the Future which says a common soil bacterium was used to induce calcite precipitation which is highly desirable because the mineral precipitation induced as a result of microbial activities is pollution free and natural. The workability test of the bacterial concrete resulted in 90mm of slump value. We have found out that the compressive strength of the bacterial concrete with 10% and 20% of addition of bacillus sphaericus as 13.07% and 13.75 % respectively. Same way we have found out that the split tensile strength of the bacterial concrete with 10% and 20% of addition of bacillus sphaericus as 3.15% and 7.25% respectively. We have also casted a beam of size 500mm x 100mm x 100mm with 20% addition of bacillus sphaericus and made some tiny cracks by giving little load and the observation of the healing process of the crack is going on.

I. INTRODUCTION

Concrete is the most commonly used building material which is recyclable. It is strong, durable, locally available and versatile. It is capable to resist the compressive load to a limit but if the load applied on the concrete is more than their limit but if the load applied on the concrete is more than their limit of resisting load, it causes the strength reduction of concrete by producing the cracks in concrete and the treatment of cracks is very expensive. Cracks in concrete affects the serviceability limit of concrete. The ingress of moisture and other harmful chemicals into the concrete may result in decrement of strength and life. The ingress of sulphates and chlorides in concrete results in decrease of durability. These effects in concrete structures by cracking might be overcome by utilizing self-healing technology which has high potential to repair cracks in concrete and enhance the service life of concrete structures with a reduction of demand for repair and maintenance. Self-healing agents such as epoxy resin, bacteria, fiber, etc., are used to heal cracks in concrete. Among these bacteria is used commonly and is found to be effective. When the bacteria is mixed with concrete the calcium carbonate precipitates forms and these precipitates fills the cracks and makes the concrete free from cracks. Self-healing concrete is a product which biologically produces limestone by which cracks on the surface of concrete surface heal. Selected types of the bacteria genus Bacillus, along with calcium-based nutrient known as calcium lactate, and nitrogen and phosphorous are added to the concrete when it is being mixed. The self-healing agents can lie dormant within the concrete for up to two hundred years. When a concrete structure damages and water starts to penetrate in the cracks present in it the bacteria starts to feed on the calcium lactate consuming oxygen and converts the soluble calcium lactate into insoluble limestone. The limestone formed thus seals the cracks present. It is similar to the process of how a fractured bone gets naturally healed by osteoblast cells that mineralize to reform bone. Consumption of oxygen in the bacterial conversion as an additional advantage. Oxygen which becomes an essential element for the corrosion of steel to take place is being used in the bacterial conversion. Hence the durability of steel in construction becomes higher. The process of bacterial conversion takes place either in the interior or exterior of the microbial cell or even some distance away within the concrete. Often the bacterial activities trigger a change in the chemical process that leads to over saturation and mineral precipitation. Utilization of concepts of bio mineralogy in concrete lead to invention of a new generation concrete in which selective cementation by microbiologically-induced CaCO3 precipitation has been introduced for remediation of micro-cracks.

1.1 Bio Concrete-The Living Concrete

Bio concrete is an example of linking nature with construction. The bio concrete or the living concrete is mixed in the same way as that of regular concrete but the extra ingredient i.e. the healing agent is added. This agent remain intact while mixing and placing, it becomes active only when it comes in contact with water if the concrete cracks. The healing agents can remain dormant in concrete for about 200 years1. Bio concrete produces limestone (CaCO3) crystals to fill up the cracks appearing on the surfaces. When the cracks begin to form in the concrete structure water enters the cracks2. After coming in contact with water and oxygen, the inactive bacteria become active. They multiply and germinate in the calcium based nutrient (calcium lactate), while feeding on the lactate they combine calcium with carbonate ions to form limestone or calcite which seals the cracks. Bio concrete mimes the principle involved in healing of bones fractures in humans naturally by mineralization caused by osteoblast cells. The oxygen consumption not only helps in bacterial conversion of calcium lactate to limestone but also helps in reducing the oxygen content in concrete which creates a medium for corrosion. Due to bacterial conversion, the oxygen gets consumed thereby increasing the durability of steel reinforcement.

1.2: Bacteria Used in Bio Concrete

In suspension state, concrete mix is added with bacteria. Concrete being extremely alkaline in nature, the bacteria added should fit in some special norms. The added bacteria should be able to withstand the harsh environmental conditions of concrete. Concrete is a dry material and the pH value of cement and water when mixed is up to 13 which makes it confrontational as most of the organisms cannot survive in an environment having pH value higher than 10.

1.2.1: Types of Bacteria

Bacteria naturally occur in nature in various forms. They are present not only on the surface but also beneath the surface of the earth. The various bacteria that can be used in concrete are:

1.2.2: Anaerobic Bacteria

If anaerobic bacteria like closely related specie of shewanella are added to concrete, the compressive strength increases from 25-30%

1.2.3: Aerobic Bacteria

The various types of aerobic bacteria that can be used in concrete are:

a. Bacillus pasteurii
b. Bacillus sphaericus
c. Escherichia coli
d. Bacillus subtili
e. Bacillus cohnii
f. Bacillus pseudofirmus
g. Bacillus halodurans
h. Bacillus massiliensis

It has been observed after 7 days strength the s.soli and L. fusiformis showed better compressive strength while as B. massiliensis and A. crystallopoietes no strength improvement was observed. A.crystallopoietes showed the maximum strength after 28 days.

II. Literature Review:

Z.P.Bhathena and NamrataGadkar1 , The screened urease producing isolates were checked for the ability to grow at varying ph. A total of 10 OUT (Operational Taxonomical Units) were obtained from 6 different samples after an incubation period of 7 days. Out of 10 isolates 8 isolates showed urease activity indicated by change in color of media around the colony. Out of 8 isolates only 3 isolates showed growth at all temperatures. The ability of the isolates to initiate calcium carbonate precipitation was assessed by in-vitro assay. Compressive strength of organisms within the cement matrix was analysed as per IS 4031:1988 taken after 3 and 7 days of curing in water. It was observed that their value was higher than the required value of OPC.value was higher than the required value of OPC.**Vijeth N Kashyap and Radhakrishna2** have published a paper on Study on effect of Bacteria on Cement composites. In this paper two different types of bacteria named Bacillus sphaericus and Sporosarcinapastuerii was obtained from Microbial type culture collection and gene bank, Chandigarh in a freeze dried condition.The cubes were cured under tap water at room temperature and tested at 7 and 28 days. The strength gain was about 39.8% and 33.07% in case of paste and 50% and 28.2% in mortar for sphaericus and Sporosarcinapastuerii respectively compared that of conventional mix. **L.Soundariet.al3,**For M25 grade concrete, with the addition of bacteria the percentage of improvement in the compressive strength is in the order of 12.32% to 30.05% at different ages, the percentage of improvement in the split tensile strength is in the order of 13.80% to 18.45% at different ages, the percentage of improvement in the flexural tensile strength is in the order of 13.19% to 15.56% at different ages.

III. METHODOLOGY AND MATERIAL

3.1: Test on materials:

3.1.1Compressive studies:

M20 concrete design mix was made as per I.S 10262:2009.Cubes of size 150mm X 150mm X 150mm were casted with and without adding bacteria and super absorbent polymer. Dosage of 50, 100 & 150 cells/ml bacteria were added in 2nd mix design while 0.5%, 1.0% and 1.5% of Super Absorbent Polymer (SAP) were added with respect to cement weight in 3rd mix design. Cubes then tested for compressive strength at 3, 7, 28, 56, 90 days as per I.S 516:1959

3.1.2: Durability studies:

An experimental program was conducted on controlled mix and optimum dosage of bacterial and SAP concrete sample. Specimens were immersed in 5% solution of Sulphate attack (H_2SO_4). The specimen are arranged in the plastic tubs in such a way that the clearance around and above the specimen is not less than 30 mm. The solution has been changed for an interval of 15 days after taking the measurement. The response of the specimen to the solution was evaluated through changed in compressive strength. for determining resistance of concrete specimen to aggressive environment the durability factors are proposed by the philosophy of ASTM C 666_1997, as the basis. In present investigation "Acid Durability Factor" (ADF) is derived with respect to the strength.

Acid Durability Factor (ADF) = Sr. (N/M)

Where, M= number of days at which the exposure is to be terminated.

N= numbers of days at which durability factor is needed

Sr. = relative strength at N days (%)

3.2: Materials:

The ordinary concrete used in the test program consisted of cementing materials, mineral aggregates and corrosion inhibitor with the following specifications:

Ordinary Portland Cement (43 Grade) Graded fine aggregates. Graded coarse aggregates.

Water. Bacteria – Bacillus subtilis

a. Ordinary Portland cement

The cement is a binding material. It conforming to IS456-2000-43 gradeThe clinker is cooled and ground to a fine powder with addition of 2 to 3% of gypsum the product formed by using this procedure Portland cement. Of all the materials that influence the behavior of concrete, cement is the most important constituent, because it is 11 used to bind sand and aggregate and it resists atmospheric action. Portland cement is a general term used to describe hydraulic cement.

b. Graded Fine Aggregates

The materials smaller than 4.75 mm size is called fine aggregates. Natural sand is generally used as fine aggregate. In this experimental work replacement of river sand by quarry waste (fineness modulus of crushed sand equal to 3.2)conforming to grading Zone III of IS – 383 – 1970 was used as fine aggregates

c. Graded Coarse Aggregate

Locally available well graded granite aggregates of normal size greater than 4.75 mm and less than 16mm having fineness modulus of 2.72 was used as coarse aggregates.

d. Water

The water is free from oils, acids, and alkalis and has a water-soluble Chloride content of 140 mg/lit. As per IS 456 – 2000, the permissible limit for chloride is 500 mg/lit for reinforced concrete; hence the amount of chloride present is very less than the permissible limit.

e. Bacteria

Bacillus sphaericus is an obligate aerobe bacterium used as a larvicide for mosquito control. It forms spherical endospores. Bacillus sphericum is a gram positive bacteria, with rod shaped cells that form chains-Medium-sized, smooth colonies with an entire margin. And also Rod-shaped cells. Gram-variable, large, spore-forming rods with a diameter < 0.9 µm. Catalase -positive. Lecithinase-negative. Does not attack sugars. Grow thing range of Temperature: 37 c Optimum Temperature- 35-37 c

3.2.1: Mix Proportioning

The quality of concrete mainly depends upon the proportioning of its constituents materials. The mix proportioning mainly influences the permeability of concrete and cause cracks. Design mix is more appropriate to know the exact behavior of cracks rather than nominal mix. In this experiment the concrete used is 20 Mpa having mix proportion of1:1.27:2.89 with water cement ratio 0.5.

3.2.2: Mix Design

The aim of studying the various properties of materials of concrete, plastic concrete and hardened concrete is to design a concrete mix for particular strength. Design of concrete mix needs complete knowledge of the various properties of the constituent material, the implications in place of change on the conditions at site, the impact of the properties of plastic concrete on the hardened concrete and the complicated interrelationship between the variables. Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. The mix design procedure is explained in the following section.

3.2.3: Indian Standard Method Design Stipulations

a. Concrete grade: M20
b. Exposure: Mild
c. Quality control: Fair
d. Size of aggregate: 20 mm
e. Degree of workability: 0.9
f. Cement used: OPC 43 grade cement
g. Sand grading zone: III

3.3: PREPARATION OF BACTERIA

3.3.1: Mixing of Bacteria

Luria Berta-powder form (6.75gms)+500ml of distilled water + peptone(3gms)+yeast extract(1.5gms)+Beef extract(1.5gms) +sodium chloride (3gms/100ml) +1Loop of Bacteria (gel medium) = Incubator 37oC

3.3.2: Preparation of Nutrient Agar

Bacteriological media came an wide range of types. Nutrient Agar is a complex medium. Nutrient Agar contains beef extract (0.3%), pepton (0.5%), and Agar (1.5%) in water. Beef extract is prepared as dehydrated form of autolysed beef and is supplied in the form of paste. Beef extract also contains water soluble digest products of all other macro molecules (nucleic acids, fats, polysaccharides) as well as vitamins trace minerals. Agar is purified from red algae in which it is an accessory polysaccharide (polyalacturonic acid) of their cell walls. Agar is added to microbiological media only as a solidification agent.Agar is an excellent solidification agent because it dissolves at near boiling point solidifier at 45ºC. Thus one can prepare molten (liquid) agar at 45ºC, mix cells with it, then allow it to solidify thereby trapping living cells. Below 45ºC agar is a solid and remains so as the temperature is raised melting only when greater than 95oC is obtained.

3.3.3: Processing of Bacteria

In this method Bacteria are added during casting of concrete. The amount of Bacteria added in the range of 10ml & 15ml/m3 of concrete. Concrete could soon be healing its own hairline cracking. Holes and pores of wet concrete are healed. Combined calcium with oxygen and carbon di oxide to form calcite is essential for healing tiny cracks which arrest the seepage of water. The technique of using soil bacterium is highly desirable because the mineral precipitation induced as a result of microbial activities, is pollution free and natural. Bacillus sphareciu s was yet another partially characterized species, having the capability of precipitating calcium carbonate. Its Far better would be to use bacillus sphaericus as a material that heals itself just as the cell divines and produces a visible mass. The colony isolated from other colonies, isolated colonies are assumed to be pure culture.

3.3.4: Culturing and Isolation

Microorganism must have a constant nutrient supply if they are to survive. Media may be liquid (broth) or solid (agar). Any desired nutrients may be in corporate in to the broth (or) agar to grow bacteria. Organism grown in broth cultures causes' turbidity, (or) cloudiness, in the broth. On agar, masses of cells known as colonies, appear after a period of incusation certain separated on agar so that as the cell divines and produces a visible mass. The colony isolated from other colonies, isolated colonies are assumed to be pure culture.

3.3.5: Ability of the Bacterial Concrete to Repair the Cracks

Both attention will be given on closure of cracks (blocking the path for ingress of water and ions) and on regaining mechanical properties. Cracks in concrete specimen subjected to various loading situations will be investigated before and after the healing. For this impregnation techniques and SEM will be applied. (Scanning electron microscope). On the other hand the micro-organisms such as bacteria, cyono bacteria, algae, lichens, yeasts, fungi and mosses etc. Which are omnipresent and omnipotent are responsible for metabolism action that results in a microbial deposition of a protective $CaCO_3$ layer. A so, this process results in re-establishment of the cohesion b\n particles of mineral building materials and protects against further decay of stone material. To prove the positive effects of microbial $CaCO_3$ precipitation. The increase in porosity in concrete leads to increase in capillary water uptake, increase in gas permeability along with higher carbonation rate, high chloride migration and freeze-thaw damage.

3.3.6: Processing of Bacteria

Concrete could soon be healing its own hairline cracking. Holes and pores of wet concrete are healed. Combined calcium with oxygen and carbon di oxide to form calcite is essential for healing tiny cracks which arrest the seepage of water.

3.4: EXPERIMENTAL STUDY

3.4.1 Process of Manufacture of Concrete

Production of quality concrete requires meticulous care exercised at every stage of manufacture of concrete. If meticulous care is not exercised, and good rules are not observed, the resultant concrete is going to be of bad concrete. Therefore, it is necessary for us to know what are the good rules to be followed in each stage of manufacture of concrete for producing good quality concrete. The various stages of manufacture of concrete are:

1. Batching 2. Mixing 3. Placing 4. Compacting 5. Curing

3.4.2: Weigh Batching

Weigh batching is the correct method of measuring the materials. For important concrete, invariably, weigh batching system should be adopted. Use of weight system in batching , facilitates accuracy , flexibility and simplicity. Different types of weigh batchers are available, the particular type to be used, depends upon the nature of job. When weigh batching is adopted, the measurement of water must be done accurately using measuring jars.

3.4.3: Hand Mixing

Hand mixing is practiced for small scale concrete works. Hand mixing should be done over an impervious concrete or brick floor of sufficiently large size to take one bag of cement. Spread out the measured quantity of coarse aggregate and fine aggregate in alternate layers. Pour the cement on the top of it, and mix them dry by shovel, turning the mixture over and over again until uniformity of colour is achieved. This uniform mixture is spread out in a thickness of about 20 cm. This operation is continued till such a good time a good uniform, homogenous concrete is obtained. It is a particular importance to see that the water is not poured but it is only sprinkled.

3.4.4: Placing

It is not enough that a concrete mix correctly designed, batched, mixed, it is of utmost importance that the concrete must be placed in systematic manner to yield optimum results. The precautions to be taken and methods adopted while placing concrete in the moulds.

3.4.5: Hand Compaction

Hand compaction of concrete is adopted in case of small concrete works. Sometimes ,this method is also applied in such situation, where a large quantity of reinforcement is used, which cannot be normally compacted by mechanical means. Hand compaction consists of rodding, ramming or tamping. When hand compaction is adopted, the consistency of concrete is maintained at a high level. Tamping is one of the usual methods adopted in compacting roof or floor slab or road pavements where the thickness of concrete is comparatively less and the surface to be finished smooth and level.

Figure 2: Hand compaction

3.4.6: Curing

Concrete derives its strength by the hydration of cement particles. The hydration of cement is not a momentary action but a process continuing for long time. Curing can also be described as keeping the concrete moist and warm enough so that the hydration of cement can continueThe casted cubes and cylinders are immersed in water tanks for 3 days, 7days, 14days and 28 days.

3.4.7: Workability of Concrete

Workability is the amount of useful internal work required to produce full compaction of concrete. It depends on,

1. Types of aggregate
2. Grading of coarse and fine aggregate
3. Quantity of cement paste
4. Consistency of the cement paste

5.1.8 Mixing, Compaction and Curing

After 24 hours, the specimens were remolded and kept immersed curing tank containing potable water till the required curing period of1:1.27:2.89 with water cement ratio 0.45cement replaced. The mix proportions are given in table. For control specimen the w/c ratio is 0.4. The same amount of water used for all other specimen. The following table shows the mix proportion used for all other specimens. In this study the effect of Bacillus Sphaericus in concrete is studied. Bacteria added in concrete with 10ml and 20ml proportions and proper curing makes a substantial improvement in enhancing the protection of embedded in concrete.

IV. RESULTS

The test results of bio concrete and conventional concrete showed an eloquent difference. The table and charts given shows the clear information regarding compressive strength of M20 Grade concrete.

TABLE 4.1: SHOWING COMPARISION OF RESULTS:-

S.NO	BACTERIAL CONCRETE				CONVENTIONAL CONCRETE		
	COMPRESSIVE STRENGTH (N/mm²)				COMPRESSIVE STRENGTH(N/mm²)		
	Name of bacteria	7 Days	14 Days	28 Days	7 Days	14 Days	28 Days
1.	Bacillus Subtilis (5%)	7	24	22.8	11.5	26.2	28.4
2.	Bacillus Subtilis (10%)	12.5	29.5	32.5	11.5	26.5	28.4
3.	Bacillus Subtilis (15%)	8.3	26	24.5	11.5	26.5	28.4

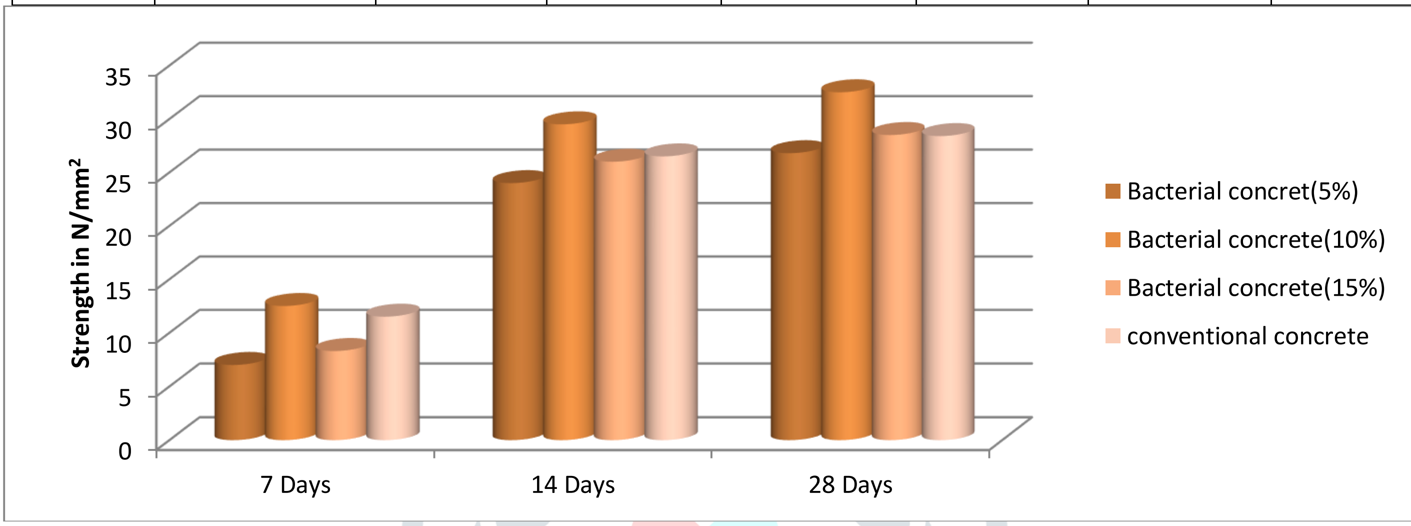

Fig. 4.1: Bar chart showing the comparison of conventional concrete and bacterial concrete.

V. CONCLUSION AND DISCUSSION

Concrete plays a major role in the construction industry. For a durable structure, good quality concrete must be used. A Self- Healing Concrete for the Future which says a common soil bacterium was used to induce calcite precipitation which is highly desirable because the mineral precipitation induced as a result of microbial activities is pollution free and natural. The workability test of the bacterial concrete resulted in 90mm of slump value. We have found out that the compressive strength of the bacterial concrete with 10% and 20% of addition of bacillus sphaericus as 13.07% and 13.75 % respectively. Same way we have found out that the split tensile strength of the bacterial concrete with 10% and 20% of addition of bacillus sphaericus as 3.15% and 7.25% respectively. We have also casted a beam of size 500mm x 100mm x 100mm with 20% addition of bacillus sphaericus and made some tiny cracks by giving little load and the observation of the healing process of the crack is going on.

Bacteria are added with the following:
1. Urea CaCl2
2. Buffer -solution (phosphate buffer)

Bacteria will not survive in water. So it cannot be mixed with water and it was found out in the Research when the bacteria mixed with Buffer - solution give better results. Even it will not change the pH value when added with acid (or) alkali is added to it. The bacteria will be mixed in different ratios in the specimen concretes for testing and Research. The cost of bacterial concrete when compared to conventional concrete is more or less the same which will not require any rehabilitation work which is costlier for rectification of crack after 15 years, but this self- healing concrete will help in regaining of strength and healing of cracks automatically without any human intervention.

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