Experinmental Analysis of Bacterial Concrete

D. Hanumantharao Naik[1] Y. Anjaiah[2]
[1]P.G Student [2]Assistant Professor
[1,2]Department of Civil Engineering
[1,2]Narasaraopet Engineering College, Narasaraopet, Guntur (Dist), A. P, India

Abstract— Concrete is the predominate material used in the structural engineering stream. Concrete is widely adopted in huge structures (commonly used in buildings).It is known for its durability, ductility and resistance towards the external loads. If water droplets enter into the concrete structure due to lack of permeability then it can damage the steel reinforcement present in the concrete member .when this phenomenon occurs, the strength of the concrete decreases and which results in the decay of structure. To prevent these phenomenon bacteria was introduce in concrete. Now a day's calcium lactate powder has been used along with bacteria in concrete which results in the formations of calcium carbonate crystals. These crystals look like precipitate chain which locks the minute cracks and also the pores in the concrete. Cracks are the major reason for the reduction of strength and permeability in the concrete. Therefore a novel technique has been developed by using a selective microbial plugging process, in which microbial metabolic activities promote calcium carbonate (cacite) precipitation, this technique is referred as microbiologically enhanced crack remediation . In this technique bacillus subtil us bacteria are used hence the concrete is called bacterial concrete. The percentages of bacteria selected for the study are 3.5% and 5% by weight of cement in addition , calcium lactate was used at 5% and 10% replacement of cement by weigh .test conducted as compresive strength. The following conclusions are reported from the experimental work carried out and from the results obtained from compressive strength and self healing capacities of casted specimens. The optimum compressive strength of bacterial concrete is obtained at 15gm of bacteria and 5% of calcium lactate. It is observed that the compressive strength of bacterial concrete is more than that of the conventional concrete. By using the bacteria we can decreases the maintenance cost of construction and helps in self healing. The total cost of the project is increased at the stage of construction and after that there is a decrease in the maintenance cost.

Key words: Concrete, Calcium Lactate, Ductility, Bacterial Concrete

I. Introduction

Now-a-days Concrete is the pre dominate material used in the structural engineering stream. Concrete is widely adopted in huge structures (commonly used in buildings).It is known for its durability, ductility and resistance towards the external loads. If water droplets enter into the concrete structure due to lack of permeability then it can damage the steel reinforcement present in the concrete member .when this phenomenon occurs, the strength of the concrete decreases and which results in the decay of structure. To prevent these phenomenon bacteria was introduce in concrete. Now a day's calcium lactate powder has been used along with bacteria in concrete which results in the formations of calcium carbonate crystals. This crystal look like precipitate chain which locks the minute cracks and also the pores in the concrete. Cracks are the major reason for the reduction of strength and permeability in the concrete .

Bacteria used in concrete totally based on the PH value of water that which bacteria cannot sustain higher pH value of more than 10. These bacteria is added in the form of spores into concrete. When contacted with water this bacteria gets active and it starts making lime stone in the sense calcium carbonate crystals out of calcium lactate powder many of bacteria are adopted by many researchers. But for this study Bacillus sub til is was used. The bacteria that which used as self healing agents must be able to survive for the longer time periods ,and it should be the effective crack healing agent. The main mechanism of self healing concrete is , the bacteria that which we added into the concrete should perform as a catalyst for the whole reaction for the longer periods , and also it should convert the precursor compound into the best filling material . this filled up material that originated newly is from the calcium lactate that we added to the concrete. This newly filled up material performs as a kind of bio cement which clearly fills up the newly originated cracks . these spores can survive in dry state for 45 to 50 years.

II. Literature review

In order to carry out the project work various literatures were studied and findings obtained by them were used to identify the research area, summarizations of literatures are as follows:-

A method of strength improvement of cement sand mortar by the microbiologically induced mineral precipitation was described by P.Ghosh et al. (2005). A thermophilic anaerobic microorganism is incorporated at different cell concentrations with the mixing water. The study showed that a 25% increase in 28 day compressive strength of cement mortar was achieved with the addition of about 105 cell/ml of mixing water. The strength improvement is due to growth of filler material within the pores of the cement sand matrix as shown by the scanning electron microscopy. The modification in pore size distribution and total pore volume of cement sand mortar due to such growth is also noted. *E. coli* microorganisms were also used in the cement mortar for comparison, but no improvement in strength was observed.-Use of microorganism to improve the strength of cement

Microorganism is a unique living element and has the ability to precipitate minerals through the process of biomineralization. The precipitation process occurred naturally and most of the precipitated products are very important compound composed of such as carbon, nitrogen, oxygen, sulphur, phosphorus and silica. So far, concrete incorporated with microorganism that able to precipitate calcium carbonate (calcite) was reported. However, little information on silica precipitation and its effect on concrete properties had been revealed. The concrete specimens were incorporated with Bacillus subtilis silica adsorbed in their cell wall by H Afifudin et al. (2011) -. Concrete specimens with five different concentrations of Bacillus subtilis cell with 104, 105, 106 and 107 cell/ml and control (without Bacillus subtilis) were cast. The experimental investigation made to prove that the silica precipitated by this microorganism can enhae the concrete properties namely its compressive strength and resistance to carbonation. The microstructure of the concrete contained Bacillus subtilis was also examined. It was found that the inclusion of Bacillus subtilis into the concrete enhanced the compressive strength. The concentration of 106 cell/ml was found to be the optimum concentration to give most enhanced effect to the compressive strength. However the effect of including Bacillus subtilis to the resistance to carbonation of the concrete specimen is found to be insignificant.-Microorganism precipitation in enhancing concrete properties.

The role of bacterial cell walls of *Bacillus subtilis* as a concrete admixture to improve the mechanical performance of concrete. The bacterial cell walls are known to mediate microbial induced carbonate precipitation, a process in which CaCO3 is formed from Ca2+ ions and dissolved CO2. Consistent with such knowledge, incorporation of bacterial cell walls increased carbonation of Ca(OH)2 and formation of CaCO3 in concrete. Furthermore, the bacterial cell walls significantly increased compressive strengths of concrete by 15% while also decreased porosity at 28 days of curing as described by R.Pei et al. (2013). Assay for CaCO3 precipitation *in vitro* indicated that bacterial cell walls, but not dead cells, accelerated carbonation of Ca2+ ions in Ca(OH)2 solution. Since CaCO3formed can fill up the void, decrease the porosity and increase the compressive strength in concrete, bacterial cell walls could act as a promising concrete admixture with benefits in enhancing mechanical performance and improving other carbonation-related properties.-Use of bacterial cell walls to improve the mechanical performance of concrete

The well-known fact that concrete structures are very susceptible to cracking which allows Chemicals and water to enter and degrade the concrete, reducing the performance of the structure and also requires expensive maintenance in the form of repairs. Cracking in the surface layer of concrete mainly reduces its durability, since cracks were responsible for the transport of liquids and gasses that could potentially contain deleterious substances. When micro cracks growth reaches the reinforcement, not only the concrete itself may be damaged, but also corrosion occurred in the reinforcement due to exposure to water and oxygen, and possibly CO2 and chlorides too. Micro-cracks are therefore the main cause to structural failure. One way to circumvent costly manual maintenance and repair is to incorporate an autonomous self -healing mechanism in concrete. One such an alternative repair mechanism is currently being studied by M.V.S.Rao et al. (2013) i.e. a novel technique based on the application of bio mineralization of bacteria in concrete. The applicability of specifically calcite mineral precipitating bacteria for concrete repair and plugging of pores and cracks in concrete had been recently investigated and studies on the possibility of using specific bacteria as a sustainable and concrete -embedded self-healing agent was studied and results from ongoing studies were discussed. Synthetic polymers such as epoxy treatment etc were currently being used for repair of concrete are harmful to the environment, hence the use of a biological repair technique in concrete is focused. In the present paper, an attempt is made to incorporate dormant but viable bacteria in the concrete matrix which will contribute to the strength and durability of the concrete. Water which enters the concrete will activate the dormant bacteria which in turn will give strength to the concrete through the process of metabolically mediated calcium carbonate precipitation. Concrete, due to its high internal pH, relative dryness and lack of nutrients needed for growth, is a rather hostile environment for common bacteria, but there are some extremophiles spore forming bacteria may be able to survive in this environment and increase the strength and durability of cement concrete. Overview of development of bioengineered concrete using bacterial strain Bacillus subtilis JC3 and its enhanced mechanical and durability characteristics was briefly described in this paper.-A sustainable self-healing construction material.

III. MATERIALS

A. Cement:

The cement used in the experimental work is ORDINARY PORTLAND CEMENT of 53 grade is used.The physical properties of the cement obtained on conducting appropriate tests as per IS:269/4831 and the requirements as per 1489-1991.

B. Coarse Aggregate:

Aggregates of size greater than 4.75 mm are known as the coarse aggregate. The maximum size of coarse aggregate is 80 mm. 20 mm size aggregates are used in this Experimental work. Coarse aggregate occupies the maximum volume of concrete. Locally available crushed angular aggregates are used. The specific gravity of the aggregate is 2.7.The fineness modulus is determined by sieve analysis in the laboratory.

C. Fine Aggregate:

The aggregates whose size is less than or equal to 4.75 mm is known as fine aggregate. Locally available sand satisfying the requirements of ASTM C33-03 was used in the concrete mixes. The sand obtained from river beds or Quarries is used as fine aggregate. The fine aggregate along with the hydrated cement paste fill the space between the coarse aggregate. The sand passing through 2.36 mm is used in concrete. The specific gravity of the cement is 2.7 and it comes under ZONE II.

D. Bacteria:

The starting point of the research was to find bacteria capable of surviving in an extreme alkaline environment. Cement and water hasa pH value of more than13. When mixed together, usually a hostile environment for his life. Most organism die in environment with a pH value of 10 or above. The search concentrated on microbes that thrive in alkaline environments which can be found in natural environments, such as alkali lakes in Russia, carbonate-rich soils in desert areas of Spain and soda lakes in Egypt. Samples of endolithic bacteria(Bacteria that can live inside stones) were collected along with bacteria found in sediments in the lakes. Strains of the bacteria genus Bacillus were found to thrive in this high alkaline environment. Different types of bacteria's are incorporated into a small blocks of concrete. Each concretes block would be lefts to two month to set hard. Then the block would be pulverized and the remains tested to see whether the bacteria had survived. It was found that the only group of bacteria that were able to survive were the ones that produced spores comparable to plant seeds. Such spores have extremely thick cell walls that enable them to remain intact for up to 200 years while waiting for a better environment to germinate. Further it would become activated at the time of cracking, food is available and water seeps into the structure. This induces low pH value of highly alkaline concrete of the ph(10 to 11.5)

Types of bacteria:-

1) Bacillus pasteurii,
2) Bacillus sphaericus,
3) Bacillus subtilis(used in the present study)
4) Escherichia coli

E. Bacillus subtilis:

Bacillus subtilis is a ubiquitous naturally occurring saprophytic bacterium that is commonly recovered from soil, water, air and decomposing plant material. Under most conditions, however, it is not biologically active and is present in the spore form. Different strains of B. subtilis can be used as biological control agents under different situations. There are two general categories of B. sub-tilis strains; those that are applied to the foliage of a plant, and those ap-plied to the soil or transplant mix when seeding. The B. subtilis is a naturally occurring strain that was isolated from soil and is applied either as a foliar,seed treatment or directly to soil and is not considered a genetically modified organism. How It Works: subtilis bacteria produce a class of lipopeptide antibiotics including iturins. Iturins help B. subtilis bacteria out compete other microorganisms by either killing them or reducing their growth rate. B. subtilis are made for many uses. For plant disease control, these include foliar application and products applied to the root zone, compost, or seed. When applied directly to seeds, the bacteria colonize the developing root system, competing with disease organisms that attack root systems. B. subtilis inhibits plant pathogen spore germination, disrupts germ tube growth, and interferes with the attachment of the pathogen to the plant. It is also reported to induce systemic acquired resistance (SAR) against bacterial pathogens.

F. Calcium lactate:

Calcium lactate is available in different forms it is formed on surface of the curd. Calcium lactate is food for the bacteria. Calcium lactate is add to the concrete by the weight of cement. In this project we use calcium lactate 5% add to the concrete. If calcium lactate increases 20% by weight of cement it effect on strength of concrete.

G. Water:

Water Available in our lab is used in this investigation.

IV. RESULTS AND DISCUSSIONS

A. Compressive strength:

The compressive strength of concrete is one of the most important and useful properties of concrete. The compressive strength of concrete is generally determined by testing cubes or cylinders made in laboratory. The main function of the concrete in structure is mainly to resist the compressive forces. Compressive strength is also used as a qualitative measure for other properties of hardened concrete. The compression test is carried on cube specimens of the size 150*150*150 mm. The mould and base plate are coated with a thin film of mould oil before use, in order to prevent adhesion of concrete. A steel bar 16mm in diameter, 0.6m long and bullet pointed at the lower end serves as a tamping bar. The concrete is filled into the mould in layers approximately 5cm deep. Each layer is compacted using vibrator. After the top layer of the concrete is compacted the surface of the concrete is brought to the finished level with the top of the mould, using a trowel. The casted specimens are given identity numbers and are left undisturbed for one day. Then the specimens are removed from the mould and are cured for 28 days. For testing in compression, no cushioning material should be placed between the specimen and the plates of the machine. The load was applied axially without shock till the specimen was crushed. Three cubes of conventional mix are tested at 7 days and three at 28 days. The obtained results are reported and analyzed.

Mix ID	Bacteria gms	7 Days (N/mm^2)	14 Days (N/mm^2)	28 Days (N/mm^2)
Normal	0	22.95	30.60	39.95
A	5	32.13	42.84	52.65
B	10	34.16	44.65	53.42
C	15	36.05	46.01	54.00
D	20	36.05	46.01	54.00

Table 1: Compressive strength (MPa) values for bacterial concrete

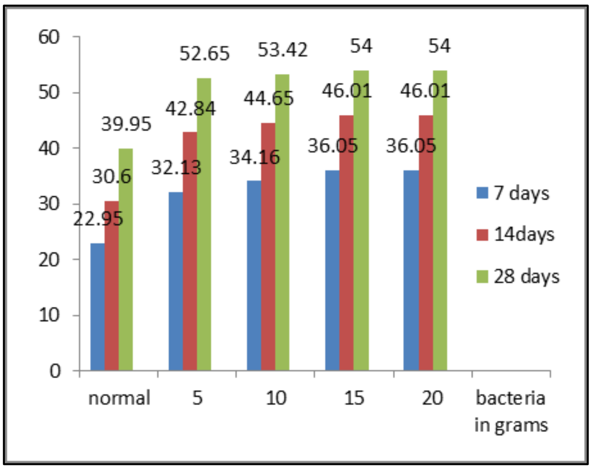

Fig. 1: Variation in Compressive strength for all the mixes.

B. Self Healing Behavior:

The self healing capacity of bacteria concrete is observed by the curing of compressive strength tested cubes for a minimum period of 7 days. The casted specimens of bacteria concrete are tested for compressive strength in CTM. The load is applied gradually until the first crack appears on the surface of concrete specimen. Then the tested specimen is again cured in water for atleast 7 days. It was observed that the crack formed on testing in CTM is healed completely by forming the cement paste within the crack. The cubes are again tested for compressive strength after self healing and the obtained results are reported.

Fig. 2: The self healing behaviour in high percentage bacteria (20gm) is shown in above figures.

It was observed that on increasing the amount of bacteria the strength of concrete is increased upto certain level but after that the strength goes on constant. But in high percentage bacteria concrete cubes, the self healing was observed completely. Also the permeability is observed to be more in such cubes. The crack width was measured as 0.2 mm and after self healing process, no cracks were observed open.

Mix with bacteria	Compressive strength before healing(n/mm^2)	Compressive strength after healing(n/mm^2)
Normal	39.95	_
5%	52.65	50.24
10%	53.42	51.25
15%	54.00	51.65
20%	54.00	51.65

Table 2: comparison of compressive strength before and after healing

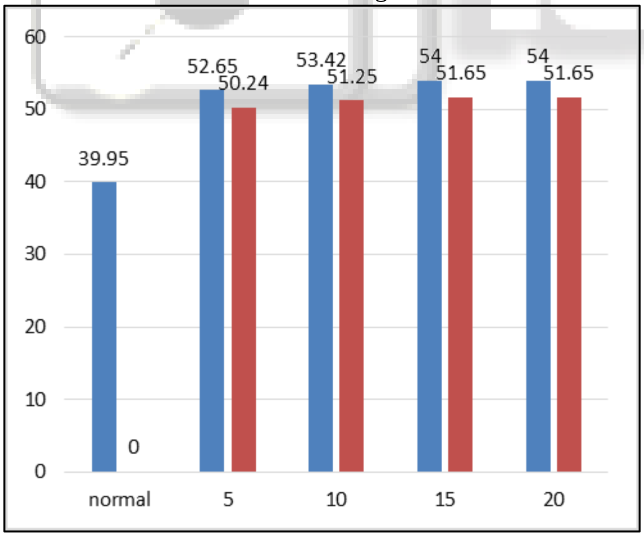

Fig. 3: Comparsion of Compressive strength before and after healing for all the mixes.

V. Conclusion

The following conclusions are reported from the experimental work carried out and from the results obtained from compressive strength and self healing capacities of casted specimens.

1) The optimum compressive strength of bacterial concrete is obtained at 15gm of bacteria and 5% of calcium lactate. i.e 54N/mm^2 at 28 days.
2) It is observed that the compressive strength of bacterial concrete are more than that of the conventional concrete, whose values are 54 N/mm^2 at 28 days.
3) By using the bacteria we can decreases the maintenance cost of construction and helps in self healing.
4) The total cost of the project is increased at the stage of construction and after that decreased the maintenance cost.

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