Critical appraisal on Bacterial Concrete

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ABSTRACT

It is an unique technique in which the bacteria undergo bio- chemical process inside the concrete in presence of calcite mineral and leads to the formation of precipitates which helps in sealing of pores and cracks generated inside the concrete. This technique is studied now a days and research is being done on use of different bacteria as sustainable and concrete embedded self-healing agent. Various materials used for repair available in market like polymers epoxies etc… are harmful to the environment; Hence this technique being environmental friendly can be used as their substitute. It was also observed in the study that the metabolic activities in the microorganisms taking place inside the concrete results into increasing the overall performance of concrete including its compressive strength. Thus, this paper is an attempt to define bacterial concrete, types ,classification of bacteria, process of fixing the cracks using these bacteria's , application and advantages as well as dis advantages of bacterial concrete in the field of construction by literature view are discussed.

INTRODUCTION

Concrete though being used and adopted as an ideal construction material because of its easy availability, low cost, good viscosity, good compressive strength etc.; has some drawback also , the major drawback of concrete is its low tensile strength due to which micro-cracks occur when the structure is subjected to sustained loading and exposed to aggressive environmental conditions results in to decreasing the life of the structure. These micro-cracks if small in width it can be sealed automatically by the expansion of the hydrated cement. But for large size cracks only partial sealing is possible. For proper health of structure if it is important to heal the freshly formed surface cracks as it will stop the entry of water and other aggressive chemicals which can damage the concrete as well as the embedded reinforcement. Therefore some man-made material like epoxy polymers are used as repair material. But they are costly, decreases compressive strength and moreover also hazardous to the environment. Therefore this leads to arise a need of some natural self-healing compound which can be used to protect the concrete and reinforcement from all the harmful effects. Calcium carbonate precipitation is one of the remedial product. It is a unique technique in which cracks and fissures are sealed using microbiologically induced calcite or calcium carbonate ($CaCo_3$) precipitation this process comes under category of Bio-mineralization. The specific species such as ureolytic are mainly used for this; they are externally and manually applied on the concrete surface, and then the process occurs inside or outside the microbial cell or even some distance away within the concrete and result in to the formation of bio minerals such as calcite ($CaCo_3$) or apatite. Which are relatively dense and can block the cracks and prevent the entry of the water efficiently. Sometimes this biological activities of bacteria trigger change in solution chemistry which leads to over saturation and mineral precipitates. Thus, this effective use of metabolic process of bacteria in concrete leads to the development of new concept called Bacterial Concrete.

VARIOUS TYPES OF BACTERIA USED IN CONCRETE

Various types of bacteria used in construction area are as follows.

1) Bacillus pasteurii
2) Bacillne sphaericus
3) Escherichia Colli
4) Bacillus Sabtilis
5) B.Cohnii
6) B.Pseodofirrius
7) B.Balodurars

Fig. 1 various types of Bacteria used in concrete

APPLICATION OF THE VARIOUS BACTERIA

1) Bacillus Cereus: It is used as biological mortar. It oxidates the amino acids. Its growth requires (peptone extract, yeast, KNO_3, NaCl) in addition with $CaCl_2.2H_2O_2$,Acitical Natamycine.

2) Bacillus Subtilis: It is used as crack remedial material. It hydrolise the urea.Its growth requires Nutrient broth, Urea in addition with $CaCl_2.2H_2O_7$,NH_4Cl & $NaHCO_3$

3) Bacillus Sphaericus: It is used as crack remedial material..It hydrolise the urea.Its growth requires Extract yeast, Urea,$CaCl_2.2H_2O$

4) Bacillus Subtilis: It is used as bacterial concrete.It hydrolise the urea.Its growth requires Nutrient broth,Urea in addition with $CaCl_2.2H_2O_7$,NH_4Cl & $NaHCO_3$

5) Bacillus Subtilis: It is used as bacterial concrete. It oxidates the amino acids.Its growth requires peptone (5gram/lit) ,Yeast extract(3gram/lit), NaCl(5gram/lit)

Hence, the bacterial concrete is very much useful in increasing the durability of cemetous materials , repair of limestone monuments , sealing of concrete cracks to highly durable cracks etc.It also useful for construction of low cost durable roads , high strength buildings with more bearing capacity, erosion prevention of loose sands and low cost durable houses.
The conventional treatments produce large amount of green house gases during the manufacturing ,which are responsible for Global Warming and also they consume high energy during the production and conventional methods are having high cost,All these drawbacks gives invitation to the need of using eco-friendly self healing and energy efficient technology in which the small microbs are used as a remedial material

WORKING OF THE BIO-CONCRETE AS AREPAIR METERIAL

Due to the various reactions occurring in the bacteria, it results into the formation of calcium carbonate which heals the cracks. Bacteria name bacillus are added to the concrete during mixing along with calcium based nutrient known as calcium lactate,Nitrogen and phosphorus. These ingredients remain intact with the concrete up to 200 years. Because of the shrinkage in the concrete, it results into the formation of pores through which the water seeps and cracks are formed. As soon as the bacteria come in contact with the water and nutrients. The spore of the bacteria germinate and bacteria starts feeding on calcium lactate. It consumes oxygen and soluble calcium lactate gets converted in to insoluble lime stones and hence this lime stone on solidifying seals the cracks.This process takes place within 7-days in lab and outside at low temperature it takes several weeks. It resembles the mechanism in human body by which bone fractures are healed by osteoblast cells.
As the oxygen is consumed by bacteria in these process it prevents the corrosion of the embedded reinforcement. As the oxygen plays the vital role in the process of corrosion and thus the durability of the steel increases. It is taken care that both the components bacterial spores and the calcium lactate are introduced into the concrete within separate expanded clay pellets 2-4 mm wide. So that they do not get activate during the cement mixing process. They do activate only when the cracks open up the pellets and the incoming water comes in contact with calcium lactate and bacteria

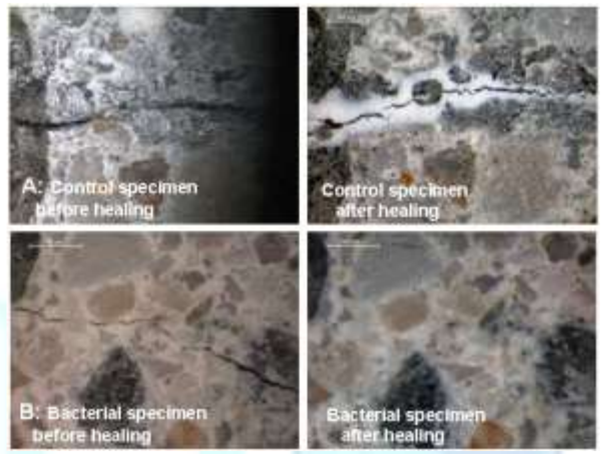

Fig. 1 self-healing admixtures composed of clay pellets.

CHEMICAL PROCESS TO SEAL THE CRACKS BY BACTERIA

Various bacteria and abiotic factors (salinity and composition of the medium) to contribute in different ways. In the process of calcium carbonate precipitation hence, the key factors governing the process are

1) The calcium concentration
2) Concentration of dissolved in organic carbon
3) The PH
4) Availability of nucleation sides

It is important that the carbonate ions and the calcium ions should be present in the sufficient amount for the $CaCo_3$ precipitation, so that the ion activity product (IAP) exceeds the solubility constants (KSO). If the ion activity product is more than the solubility constants than the system is termed as oversaturated and precipitates will be formed.

The concentration of DIC (Dissolved in organic carbon) , carbonate ions and PH are interrelated to each other. Moreover, the DIC concentration depends on various parameters of the environment like temperature and partial pressure of Co_2.These parameters of precipitation described above can be altered by micro-organisms either separately or by combination with one another.

Another microbial process that leads to an increase of both pH and the concentration of dissolved inorganic carbon is the utilization of organic acids

ADVANTAGES OF BACTERIAL CONCRETE

1) MORE RESSISTABLE TO THE CRACK AS COMPARE TO THE ORDINARY CONCRETE.

As a sand material contains bacteria which is not present in the ordinary concrete, the cracks are resisted and the concrete becomes more stiffer.

2) INCREASE IN THE COMPRESSIVE STRENGTH OF CONCRETE.

The tests have shown that the compressive strength of bacterial concrete is 10 % more than the ordinary concrete.

3) RESISTANCE AGAINST THE ATMOSPHERIC EFFECTS

The bacterial concrete helps in resistance to the freeze - thaw cycle, because of the decrease in the permeability of concrete.

4) ACT AS AN IMPERVIOUS MATERIAL.

It was studied in different research work about the permeability of concrete. Carbonation test is an effective tool in testing the permeability because, the decreasing gases permeability due to the surface treatment, increases resistance towards the injection of carbonation and chloride.

5) ACT AS AN ANTI – CORROSIVE CONCRETE.

The bacterial concrete helps in sealing the path of water or other harmful gases which results in increase in the life of steel, and makes the reinforced concrete more durable. Moreover, it also resist the attack of acid on the reinforced concrete.

DIS-ADVANTAGES OF BACTERIAL CONCRETE

1) HIGH COST

The cost of the bacterial concrete is almost double than the conventional concrete but it can be reduced by the growth of these techniques.

2) UNFAVOURABLE ATMOSPHERIC CONDITION.

Atmospheric conditions are very important for the survival of bacteria and various chemical growth processes , Hence it is very important to develop the favorable atmospheric conditions. For proper bio – chemical process to takes place.

3) NON – AVAILABILITY OF I.S. CODES

As it is a newly developed research material and not widely used in the construction area and so, there is no I.S codes available to calculate the dose of bacteria to be used for the optimum performance.

4) STUDY AND INVESTIGATION OF BACTERIAL CONCRETE IS COSTLY

As different bacteria have different tendency to produce different amount of calcite precipitates. It is very important to identify the bacteria.The bacteria investigation can be done by “Scanning electro microscopy” method. But it is very costly and requires expertise.

LITERATURE REVIEW

It was said by Van Breugel (2007) that” Enhancing the longevity of our built infrastructure will undoubtedly reduce the impact of mankind’s activities on the stability of biosphere hence increasing the service life of the structure will reduce the use of raw materials and reduce the emission of the carbon dioxide. The life of the structure can be increase by using high quality materials, and some new emerging concepts of self healing material. Nature proves that biological materials have the capability of healing them selves by nutrlizing the wound or injury and restore it s original performance.

Neville (2002) give the useful overview in this field of its literature. He gave the practical importance of auto-genious healing in reducing the seepage of water through cracks. He also concluded that there is no agreement between different studies about what happens inside the crack when self healing process occurs and therefore further research of this topic would be useful.

Ter Heide (2005) discussed about the various causes of self healing in which a material has already by nature the ability to heal itself and on other hand the materials can also be designed manually to have self healing capacity (Schlangen & Joseph 2008).

It was said by (Bangetal; Jonkers and schlangen 2007; DeMuynck 2008; Wiktor and Jonkers 2011) that bacteria can be used to stimulate the self healing mechanisms as an alternative of other hazardous adhesive materials.

Hammes & Verstraete (2003) investigated the series of events occurring during ureolytic Calcification emphasizing the importance of pH and Calcium metabolism during the process. The primary role of bacteria has been ascribed to their ability to create an alkaline environment through various physiological activities.

CHEMICAL PROCESS TO REMEDIATE CRACKS BY BACTERIA

Bacteria from various natural habitats have frequently been reported to be able to precipitate calcium carbonate both in natural and in laboratory conditions (Krumbein, 1979;

Rodriguez et al., 2003).
Different types of bacteria, as well as abiotic factors (salinity and composition of the medium) seem to contribute in a variety of ways to calcium carbonate precipitation in a wide range of different environments (Knorre & Krumbein, 2000; Rivadeneyra et al., 2004).
Calcium carbonate precipitation is a straight forward chemical process governed mainly by four key factors:
(1) The calcium concentration,
(2) The concentration of dissolved inorganic carbon (DIC),
(3) The pH and
(4) The availability of nucleation sites
(Hammes & Verstraete, 2002).
$CaCO_3$ precipitation requires sufficient calcium and carbonate ions so that the ion activity product (IAP) exceeds the solubility constant (K_{so}) (Eqs. (1) and (2)). From the comparison of the IAP with the K_{so} the saturation state (Ω) of the system can be defined; if $\Omega > 1$ the system is oversaturated and precipitation is likely (Morse, 1983):

$$Ca^{2+} + CO_3^{2-} \leftrightarrow CaCO_3 \quad (1)$$

$$\Omega = a(Ca^{2+})\, a(CO_3^{2-}) / K_{SO} \quad (2)$$

With K_{SO}calcite, 25˚C $= 4.8\times10^{-9}$)
The concentration of carbonate ions is related to the concentration of DIC and the pH of a given aquatic system. In addition, the concentration of DIC depends on several environmental parameters such as temperature and the partial pressure of carbon dioxide (for systems exposed to the atmosphere). The equilibrium reactions and constants governing the dissolution of CO_2 in aqueous media (25°C and 1 atm) are given in Eqs. (3)–(6) (Stumm & Morgan, 1981)

$$CO_2(g) \leftrightarrow CO_2(aq.) \quad (pK_H=1.468) \quad (3)$$

$$CO_2(aq.) + H_2O \leftrightarrow H_2CO_3^* \quad (pK=2.84) \quad (4)$$

$$H_2CO_3^* \leftrightarrow H^+ + HCO_3^- \quad (pK_1=6.352) \quad (5)$$

$$HCO_3^- \leftrightarrow CO_3^{2-} + H^+ \quad (pK_2=10.329) \quad (6)$$

With $H_2CO_3^* = CO_2(aq.) + H_2CO_3$
Microorganisms can influence precipitation by altering almost any of the precipitation parameters described above, either separately or in various combinations with one another,-(Hammes & Verstraete, 2002).

CONCLUSION

Due to the eco – friendly nature self - healing capacity and increase in durability, bacterial concrete has proved to be better then conventional technology. Because of the various research works, our idea and understanding on the possibilities and limitation of bio – chemical application on building material has become clear. Due to addition of bactereria there is increase in compressive strength decrease in permeability, water absorption and reinforced corrosion has been observed in ordinary concrete and mortar. Use of bacterial concrete will soon become the base for high quality structure that will be durable, cost effective and environment friendly. Moreover the bacterial concrete is easy and convenient to use but, more efforts are to be required to increase the feasibility of this concrete both from economical as well as practical view point, as its application requires skilled laborers.

RECOMMENDATIONS FOR FURTHER STUDIES

As the many researchers found out this superior and smart material although due to its various limitations, further study is require to get a more benefit from this material**.**
So, detailed studies need to focus on different types of nutrients and metabolic products used for growing calcifying microorganisms, as they influence survival, growth, and bio-film and crystal formation.

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