**BACTERIAL CONCRETE**

**INTRODUCTION**

Cracking of concrete is a common phenomenon. Without immediate and proper treatment, cracks in concrete structures tend to expand further and eventually require costly repairs. Even though it is possible to reduce the extent of cracking by available modern technology, remediation of cracks in concrete has been the subject of research for many years. There are a large number of products available commercially for repairing cracks in concrete: structures epoxy, resins, epoxy mortar and other synthetic mixtures. Cracks and fissures are a common problem in building structures, pavements, and historic monuments. We have introduced a novel technique in fixing cracks with environmentally friendly biological processes that is a continuous self-remediating process. In the study, Bacillus pasteurii that is abundant in soil has been used to induce CaCO3 precipitation. It is therefore vital to understand the fundamentals of microbial participation in crack remediation.

**Definition**: The "Bacterial Concrete" is a concrete which can be made by embedding bacteria in the concrete that are able to constantly precipitate calcite. This phenomenon is called microbiologically induced calcite precipitation. It has been shown that under favorable conditions for instance Bacillus Pasteruii, a common soil bacterium, can continuously precipitate a new highly impermeable calcite layer over the surface of an already existing concrete layer. The favorable conditions do not directly exist in a concrete but have to be created.

**CHEMISTRY OF THE PROCESS:**

Microbiologically enhanced crack remediation (MECR) utilizes a biological byproduct, CaCO3 which has shown a wide range of application potential as a sealant. Its prospective applications include remediation of surface cracks and fissures in various structural formations, in-base and sub-base stabilization, and surface soil consolidation. In principle, MECR continues as microbial metabolic activities go on. This inorganic sealant not only is environmentally innocuous but also persists in environments for a prolonged period.

Microbiologically induced calcium carbonate precipitation (MICCP) is comprised of a series of complex biochemical reactions, including concomitant participations of Bacillus pasteurii, urease (urea amidohydrolase), and high pH. In this process, an alkalophilic soil microorganism, Bacillus pasteurii, plays a key role by producing urease that hydrolyzes urea to ammonia and carbon dioxide. The ammonia increases the pH in surroundings, which in turn induces precipitation of CaC[O.sub.3], mainly as a form of calcite. In aqueous environments, the overall chemical equilibrium reaction of calcite precipitation can be described as:

[Ca2+] + [CO3 2-] → CaCO3 ↓ (1)   
  
Possible biochemical reactions in Urea-CaCl2 medium to precipitate CaCO3 at the cell surface can be summarized as follows:   
  
[Ca2+] + Cell → Cell-[Ca2+] (2)   
  
Cl + HCO3  + NH3  → NH4Cl + [CO3]2- (3)   
  
Cell-[Ca2+] + CO32- → Cell-CaCO3 ↓ (4)

**Immobilization of Bacteria**  
\* It is the technique in which microorganisms encapsulated in different porous material to maintain high metabolic activities and protect from adverse environment.   
  
\* For immobilization different materials like polyurethane (PU) polymer, lime, silica, fly ash can be used.   
  
\* PU can be used widely because of its mechanically strong and biochemically inert characteristics.   
  
\* PU mix open cell foam as a result of condensation of polycyanates (R-CNO) and polyols (R-OH).   
  
**Evidence of Calcite Precipitation Induced Bacillus Pasteurii**  
Upon polymerization, PU foam is pliable and elastic with open-cell structure of matrices. Micrographs showing cell-laden PU matrices indicate that immobilization caused no apparent morphological damage to the cells and microorganisms are entrapped throughout the polymer matrices where cells are adhered or embedded with some clumping. Calcite precipitation occurred throughout the entire matrices, including the inside of pores as well as the surface areas. It is also apparent that calcite crystals grow around the microorganisms and PU matrices.

**STRENGTH AND DURABILITY PERFORMANCE OF BACTERIAL CONCRETE**  
\* The performance of MICCP in concrete remediation was examined using hairline-cracked cement mortar beams remediated in the medium with B. pasteurii. Various levels of performance enhancement was observed in the treated specimens;   
  
\* Reduction of the mean expansion due to the alkali aggregate reactivity by 20%.   
  
\* Reduction of sulfate effects by 38%; reduction of the mean expansion by 45% after freeze-thaw cycle; and higher retaining rates (30% more) of the original weight.   
  
\* The microbiological enhancement of concrete was further supported by SEM analysis evidencing that a new layer of calcite deposit provided an impermeable sealing layer, increasing the durability of concrete against the freeze-thaw cycles and chemicals with extreme pH.

**Microbiological precipitation of caco3:**

\* Calcium carbonate precipitation appeared to be correlated with the growth of B. pasteurii and was completed within 16 hr following inoculation. A considerable amount of ammonia was produced even during the stationary phase of cell growth.

**Effect of ammonia and pH on growth of cell:**  
\* The pH of the medium also increased slowly as ammonia production increased, but did not directly increase with the growth of cells.

**Efficiency of filling material for crack remediation.**  
The results suggest that PU provides cells with protection from a high pH of concrete and further supports the growth of bacteria more efficiently than other filling materials.(Increase in Compressive Strength due to MECR).   
  
**Micro-Organisms and Growth Condition**  
A stock culture of B.pasteurii is generally maintained in a solid medium containing : 10g trypcase; 5g yeast extract; 4.5g tricine; 5g [(NH.4])2]SO4]; 2g glutamic acid and final concentration of 1.6% agar, which is autoclaved separately and added after-wards. For quantity culture use in MICCP B. Pasteurii is cultured in yeast extract (YE) broth medium with 30˚C for 24-30h with aeration facilities. After sufficient growth of bacteria in laboratory same is transfer to cracked mortar cubes by mixing with sand and required amount of cell concentration of bacteria.   
   
**Transfer of bacteria**After sufficient growth of bacteria in laboratory same is transfer to cracked mortar cubes by mixing with sand and required amount of cell concentration of bacteria.   
  
**Conclusions**Based on the experimental program carried out at SV National Institute of Technology, Surat (INDIA) conclusions are drawn as follows:   
Rod shape impression which consists with dimension of B. Pasteurii on the calcite crystal further confirm that bacteria serves as nucleation site for calcite crystals and also creates an alkaline environment surrounding to them includes more precipitation of calcite. A concentration of 9.0x108 cells per ml is most suitable for the maximum compressive strength. Specimens with higher concentration do not give higher compressive strength values probably because the greater population of bacteria does not have enough nutrients to multiply. Comparisons of Compressive Strength of Specimens having Various Crack depths with single immobilize cell concentration. B. Pasteurii however, has an ability to produce the endospore, a dormant form of the cell, to endure extreme environment so if in future cracks treated with this technique widens then again B.pasteurii starts metabolic activity, which leading to accumulation of insoluble CaCO3.The optimum concentration of B.pasteurii should be decided with considering parameters like crack size, frequency of reaction mix application, length of microbial treatment, remediation temperature and material for immobilization, environmental condition etc.   
  
Based on the observation made in this study, it is clear that MICCP has excellent potential in cementing concrete as well as several other types of structural and nonstructural cracks.