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Effects of Curing, Drying Shrinkage & Bacterial Action in Self-Healing Mechanism of Concrete – An Analysis

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ABSTRACT:*Concrete being the most widely used building material in the world falls into the category of those smart materials that have the structurally incorporated ability to repair damages caused by mechanical usage over time and this process of healing is directly related to those biological systems , which have the ability to heal after being wounded. Cracks and other damages when studied at microscopic level has shown the changes in thermal , electrical and acoustical properties even leading to complete failure of the material as well. For a material to be defined as self healing, it is necessary that the healing process occurs itself without human interventions. Such healing events can be achieved by using polymerization catalysts. The thickness in such cases also plays a vital role, if the wall of the capsule studied is created too thick then it may not fracture, but if they are too thin, they may rupture prematurely. In order for this process to happen at room temperature, and for reactants to remain in monomeric state within the capsule, a catalyst is also imbedded into the thermo sheet. The catalyst is used to lower the energy barrier of the reaction and allows the monomer to polymerize without the addition of heat. The recreativity of the catalyst must be maintained even after it is enclosed, additionally, its monomers must flow at a sufficient rate with lower viscosity to cover the entire crack before it is polymerized. The catalyst must quickly dissolve into the monomer in order to react efficiently preventing the crack from spreadingfurther. The main objective of the study is to know the effects of curing, drying shrinkage and bacterial action in self hilling mechanism of concrete. The major findings and fruitful suggestions have been given in full paper.*

KEYWORDS: BacterialAction, Building MaterialRecreativity,Crack-Healing, Permeability.

INTRODUCTION: Concrete is a material which is the most widely used building material in the world. Natural processes such as weathering,faults,land subsidence, earthquakes, and human activities creates cracks in concrete structures. Concrete expands and shrinks with changes in moisture and temperature and this tendency to shrink and expands causes cracks in concrete. Cracks form an open pathway to the reinforcement and can lead to durability

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problems like corrosion of the steel bars. These cracks should be repaired because they can reduce the service life of structure. Remediation of already existing cracks has been subject of research for many years. The various product such as structural epoxy, resins, epoxy mortar, and other synthetic mixtures are used as filling material but they are not environmentally friendly not even safe for human health.Self healing materials only emerged as a widely recognized field of study in the 21st century. The first international conference on self-healing materials was held in 2007. The field of self-healing materials is related to biomimetic materials (materials inspired by living nature) as well as to other novel materials and surfaces with the embedded capacity for self-organization, such as the self-lubricating and self-healing materials. However, some of the simpler applications have been known for centuries, such as the self repair of cracks in concrete. Related processes in concrete have been studied microscopically since the 19th century. A form of self healing mortar was known even to the ancient Romans.America's bridges are falling down. Victor Li says he knows a better way to build them. The civil and environmental engineering professor at the University of Michigan has invented a new kind of concrete that hardly ever cracks and, if it does, can repair itself.A typical American bridge is built to last 50 years (and then only if it gets frequent roadbed replacements). Today the average age of U.S. bridges is 42 years. One-quarter of all bridges were deemed either structurally deficient or functionally obsolete last year by the U.S. Department of Transportation. In a March report the American Society of Civil Engineers gave U.S. infrastructure a grade of "D," reflecting delayed maintenance and chronic underfunding; it estimates that $2.2 trillion is needed over the next five years to bring that grade up to a "B."

Last year the world swallowed up 3 billion tons of cement, the active ingredient in concrete, according to the Portland Cement Association. (Concrete's three other ingredients: gravel, sand and water.) Concrete has marvelous virtues, including low cost and high compression strength. Its main fault is brittleness. It needs steel inside for tensile strength.

Objective of the study: Specific objectives of present study are

- To know the elements which are directly relatedbacterial action in self healing mechanism of concrete.
- To discuss the factors which are directly related to dry shrinkage.

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- To make suggestions on the basis of findings.

Research methodology: For this research only secondary sources of data has been used which are collected from different kind of research work and other related books of the study. After collecting such information analyzed the study with effected materials.

Different healing mechanisms:

- Formation of material like calcite
- Blocking of the path by sedimentation of Particles
- Continued hydration of cement particles
- Swelling of the surrounding cement matrix

Need for Self–curing: When the mineral admixtures react completely in a blended cement system, their demand for curing water (external or internal) can be much greater than that in a conventional ordinary Portland cement concrete. When this water is not readily available, due to depreciation of the capillary porosity

Due to the chemical shrinkage occurring during cement hydration, empty pores are created within the cement paste, leading to a reduction in its internal relative humidity and also to shrinkage which may cause early-age cracking. This situation is intensified in HPC (compared to conventional concrete) due to its generally higher cement content, reduced water/cement (w/ c) ratio and the pozzolanic mineral admixtures (fly ash, silica fume). The empty pores created during self-desiccation induce shrinkage stresses and also influence the kinetics of cement hydration process, limiting the final degree of hydration.

Definition of Internal Curing (IC): Internal curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water that is not part of the mixing Water.Conventionally, curing concrete means creating conditions such that water is not lost from the surface i.e., curing is taken to happen 'from the outside to inside'.

Internal curing' is often also referred as 'Self–curing.

Self-desiccation: It is the drying process resulting from a decreasing relative humidity (RH) which could be the result of the cement requiring extra water for hydration. It is the reduction in the internal relative humidity of a sealed system when empty pores are generated.

Potential of Self desiccation: The finer porosity causes the water meniscus to have a greater radius of curvature, causing large compressive stress on the pore walls, leading to greater autogenously shrinkage as the paste is

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pulled inwards. Self–desiccation is only a risk when there is not enough localized water in the paste for the cement to hydrate and it occurs the water is drawn out of the capillary pore spaces between the solid particles. At later ages, a strong correlation exists between internal relative humidity and free autogenously shrinkage.

Types of Shrinkage Drying:

•Drying shrinkage

•Autogenously shrinkage

•Chemical shrinkage

Inter-dependence of Autogenously& Chemical Shrinkages: Chemical shrinkage creates empty pores within hydrating paste and stress generated is estimated by equation.The above equation is only approximate for a partiallysaturatedvisco-elastic material such as hydrating cement paste, but still provides insight into the physical mechanism of autogenously shrinkage and the importance of various physical parameters The internal drying is analogous to external drying shrinkage.

Early External Water Curing and Cracks: Reduction of autogenously shrinkage due to external curing is possible for first one or two days when the capillary pores are yet interconnected. Early water curing can lead to higher strain gradients when the skin of the concrete becomes well cured (no shrinkage) whereas, autogenously shrinkage, which is generally difficult to control, begins at the interior of the concrete.This can be done by:

- Measuring weight-loss
- X-Ray powder diffraction
- X-Ray micro chromatography
- Thermo gravimeters (TGA) measurements
- Initial surface absorption tests (ISAT)
- Compressive strength
- Scanning electron microscope (SEM)
- Change internal RH with time
- Water permeability
- NMR spectroscopy

Advantages of Internal Curing:

a. Internal curing (IC) is a method to provide the water to hydrate all the cement, accomplishing what the mixing water alone cannot do. In low w/c ratio mixes (under 0.43 and increasingly those below 0.40) absorptive lightweight aggregate, replacing some of the sand, provides water that is desorbed into the mortar fraction (paste) to be used as additional curing water.

b. IC eliminates largely autogenous shrinkage.

c. IC maintains the strengths of mortar/concrete at the early age (12 to 72 hrs.) above the level where internally & externally induced strains can cause cracking.

d. IC provides water to keep the relative humidity (RH) high, keeping self-desiccation from occurring.

Improvements to Concrete due to Internal Curing:

- Reduces autogenous cracking,
- largely eliminates autogenous shrinkage,
- Reduces permeability,
- Protects reinforcing steel,
- Increases mortar strength,
- Increases early age strength sufficient to withstand strain,
- Provides greater durability,
- Higher early age (say 3 day) flexural strength
- Higher early age (say 3 day) compressive strength,
- Lower turnaround time,
- Improved archeology
- Greater utilization of cement,
- Lower maintenance,
- use of higher levels of fly ash,
- higher modulus of elasticity, or
- through mixture designs, lower modulus
- sharper edges,
- greater curing predictability,
- Higher performance.

Bacterial action in concrete (Bacterialconcrete):

• The "Bacterial Concrete" is a concrete which can be made by adding bacteria in the concrete that are able to constantly precipitate calcite, this phenomenon is called microbiologically induced calcite precipitation.

It is process by which, living organisms form an inorganic solids.

• It is same process as we people are producing teeth and bones.

Chemistry of the Process for Bacterial concrete: Microbiologically enhanced crack remediation (MECR) utilizes a biological byproduct, CaC[O.sub.3] 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

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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:

[Ca.sup.2+] C[O.sub.3.sup.2-] [right arrow] CaC[O.sub.3] [down arrow] (1)

Possible biochemical reactions in Urea-Ca[Cl.sub.2] medium to precipitate CaC[O.sub.3] at the cell surface can be summarized as follows:

[Ca.sup.2+] + Cell [right arrow] Cell-[Ca.sup.2+] (2)

C1 + HC[O.sub.3] + N[H.sub.3] [right arrow] N[H.sub.4]Cl + C[O.sub.3.sup.2-] (3)

Cell-[Ca.sup.2+] + C[O.sub.3.sup.2-] [right arrow] Cell-CaC[O.sub.3] [down arrow] (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 (Figure. 1.a). Micrographs (Figures. 1.b-1.c) 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. As shown in Figs. 1.d and 1.e, 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: Effect of ammonia and pH on growth of cell:

* 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.

* The pH of the medium also increased slowly as ammonia production increased, but did not directly increase with the growth of cells.

Efficiency of bacteria as biosealent: 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.

Discussions: Based on the experimental program carried out at SV National Institute of Technology, Surat (INDIA) conclusions are drawn as follows:

The positive potential of MICCP that has been demonstrated in our study offer an interesting concept of the crack remediation technique in various Structures. The following summarizes our preliminary findings on MICCP.

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 9.0x[10.sup.8] 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 CaC[O.sub.3].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.

Conclusion: Higher concentration reduced the regaining strength of concrete. It was found that specimen with bacteria improved its permeability and resistance to alkaline environment, sulfate attack and freeze-thaw action. Thus we can say that crack remediated with bacteria can improve the strength and durability of structure. This all observation were done in America this results we cannot directly considered valid for our country because of difference in temperature, humidity, type of concrete, control on various parameters such astype of concrete mix, etc.In India porosity and permeability of concrete should be studied because they are the main causes of distress in many structures. If this method once studied in Indian environment then it can be used in crack remediation in many structures having more importance and containing hazardous material.In India Nuclear Power Corporation has started working on the research of bacterial concrete for using it in nuclear power plant.

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