A REVIEW OF BIO INFLUENCED SELF HEALING MECHANISM IN CONCRETE

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I) ABSTRACT: Concrete is the most widely used construction material. The formation of cracks is a major drawback in concrete. In this paper an overview is given on the evolution and advancement in self-healing mechanism. Crack formation is very common occurrence in concrete structure which allows the water and different type of chemical into the concrete through the cracks and decreases their durability, strength and which also affect the reinforcement when it comes in contact with water, CO2 and other chemicals. For mending the cracks developed in the concrete, it requires regular conservation and special type of treatment which will be very extensive. So, to overcome from this problem autonomous self-healing apparatus is introduced in the concrete which helps to repair the cracks by producing calcium carbonate crystals which block the micro cracks and pores in the concrete. The selection of the bacteria was according to their survival in the alkaline environment such as B. pasteurii, Bacillus subtilis and B. spharicus which are mainly used for the experiments by different researchers for their study. The condition of growth is different for different types of bacteria. For the growth, bacteria were put in a medium containing different chemical at a particular temperature and for a particular time period. Bactria improves the structural properties such as tensile strength, water permeability, longevity and compressive strength of the normal concrete which was found by the performing different type of experiment on too many specimens had varying sizes used by different researchers for their study of bacterial concrete in contrast with the traditional concrete and from the experiment it was also found that use of light weight aggregate along with bacteria helps in self-healing property of concrete

II) INTRODUCTION: Concrete is exceptionally important material that withstands the compressive pressure to a limit but if the load applied on the concrete is higher than their limit of bearing load it creates the force modification of concrete by allowing cracks in the concrete and the repairing of the cracks is quite exorbitant. In which strength of the concrete structure is further reduced. Due to succession in the permeability of the concrete the water smoothly proceeds through the concrete and get in contact with the reinforcement of the concrete structure and subsequently corrosion begin due to the aforementioned strength of the concrete structure will drop so it will be required to restore the cracks. Large cracks may affect the structural integrity while the small cracks reduce the durability of the structure. Cracks also increase the permeability of matrix thereby increasing the chances of corrosion in reinforcement. Therefore, the solitary cause of structural failure is cracking. In order to reduce the chances of crack formation a structure requires regular preservation which can be costly and may further increase the continuity cost of the structure. One way to reduce such costs and to increase the durability of structure is to use a concrete that has self-healing mechanism. The selection of the bacteria is depending on the survive potential of bacteria in the alkaline environment. Most of the microorganisms die in an environment with pH value of 10 or above [3]. Strains of the bacteria genus Bacillus will be found to succeed in high alkaline environment. The bacteria survive in the high alkaline environment that formed spores comparable to the plant seeds. The spores are of very thick wall and they operate when concrete start cracking and water escape into the structure. The pH of the highly alkaline concrete lowers to the values in the range 10 to 11.5 where the bacterial spores become activated. There many bacteria other than Bacillus which are survive in the alkaline environment[4].

III) Main points

The mechanism of self-healing of concrete involves many processes. This article presents detailed views of these processes. The mechanism of self-healing of concrete comprises of:

(1) Natural process;

(2) Chemical process;

(3) Biological process.

A study conducted by Wu Et Al (2012) highlighted the natural as well as man-made self-healing concrete. Extensive descriptions on the chemical and biological processes were incorporated in this study. Siddique and Chahal (2011) detached the application of ureolytic bacteria for the treatment of self-healing concrete. Toohey et al. (2007) examined micro-vascular material as self-healing material. Jonkers (2007) examined on biological methods to produce self-healing

concrete based on calcium carbonate precipitation. Al-Thawadi (2011) recognized the extent of strength improvement of sand when utilizing ureolytic bacteria and calcium carbonate composition. Although numerous investigational records have been written on self-healing concrete, a complete, interpreted version on physical, chemical as well as biological methods has never been done. For a biologist, the effect of the whole review article is to establish a sharp macro achievement from various researches.

1) Natural Self-healing process

Some processes can partly fix concrete fracture in natural ways. The four main processes than can block cracks in concrete are as follows:

1. Development of $CaCO_3$ or CaOH.
2. Impurities in the carriage of water can also prevent cracks in concrete.
3. Hydration of unreacted cements also causes the obstruction of cracks in concrete.
4. Enlargement of hydrated cementitious pattern in the crack loins such as the lump of calcium silicate hydrate gel also causes impediment of cracks in concrete.

In multiple incidents, more than one of these mechanisms can occur concurrently. Most of these mechanisms can just partly fill the opening of some cracks and cannot entirely fill the cracks. These methods are helpful to stop the expansion of cracks and help inhibit the inward penetration of corrosive chemicals such as acids inside the crack. Amongst the recommended self-healing mechanisms in the natural process, configuration of calcium carbonate and calcium hydroxide are the usual efficient techniques to repair concrete naturally. The presence of white residue on the outer surface of the concrete breaks aids this aspect. The primary mechanisms for the production of calcium carbonate ($CaCO_3$) as well as calcium hydroxide (CaOH) are described in Equation (i)-(iii).

At the first level, carbon dioxide is dissolved in water.

$$H_2O + CO_2 \longleftrightarrow H_2CO_3 \longleftrightarrow H^+ + NO_3^- \longleftrightarrow 2H^+ + CO_3^{2-} \dots (i)$$

Loose calcium ions are discharged as a sequence of cement hydration and dissipation into concrete and besides the cracking surfaces, counters with NCO_3^- and CO_3^{2-}. Therefore, calcium carbonate crystals are developed. Reaction (ii) and (iii) can just occur at pH over 8 or within 7.5 and 8. The crystals develop both near the covering of the cracks and ultimately permeate the gap.

$$Ca^{2+} + CO_3^{2-} \longleftrightarrow CaCO_3 + H^+ \dots (ii)$$

$$Ca^{2+} + HCO_3^- \longleftrightarrow CaCO_3 + H^+ \dots (iii)$$

Neville (2002) observed that additional hydration of anhydrate cementations elements is essentially due to the natural self-healing attributes in concrete. Nevertheless, this method simply implements to quite young concrete and the configuration of calcium carbonate several reasonable causes self-healing at succeeding duration Neville (2002).

2) Chemical Healing Method

This process principally refers to the unnatural healing by introducing chemical composites. The production of self-healing concrete occurs by the inclusion of chemical liquid reagents (that is glue) amidst new concrete in tiny containers. This inclusion of chemicals happens by the use of hollow pipettes and vessel networks. The chemical self-healing method of concrete is classified into two sections:

1. Active Method: It employs a capillary system associated by outer supply from glue to distribute the glue.
2. Passive Method: It employs hollow pipettes, capsules or capillary system in the distribution of glue which cannot link to outer glue cause.

Hollow pipettes should be employed at various length measures by many researchers that form various self-healing substances like polymers and polymeric. These hollow pipettes are associated with the new concrete and they contain glue. Through crack distribution, these pipettes will be broken down and glue will be released to fractures and it will eventually fix a crack. Self-healing concrete comprising hollow pipettes can be incited in blood vessels of beings. The appropriateness of hollow pipettes in releasing glue inside cracks is shown in various ways, according to Wu et al. (2012). In the current system of self-healing methods employing hollow pipettes, a design for glue sharing inside cracks is observed, during the mix of glue plus fluorescent dye, it is discharged following the break in hollow pipettes. Samples of

glue which are suitable for saturating hollow pipettes in concrete are methyl methacrylate, ethyl cyanoacrylate, acrylic resin, and epoxy resin Homma et al. (2009). The self-healing concrete containing the glue type in the hollow pipettes, according to Dry (1994), employs a vessel network inside the concrete specimen to the delivery of glue. The vessel network remained fragile located inside the concrete specimen, beside one (1) point connected to provide glue and opposite side closed. Some researchers like Mihashi et al. (2000), Joseph et al. (2007) carried related research. Additional research revealed concrete comprising of hollow pipettes after flexural analysis. Due to the glue being released inside fractures, a 20% gain in weight for subsequent flexural test was observed, Hammond (2009). Even though many researches announced the use of hollow pipettes and vessel networks comprising glue as a technique creating self-healing concrete, the system still requires being checked for its use in actual projects, Mihashi et at, (2000).

3 Biological self-healing process

The application of microorganisms to create self-healing concrete has been classified as a biological approach by many researchers. Microorganisms can emerge almost everywhere such as water, soil, and oil storage, acidic hot springs, and industrial wastewater. Microorganisms are often classified into three noteworthy classes: bacteria, fungi, and viruses. Amongst these microorganisms, particular stretches of bacteria capable of precipitating specific chemicals are utilized to sketch the biological self-healing concrete. Precipitation of polymorphic iron-aluminum-silicate and calcium carbonate are the various significant processes apply for planning the biological self-healing concretes. Microorganisms can be added to the biological self-healing concrete through different policy. These constitute the addition of microbial brew straight toward the fresh concrete positioning as detailed beneath the chemical process to share the microorganisms. The pH, temperature and moisture content of the concrete are typically not proper for the addition of bacteria. Therefore, in particular cases, the resistant kind of bacteria (spore) is practiced rather than applying fresh microbial broth. Alternatively, encapsulated microorganisms can similarly be applied to endure the harsh condition of the concrete. Encapsulation of microorganisms is, however, a expensive and complex process. The application of vascular networks to proclaim the microbial broth throughout the cementitious matrix is a different means of guard the microorganisms against the improper conditions. Nevertheless, these processes are complex and subject to lack of constructability applying current technology. The application of immobilized microorganisms upon silica gel or stimulated carbon is a proper means in terms of financial perspective. However, the impact of using these materials on a strengthening of concrete is however not absolutely clear. Jonkers et al., (2010) recorded that execute 6×108/cm3 bacterial spores to design self-healing concrete resulted in a cutback in strength of less than 10 percent for 3, 7 as well as 28 days conserved specimens. There are different biological precipitations which include: a) Precipitation of calcium carbonates b) Precipitation of polymorphic iron aluminum silicate Moreover, these Precipitation reactions are usually conducted by: (a) Fungi (b) Bacteria However, there are also different microorganism groups, which can be used in order to design or generate selfhealing concrete. These are

(a) Mesophilic microorganisms

(b) Thermophilic microorganisms

3.1) Classification

3.1.1) Autogenous Self-Healing:

The autogenous self-healing depends on most part of modern hydration of concrete, carbonation of calcium hydroxide as well as another binder while. The autogenous self-healing is a traditional and famous method for concrete that occurred because of: (1) Blocking cracks by waste (2) Carbonation of Ca0H, (3) Expansion of the hydrated concrete matrix in crack flanks and (4) Ongoing hydration of clinker minerals cracks may heals after a while.

3.1.2) Autonomous Self-Healing Concrete:

Autonomous self-healing concrete entirely relied on manual method that operates manually. The autonomous self-healing is been identify through a special terminology such as: i. the vascular method; ii. capsule method; iii. The bacterial method; iv. The electrodeposition method; v. the shape memory alloy method; vi. The microwave method and/or induction energy. The self-healing of cracks in concrete is advantageous because it's very less in cost of preservation as well as the infrastructures' long lifespan.

IV) THE ENVIRONMENTAL ADVANTAGE :

Self-healing concrete generally reduces a significant amount of carbon dioxide emissions that result from concrete production. This is because the concrete production to some extends is very energy concentrated, when transportation,

mining, as well as the concrete plants are been observed. However, the industries are the main actors that are accountable for about 10% carbon dioxide emitters in the United State of America. As far as self-healing concrete increases the existence of the concrete as well as reduce maintenance and repairs, it will definitely reduce the production of excess amounts of concrete and this will surely reduce the carbon dioxide emissions in our environment.

V) DISADVANTAGES

There are two key obstacles that couple key hindrance that require being overwhelmed if selfhealing cement is to modify concrete structure in the next ten years. The primary concern is that the clay pellets carrying the self-healing agent constitute 20 percent of the volume of the concrete. This same twenty percent usually include hard aggregate like gravel. The clay is extremely weaker than ordinary aggregate and this undermines the concrete by about 25 percent and significantly decreases its compressive intensity

VI) CONCLUSION

Introducing the bacteria within the concrete performs is extremely useful it improves the accredit of the concrete, which is higher than the ordinary concrete. Bacteria fix the cracks in concrete by providing the calcium carbonate crystal that block the cracks and fixes it. Many researchers have done their job on the selfhealing sort of concrete and they had obtained the subsequent result that bacteria develop the property of conventional concrete such as supplement in 13.75 percent strength raised in 3 days, 14.28 percent in one week as well as 18.35% in week one. Nevertheless, if concrete could identify cracking and heal itself, then there would not only be meaningful cost savings, save an environmental gain in addition because concrete production accounts for an important quantity of the world's CO2 emissions.

1) Limitations of biotechnological applications on building materials could be clearly understood from the past literature studies.

2) Many cementitious and stone materials can exhibit enhanced compressive strength and reduction in permeability, water absorption, corrosion of reinforcement etc.,

3) Cementation by bacteria is very easy and convenient for usage. This will soon provide the basis for high quality structures that will be cost effective and environmentally safe, but more work is required to improve the feasibility of this technology from both economical and practical point of views.

4) Increase in compressive strength is mainly due to the consolidation of the pores inside the cement mortar with microbiologically induced calcite precipitation.

VII) REFERENCES

[1]. Use of bacteria to repair cracks in concrete by Kim Van Tittelboom a, Nele De Belie a,*, Willem De Muyncka, b, Willy Verstraete b., 2008.

[2]. Rafat Siddique, Navneet Kaur Chahal, (2011) "Effect of ureolytic bacteria on concrete properties", Construction and Building Materials 25 (2011) 3791–3801.

[3]. Abo-El-Enein, Ali, FatmaTalkhan, Abdel-Gawwad, "Application of microbial biocementation to improve the physico-mechanica properties of cement mortar", Housing and Building National Research Center (2013).

[4]. Abo-El-Enein, Ali, FatmaTalkhan, Abdel-Gawwad, "Application of microbial biocementation to improve the physico-mechanica properties of cement mortar", Housing and Building National Research Center (2013).

[5]. H.M. Jonkers, A. Thijssen, O. Copuroglu, E. Schlangen, Application of bacteria as self-healing agent for the development of sustainable concrete, Proceedings of the 1st International Conference on BioGeoCivil Engineering, 23–25 June 2008, Delft, The Netherlands.

[6]. K. Santhosh, S.K. Ramachandran, V. Ramakrishnan, S.S. Bang, Remediation of concrete using microorganisms, American Concrete Institute Materials Journal 98 (2001) 3–9.

[7]. J.L. Day, V. Ramakrishnan, S.S. Bang, Microbiologically induced sealant for concrete crack remediation, 16th Engineering Mechanics Conference, 16–18 July 2003, Seattle, Washington.

[8]. S.S. Bang, J.K. Galinat, V. Ramakrishnan, Calcite precipitation induced by polyurethane- immobilized Bacillus pasteurii, Enzyme and Microbial Technology 28 (4) (2001) 404–409.

[9]. J. Dick, W. De Windt, B. De Graef, H. Saveyn, P. Van der Meeren, N. De Belie, W. Verstraete, Bio-deposition of a calcium carbonate layer on degraded limestone by Bacillus species, Biodegradation V17 (4) (2006) 357–367.

[10]. Reinhardt, H.-W.; Jooss, M. Permeability and self-healing of cracked concrete as a function of temperature and crack width. Cem.Concr. Res. 2003, 33, 981–985.

[11]. Potential application of Bacteria to improve the strength of cement concrete. C. C. Gavimath*, B. M. Mali1, V. R. Hooli2, J. D. Mallpur3, A. B. Patil4, D. P. Gaddi5, C.R. Ternikar6 and B.E. ravishankera7.

[12]. Aldea, C.-M.; Song, W.-J.; Popovics, J.S.; Shah, S.P. Extent of healing of cracked normal strength concrete. J. Mater. Civ. Eng. 2000, 12, 92–96.

[13]. Edvardsen, C. Water permeability and autogenous healing of cracks in concrete. ACI Mater. J. 1999, 96, 448–454.

[14]. Jacobsen, S.; Sellevold, E.J. Self-healing of high strength concrete after deterioration by freeze/thaw. Cem.Concr. Res. 1995, 26, 55–62.

[15]. Wiktor, V. and Jonkers, H.M., 'Quantification of crack-healing in novel bacteria-based self healing concrete', Cement and Concrete Composites 33 (7) (2011) 763-770.

[16]. A. Neville, (2002). Autogenous Healing Concrete Miracle. Concrete International, 24(11), 76-82.

[17]. V. C. Li, & E. Yang, Self-healing in concrete materials. In S. van der Zwaag (ed.) (2007) Self-healing materials – An alternative approach to 20 centuries of materials science. Springer, The Netherlands, 161–194.

[18]. Mathematical Model for Predicting Stress-Strain Behaviour of Bacterial Concrete Srinivasa Reddy V1, Rajaratnam V1, SeshagiriRao M V1, SasikalaCh.

[19]. J. Dick, W. Windt, B. Graef, H. Saveyn, P. Meeren, N. De Belie, W. Verstraete, Biodeposition of a calcium carbonate layer on degraded limestone by Bacillus species, Biodegradation 17 (4) (2006) 357–367.

[20]. F. Hammes, N. Boon, J. de Villiers, W. Verstraete, S.D. Siciliano, Strain-specific ureolytic microbial calcium carbonate precipitation, Applied and Environment Microbiology 69 (8) (2003) 4901–4909.

[21]. 20 C. Joseph, A. D. Jefferson, M. B. Cantoni, (2007) Issues relating to the autonomic healing of cementitious materials. In: Proceedings of first international conference on self-healing materials, Noordwijkaan Zee, Netherlands.Paper 61.Springer CDROM.

[22]. D. Homma, H. Mihashi, T. Nishiwaki, (2009) Selfhealing capability of fibre reinforced cementitious composites. J AdvConcrTechnol, 7:217–28.

[23]. H. Mihashi, Y. Kaneko, T. Nishiwaki, K. Otsuka, (2000) Fundamental study on development of intelligent concrete characterized by self-healing capability for strength. Trans JpnConcr Inst, 22: 441–50.