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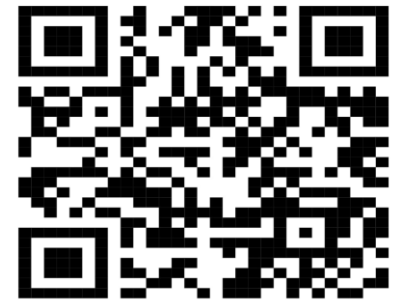

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AN EXPERIMENTAL STUDY ON SELF HEALING CONCRETE

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ABSTRACT

Recent studies have examined the durability, toughness, and strength of concrete structures made of cement. Given that concrete tends to crack easily and deteriorate quickly, there is growing interest in the material's ability to self-heal. In concrete structures, crack formation is a common phenomenon that allows water and various chemicals to seep into the concrete, reducing its strength and durability. When water, CO2, and other chemicals come into contact with the reinforcement, they can also have an adverse effect. Regular maintenance and repairs for structures made of concrete are expensive. A self-healing concrete mechanism is added to the mixture to help with the problem's resolution. This mechanism creates calcium carbonate crystals that obstruct the concrete that aids in crack repair by forming crystals of calcium carbonate that obstruct the pores and microscopic cracks in the concrete. The two types of self-healing concrete are autogenous self-healing concrete and autonomous self-healing concrete.

KEY WORDS: *Concrete, Self-healing, Cracks, Repair, Strength, Bio-concrete.*

1. INTRODUCTION

The most common building material is concrete, which has a low tensile strength and a high compressive strength. Concrete cracking is a frequent occurrence. Concrete structure cracks tend to worsen over time and necessitate expensive repairs if they are not properly and promptly treated. Remedial of cracks in concrete has been the focus of research for many years, even though the extent of cracking can be reduced with current technology. Commercially available products for fixing concrete cracks include epoxy mortar, resins, structures epoxy, and other synthetic mixtures. Historic monuments, pavements, and building structures frequently experience cracks and fissures. We have presented a brand-new method for mending cracks using biological processes that are safe for the environment.

Definition

A type of concrete known as "Bacterial Concrete" is created by incorporating bacteria into the concrete that have the ability to continuously precipitate calcite. Calcite precipitation induced by microbes is the term used to describe this phenomenon. It has been demonstrated that, in the right circumstances, a common soil bacterium called Bacillus Pasteruii can continuously precipitate a new layer of highly impermeable calcite over the top of an existing layer of concrete. The right circumstances must be created because they do not naturally exist in concrete.

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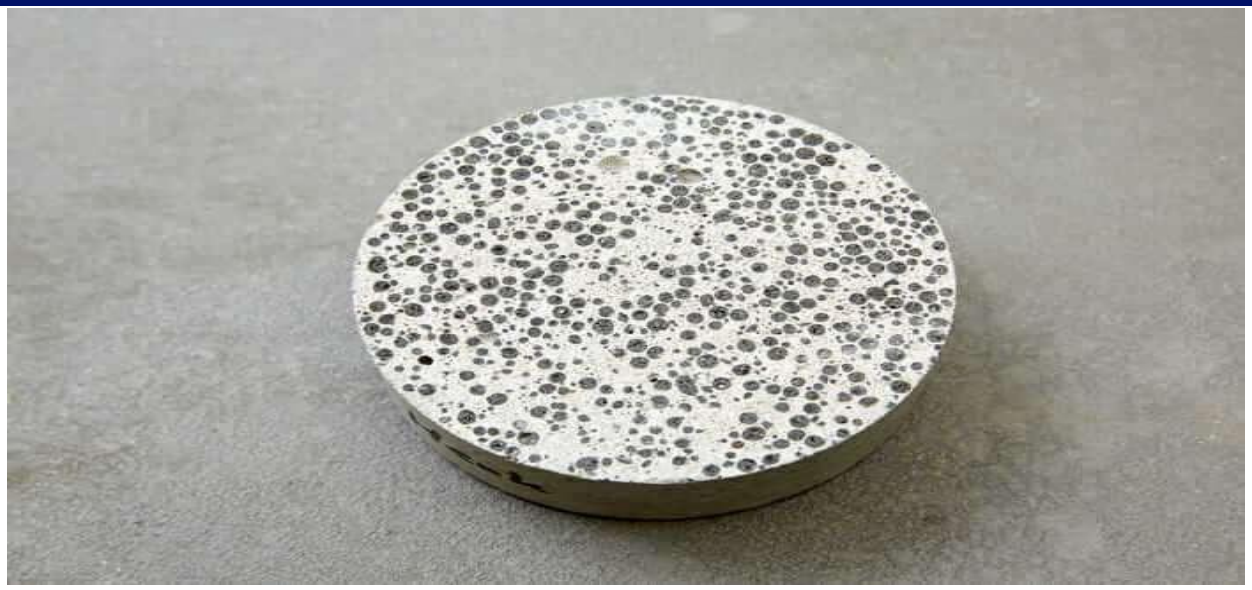

Figure: Self-Healing Concrete

Classification

Autogenous Self-Healing

The autogenous self-healing depends on most part of advanced hydration of concrete, carbonation of calcium hydroxideas well as another binder while. The autogenous self-healing is a traditional and famous method of 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 heal after a while.

Autonomous Self-Healing Concrete

Autonomous self-healing concrete entirely relied on manual method that operates manually. The autonomous self-healingis been identify through a special terminology such as:

1. The vascular method;
2. Capsule method;
3. The bacterial method;
4. The electrodepositing method;
5. The shape memory alloy method;
6. The microwave method and/or induction energy.

2. Processes of Self-Healing Concrete

There are many processes of self-healing concrete technologies which are given below:

(i) Natural process;

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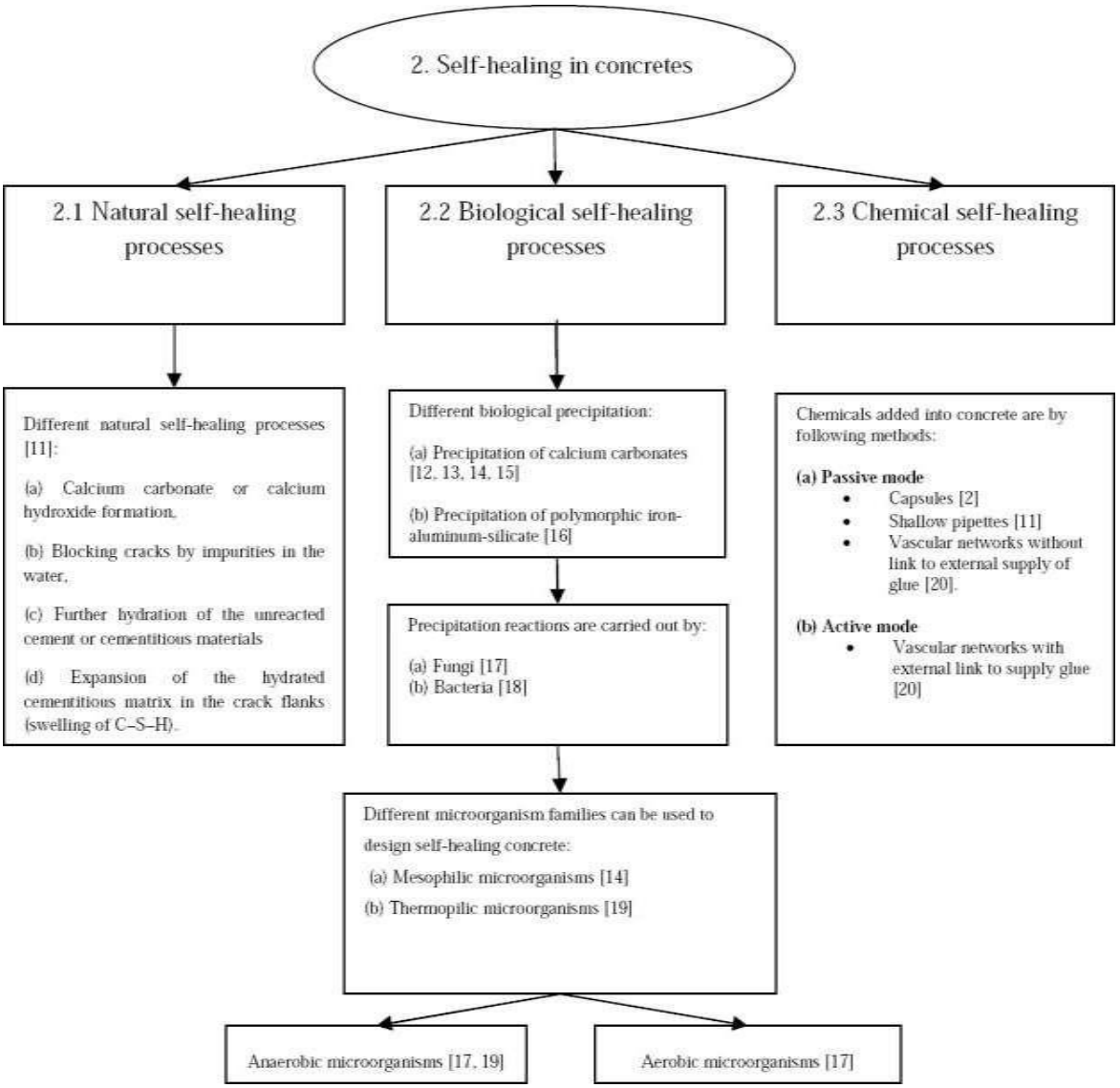
(ii) Chemical process;
(iii) Biological process.

Natural Self-healing process

Some processes can partly fix concrete fracture in natural methods. Following are the four processes that can block cracksin concretes:

1. The development of CaC03 or Ca0H is another method to prevent crack
2. Crack is obstructed by impurities in the carriage of water
3. Crack is further obstructed by hydration of the unreacted cement
4. 4.Crack is impeded by the enlargement of hydrated *cementitious* pattern in the crack loins (such as the lump of calciumsilicate hydrate gel)



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Chemical self-healing process

Chemical healing process mainly refers to the artificial healing by injecting chemical compounds into the crack forhealing. Self-healing concrete is designed by mixing chemical liquid regents (i.e. glue) with fresh concrete in small containers.

The two common chemical methods that make use of glue addition to the concrete for healing purposes: (1)
Hollow pipettes and vessel networks containing glue
(2) Encapsulated glue.

Biological self-healing process

The use of microorganisms to design self-healing concrete has been categorized as biological strategy by several researchers. Microorganisms can grow almost everywhere such as soil, water and oil reservoir, acidic hot springs and industrial wastewater. Microorganisms are mostly divided into three important categories: bacteria, fungi, and viruses. Among these microorganisms, special strains of bacteria capable of precipitating certain chemicals are used to design the biological self-healing concrete.

Precipitation of polymorphic iron-aluminum-silicate ((Fe_5AI_3) $(SiAl)O_{l0}(OH)_5$) and calcium carbonate ($CaCO_3$) are the most important processes use for designing the biological self-healing concretes. The process of calcite precipitation is influenced by the decomposition of urea by bacteria, with aid of the bacterial urease enzyme. As a result of metabolism of bacteria species give urease, that catalyses' urea to ammonia and carbonate. Further these components hydrolyze to carbonic acid and ammonium chloride that leads to the formation of calcium carbonate (calcite crystal).

$$CO(NH2)2 + H2O \rightarrow NH2COOH + N \quad (1)$$
$$NH2COOH + H2O \rightarrow NH3 + H2CO \quad (2)$$
$$H2CO3 \leftrightarrow HCO^{-}3 + H^{+} \quad (3)$$
$$2NH3 + 2H2O \leftrightarrow 2NH4+ + 2OH- \quad (4)$$
$$CHO3- + H+ + 2NH4+ + 2OH- \leftrightarrow CO32- + 2NH4+ + 2H2O \quad (5)$$

3. Material

Self-healing materials are group of energetic materials that have the structurally combined strength to fix damage created by mechanical way over time. The thought arises from biological methods, which have the capacity to fix after being damage.

(1) Biomimetic Design Approaches
(2) Liquid-Based Healing Agents
(3) Self-Healing of Cementitious Composites

4. Tests on Self-Healing Concrete

Water Permeability Test

The water permeability of concrete plays a significant role in its self-healing properties. Upon completion

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of the splitting test, the concrete specimen broke to pieces. After the cylinder was submerged in water for three days, some of the fluid from the splitting test leaked out of the tube and into the cracks. The specimen was then placed in the curing room to wait for the solution to solidify and the polyurethane foam to form. After three days, remove the cylinder and let it dry. The pvc ring held the dry cylinder in place. A specimen was first vacuumed in the vacuum chamber for two to three hours, and after that, de-mineralized water was added to the specimen to create a steady flow condition for the water permeability test.

Compressive Strength

The ability of the structure to withstand the load placed on it is known as the concrete's compressive strength. When compared to conventional concrete, the compressive strength of the added bacteria-infused concrete is increased. When compared to conventional concrete, the addition of Bacillus subtilisjc3 increased the compressive strength of concrete by 14.92%. In comparison to conventional concrete, it was discovered that b. Sphaericus increased the compressive strength of concrete by 30.76% in 3 days, 46.15% in 7 days, and 32.21% in 28 days.

S.No	Bacterial concrete			Conventional concrete	
	Compressive strength (N/mm^2)			Compressive strength(N/mm^2)	
	Name of bacteria	7 days	28 days	7 days	28 days
1	Bacillus Subtilis	22.18	32.74	20.84	29.99
2	Bacillus sphaericus	34.58	45.72	20.84	29.99
3	Bacillus pasteurii	27.09	38.98	20.84	29.99

Oxygen Consumption Measurement

Oxygen consumption as determined by the metallic conversion of calcium lattice by aerobic bacteria. Fick's first law of diffusion was utilized in the study to calculate the change in oxygen concentration in the linear part of the gradient in the diffusive boundary layer. Optical oxygen micro sensors were used for quantification of mortar specimens containing biochemical healing agents and submerged control.

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$J = -D_{(oxygen)} * dC_{(z)}/dZ$

Where D_{oxygen} is the diffusion coefficient of O_2 in water, and $C_{(z)}$ is the concentration of O_2 at depth Z.

Gas Permeability

Rilem- cembureau method can be used to find the gas permeability using the principal as the hagen-poiseuille relationship for laminar flow of a compressible fluid through a porous body having small capillaries under steady state. Martin sommer oxygen permeability experiment measures the rate of flow of oxygen.

Treatment Procedure

For the treatment procedure the specimen is immersed in the 0.3 and 0.6 L of a 1 day old stock culture of B. sphaericus prior to submerge in the nutrition solution for 24 days due to this ureolytic activity primarily result from bacteria inside the specimens. Selection of the treatment based on the commercial availability according to their different mechanisms in table

Group	Subgroup	Composition of conventional technique/nutrient solution
Biodeposition treatment	Ureolytic mixed cultures	1. Urea, NBP 2. Urea, calcium acetate 3. Urea, calcium chloride 4. Urea, NBP calcium acetate 5. Urea, NBP calcium chloride
	Bacillus sphaericus	1. Ureas, NBP 2. Urea, calcium acetate 3. Urea, calcium chloride 4. Urea NBP, calcium acetate 5. Ureas NBP, calcium chloride

Effect on the Strength Test

As amalgamation of healing agent to concrete may have unwanted negative effects on the mechanical properties. The consolidation of a high number of bacteria (5.8 x 108 cm-3 cement stone) will have a negative effect on the compressive strength development as bacterial test specimen appeared almost weaker than control specimen. Tensile strength is the ability of a material to withstand a pulling (tensile) force. Earlier studies have proven that bacterial concrete shows the better tensile strength as compare to the conventional tensile strength as shown below.

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S.No.	No. of days	Split tensile strength of conventional concrete cylinders, N/mm^2	Split tensile strength *B. sphaericus* concrete cubes, N/mm^2	% increase in Strength
1.	3	3.78	4.30	13.75
2.	7	4.62	5.28	14.28
3.	28	4.85	5.74	18.35

Advantage and disadvantages of Self-Healing Concrete

Advantages

- Redressing of cracks can be done efficiently.
- It offers great resistance against freeze and thaw attacks.
- It has lower permeability when compared to conventional concrete.
- The use of self-healing concrete significantly enhances the strength of concrete.
- The chances of corrosion of reinforcement are reduced to negligible.
- Overall maintenance cost of this concrete is low.

Disadvantages

- The investigations involved to observe calcite precipitation are costly.
- Cost of this concrete is comparatively higher than conventional concrete; it's about 10-30% more thanconventional concrete.
- There is no design of bacterial concrete is mentioned in IS codes or any other codes.
- Bacteria that are used in concrete are not good for human health; hence its usage should be limited to thestructure.

5. Conclusion

The techniques for creating self-healing concrete are provided in this paper. The addition of bacteria to concrete is very beneficial as it raises the concrete's attribute level above that of regular concrete. The study examined various bacterial species that can be employed to treat concrete cracks. Concrete cracks are filled in and repaired by bacteria through the production of calcium carbonate crystals that block the cracks. Numerous researchers investigating the self-healing properties of concrete have discovered that bacteria enhance the properties of traditional concrete, increasing its strength by 13.75% in 3 days, 14.28% in 7 days, and 18.35% in 28 days. As everyone knows, self-healing concrete is less expensive to maintain and repair using traditional methods. Therefore, in order to improve concrete structures, we must refine and apply these techniques. The concepts and techniques for creating self-healing concrete are presented in this paper.

REFERENCES

[1] W. Zhong, W. Yao, (2008) Influence of damage degree on Self-healing of Concrete. Construction and BuildingMaterials, 22: 1137-1142.
[2] K. van Breugel (2007) Is There a market for self-healing cement-based materials. In: Proceedings of the first international conference on self-healing materials, Noordwijkaan zee, the Netherlands.Pecker Alain, "Earth Quake Foundation Design, Soil Mechanics Laboratory, Palaoseau, France.
[3] Jonkers, H., 'Bacteria-based self-healing concrete', *HERON* 56 (1) (2011) 1-12.
[4] 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.
[5] H.M. Jonkers, A. Thijssen, O. Copuroglu, E. Schlangen, Application of bacteria as self-healing agent for thedevelopment of sustainable concrete, Proceedings of the 1st International Conference on BioGeoCivil Engineering, 23–25 June 2008, Delft, The Netherlands.
[6] Abo-El-Enein, Ali, FatmaTalkhan, Abdel-Gawwad, "Application of microbial biocementation to improve thephysico-mechanica properties of cement mortar", Housing and Building National Research Center (2013).
[7] J. Dick, W. Windt, B. Graef, H. Saveyn, P. Meeren, N. De Belie, W. Verstraete, Biodeposition of a calciumcarbonate layer on degraded limestone by Bacillus species, Biodegradation 17 (4) (2006) 357–367.
[8] 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.
[9] Kusuma K., Amit Kumar Rai, Prashant Kumar, Harini K. and Harshita M.N, (2018) 'SELF-HEALING COCRETE'. International Research Journal of Engineering and Technology Volume: 05 Issue: 05
[10] Amirreza Talaiekhozan, Ali Keyvanfar, Ramin Andalib and Rosli Mohamad Zin, 'A Review of Self-healing Concrete Research Development', Journal of Environmental Treatment Techniques 2014, Volume 2, Issue 1, Pages: 1-11
[11] Abubakar Magaji, Mathias Yakubu and Yakubu Mamman Wakawa, 'A Review Paper on Self-Healing Concrete',The International Journal of Engineering and Science (IJES) Volume 8 Issue 5 Series I Pages PP 47-542019
[12] A. Neville, (2002). Autogenous Healing Concrete Miracle. Concrete International, 24(11), 76-82.
[13] Salmabanu Luhar and Suthar Gourav, 'A Review Paper on Self-Healing Concrete', Journal of Civil EngineeringResearch 2015, 5(3): 53-58
[14] 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.
[15] Wiktor, V. and Jonkers, H.M., 'Quantification of crack-healing in novel bacteria-based self healingconcrete',
Cement and Concrete Composites 33 (7) (2011) 763-770.
[16] D. Homma, H. Mihashi, T. Nishiwaki, (2009) Selfhealing capability of fibre reinforced cementitious composites.J AdvConcrTechnol, 7:217–28.
[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] H.M. Jonkers, A. Thijssen, O. Copuroglu, E. Schlangen, Application of bacteria as self-healing agent for thedevelopment of sustainable concrete, Proceedings of the 1st International Conference on BioGeoCivil Engineering, 23–25 June 2008, Delft, The Netherlands.

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

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