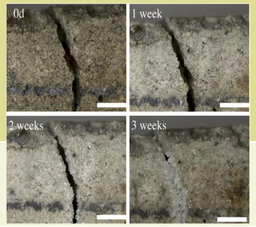
SELF-HEALING CONCRETE: THE USE OF MICROENCAPSULATION TO REPAIR INFRASTUCTURAL DETERIORATION



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Causes Of Concrete Deterioration

One major way concrete cracks is through plastic shrinkage. Plastic shrinkage cracks take place during the concrete's loss of water. Concrete (before it hardens) is in a plastic state, and as it begins to lose water, the slab begins to shrink. Because concrete is a rigid structure, the shrinking that takes place puts pressure on the slab, causing it to crack. Another common way concrete can crack is through expansion. In very warm environments, concrete begins to expand and will eventually run into another material: whether that be a metal beam or another concrete slab. The expansion of the slab is upheld by the other material it encounters, putting a great deal of stress on the concrete, eventually causing it to crack. The final form of cracking is cracking due to heaving. Heaving involves ground movement brought on by, "freeze/thaw cycles". When the ground freezes it can raise several inches, and when it thaws the ground returns to its original height or sinks lower. In places where this process is recurrent, the concrete that sits on these grounds will continually be moved from their resting spot. The constant movement causes stress to be brought onto the slabs, leading to cracks forming within.

Ethical Obligations

Surrounding weather is always a factor that must be taken into account; building in an area that is warmer than other areas could cause a decrease in the excess free water needed for the bacterial microencapsulation to work. If a crack arises and is expected to be fixed on its own and does not, the crack could cause the concrete structure to deteriorate and could eventually collapse, causing severe injuries or death to those who use the structure. An important aspect to this is to continually inspect these structures. These inspections should be completed as if it were normal concrete, checking for faults within the structure.

Economic Effect

- It is estimated that it would cost $1 trillion to repair the entirety of the nation's interstate and highway system, and close to $3.6 trillion to repair all of the country's infrastructure
- Motorist's spend an average of $523 a year on problems that arise from driving on deteriorated roads

Microencapsulation

The process of microencapsulation is when micron-sized particles of gases, solids, and liquids are placed into a shell that isolates and protects them from the environment. These bacteria and polymers are contained in capsules in the concrete that break down when in contact with water, releasing the healing agents. The agents then react with the water producing precipitates that combine with the concrete to reinforce the material. Experiments are ongoing to find the optimal shell material to withstand the fluctuation of pH, temperature and agitation rate.

- The results in Figure 1(a) show the relative decrease in the thickness of the shell containing DCPD after increasing the pH. In Figure 1(b), the results show that as the pH increases, so does the shell of the sodium silicate.
- In Figure 2(a), displaying the effect of temperature on DCPD, the graph shows that at a temperature of 49 ℃ (120.2 ℉) no encapsulation took place. For the sodium silicate, shown in Figure 2(b), at a temperature of 53 ℃ (127.4 ℉) no encapsulation took place.
- In Figure 3(a), as the agitation rate of the solution containing the DCPD increases, the diameter of the shells produced decreases. For the sodium silicate in Figure 3(b), as the agitation rate increases, the average shell thickness remains close to the same.

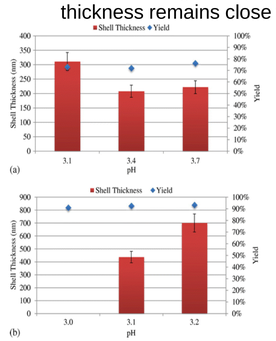

Figure 1

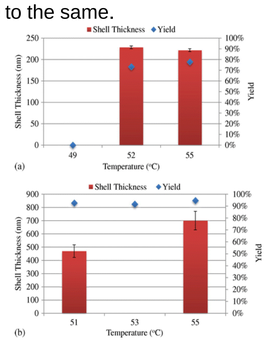

Figure 2

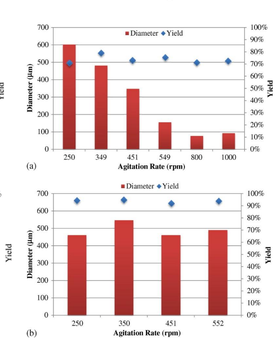

Figure 3

Environmental Impact

- The carbon dioxide levels in the atmosphere are nearing the highest they have been in human history (approximately 400 ppm)
- The manufacturing of concrete roughly accounts for 9.5% of all the emitted CO_2
- If the cement needed to repair concrete was eliminated, due to the self-healing additives of concrete, a large amount of the emitted carbon dioxide could be eliminated as well.

Forms of Self-Healing Concrete

Method	Advantages	Disadvantages
Continued Hydration	• Uses the unmixed materials within the concrete itself	• Takes a long period of time to heal • Needs constant contact with water
Autogenous Healing	• Use of unmixed agents within the concrete	• Only can fix small cracks, and at a slow rate • Needs constant contact with water
Microencapsulation	• Can be used in hard to reach places • Increases strength of structure	• More expensive

Increasing the Longevity

Compressive strength is a structure's ability to withstand a load that tends to compress it. When it comes to the compressive strength of self-healing concrete, research has shown the that implementation of the microcapsules into the concrete has been found to increase. Increasing the compressive strength of the concrete before a crack forms, can increase the longevity of it by reducing the frequency of cracks early in the concrete's lifespan. The extended lifespan provided by the encapsulated bacteria and polymers allows for a more sustainable replacement compared to the concrete used today. The social, economic and environmental aspects of sustainability will be amplified. Limiting the use of excess concrete to repair structures will decrease their emissions of CO_2 into the atmosphere, minimize the expenses used to amend the deteriorating concrete, and finally, increase the livability of the surrounding area for the benefit of the community.

Future of Microencapsulation

The future application of microencapsulation would make the best impact in places such as:

- Locations where it would be difficult to perform extensive repairs on the cracks. These include high altitude buildings and underground piping.
- Applications where reliability and safety are key issues, even during overload or unforeseen circumstances: storm surge barriers or nuclear reactors or long-term storage of nuclear waste
- Locations where having to repair a cracked structure would become an inconvenience to the society.