Self Healing Concrete: Promising New Development in Concrete Technology – A Review

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Abstract

As we all know that Concrete being the vital element of the construction industry, the strength of any structure depends on the quality of concrete used in the construction. Concrete contains Cement, Coarse aggregate, Fine aggregate & Water in required proportion. In 21st century, all the structures over the world are constructed with Concrete as a main material. Generally, any concrete structure is having life period of less than 100 years but due to deterioration of concrete, the life period of concrete decreases. The deterioration of concrete occurs mostly in every structure which are exposed to weather conditions. Concrete structures usually have some Self-Healing Capacity, i.e. the ability to heal or seal freshly formed micro-cracks. This property is mainly due to the existence of non-hydrated excess cement particles in the materials matrix, which undergo delayed or secondary hydration upon reaction with access water. In this research paper, it is tried to show some characteristics and uses of a new type of self-healing concrete in which bacteria facilitate the production of minerals which rapidly seal freshly formed cracks, a process that alongside decreases concrete permeability, and thus better protects embedded steel reinforcement from corrosion. Initial results show that the addition of specific organic mineral antecedent compounds plus spore-forming alkaliphilic bacteria as self-healing agents produces up to 100-µm sized calcite particles which can potentially seal micro- to even larger-sized cracks[1].Further development of this bio-concrete with significantly increased self-healing capacities could represent a new type of durable and sustainable concrete with a wide range of potential applications.

Keywords : Self Healing Concrete, alkaliphilic bacteria ,

Introduction

Self-healing in concrete is defined as the ability for the concrete to sense its damage and reinstate its degraded properties through the use of inherently available resources within the concrete. The overall goal of this paper is to produce a state-of the art report on this technology in order to identify areas of needed research, thereby increasing the application of this technology.

Self healing concrete is a type of concrete which is typically used as a replacement for the conventional type of concrete. We should first of all identify the different methods used for the production of the self – healing concrete and how efficient and accurate the method is in producing the self healing concrete[2].

This paper will explore the various uses involving for self healing concrete. The cost effectiveness is also an important parameter and it should be considered while producing the self healing concrete. The self healing concrete is not yet being made widely available and the awareness of the self healing concrete is not being made up to the point.

The main objective of self healing concrete is to decrease the minor cracking of the structural members and thereby increasing the durability and workability of concrete.

Every concrete has some resistance capacity and self healing tendency but by using self healing concrete instead of normal concrete.

I. INTRINSIC SELF HEALING

Intrinsic self healing is also called natural healing of concrete is generally relies on the inherent components of cementitious materials. Whenever a crack is formed in the outer surface of concrete, due to the inherent property of the material, the cracks gets healed due to the intrinsic property of the materials. In this method, the Calcium Carbonate and Calcium hydroxide is formed inside concrete. The cracks are blocked due to the presence of debris in ingress water or loose concrete which results from cracks spalling. The hydration of un-reacted Portland cement occurs and it heals the cracks[3].

There are three types of Intrinsic Self Healing, Autogenously Healing, Improved Autogenously Healing & Polymer Modified Concrete.

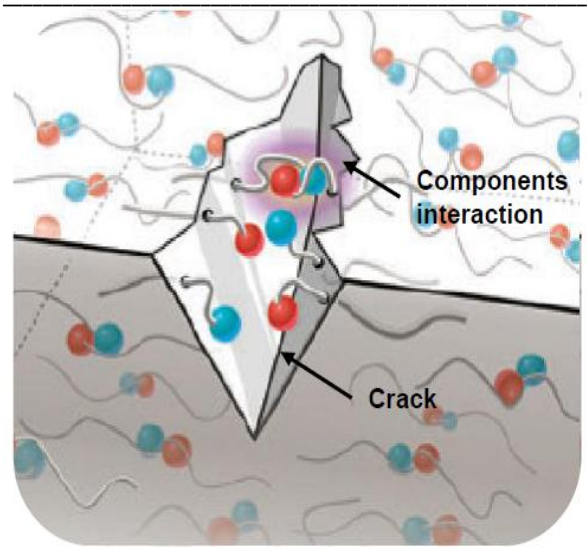

Fig. 1 Intrinsic Self Healing of Concrete[4]

II. BIOLOGICAL BASED SELF-HEALING

The biological based self-healing is a type of self healing in which intrusion of bacteria or such type of living organisms is used. These healing agents can be inserted during in concrete during its placement or it can also be directly mixed during preparation.

The biological self healing has three types namely vascular, mixing with other ingredients and encapsulation. This method is used as a healing technique for the concrete in which micro cracks are developed and it is having the dimensions not more than 5mm. This method is widely used in concrete due to its easy applicability and self healing tendency.

This method has been inspired by the configuration of human bone. Bone consists of two parts. The outer layer is the cortical bone which is solid and the inner spongy layer is the trabecular bone. As shown in Figure, vascular technique supplies healing agent from outside of structure by using scattered vascular networks which have been already rooted in matrix during concrete preparation. As cracks appear, healing agent moves through it due to pressure gradient between agent source and cracks positions.

Dry proposed a self-healing mechanism in which the interior and exterior concrete parts were joined via single or multiple hallow vascular fibres.

Firstly, healing agent should have continual thickness throughout the concrete's service life to help it flow easily as well as to prevent escape under environmental circumstances

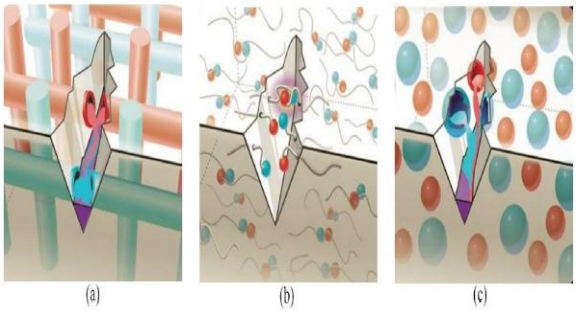

Fig. 2 Three main self-healing types: (a) vascular; (b) mixing with other ingredients; (c) encapsulation[3]

As shown in figure 2, the mixing with the other ingredients procedure follows with the bacteria's which are present in the nature is mixed with the production of concrete itself. The main advantage of mixing at the production of concrete stage is it is mixed in required proportion and it prevents the micro cracking of the concrete at the former stages of concrete. The proportion of bacteria is assumed at this stage which prevents the formation of micro cracks.

As shown in figure 2, in encapsulation technique, the bacteria are covered in form of capsules in the micro cracks which are formed on the surface of concrete. This way , the formation of cracks are treated in order to prevent the deformation of concrete further.

III. ENVIRONMENTAL ADVANTAGE

Self-healing concrete could decrease the significant CO2 emissions that result from concrete production. Because the production of concrete is very energy intensive – when mining, transportation and concrete plants are considered the industry is responsible for about 10 per cent of all CO2 emissions in the country. If self-healing concrete can lengthen the life of the concrete and reduce maintenance and repairs, it will ultimately reduce the production of excess amounts of concrete and result in a decrease in CO2 emissions.

IV. AUTONOMOUS CRACK REPAIR OF BACTERIAL SELF HEALING CONCRETE

Concrete test specimens were arranged in which part of the aggregate material, i.e. the 2-4 mm size class, was substituted by similarly sized expanded clay particles loaded with the biochemical self-healing agent (bacterial spores 1.7x105 g-1 expanded clay particles, corresponding to 5x107 spores dm-3 concrete, plus 5% w/w fraction calcium lactate, corresponding to 15g dm-3 concrete). Before solicitation, loaded expanded clay particles were oven-dried until no further weight loss due to water evaporation was observed (one week at 40ºC). Control specimens had a similar aggregate

composition but these expanded clay particles were not loaded with the bio-chemical agent. Both types of expanded clay particles (empty for control specimens and loaded for bacterial specimens) were Composition of concrete specimens is shown in Table 1.[4]

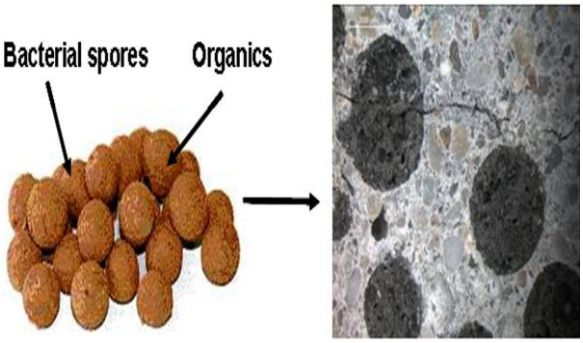

Figure 1. Self healing admixture composed of expanded clay particles (left) loaded with bacterial spores and organic bio-mineral precursor compound (calcium lactate). When embedded in the concrete matrix (right) the loaded expanded clay particles represent intern[5].

V. TABLE I

COMPOSITION OF CONCRETE SPECIMENS. LWA REFERS TO LIAPOR SAND R 1/4 EXPANDED CLA

Compounds	Volume (cm3)	Weight (g)
2 - 4 mm LWA	196	167
1 - 2 mm LWA	147	125
0.5 - 1 mm Sand	147	397
0.25 - 0.5 mm Sand	128	346
0.125 - 0.25 mm Sand	69	186
Cement CEMI 42.5N	122	384
Water	192	192
Total	1001	1796

The amount of light weight aggregate applied in this case represents 50% of the total aggregate volume. Replacement of such a high fraction of sand and gravel for expanded clay has consequences for strength characteristics of the resulting concrete. In this specific case a 50% decrease in compressive strength was observed after 28 days curing when compared to specimens of similar aggregate composition without replacement of sand and gravel fractions for expanded clay particles. Although the expanded clay-based specimens featured a considerable decrease in strength, crack-healing capacity of specimens in which expanded clay particles were loaded with bacteria and organic mineral precursor[5].

Comparison between bacterial and control specimens exposed a significant difference in permeability and thus in self-healing capacity. While cracks of all six bacterial specimens were totally sealed resulting in no assessable permeability (percolation of 0 ml water / h), only 2 out of six control specimens appeared perfectly healed. The four other control specimens featured permeability (water percolation) values between 0 and 2 ml/h. Microscopic examination of cracks (at the side of the slab being exposed to the water 7 column) revealed that in both control and bacterial specimens precipitation of calcium carbonate-based mineral precipitates occurred. However, while in control specimens precipitation largely occurred near the crack rim leaving major parts of the crack unhealed, efficient and complete healing of cracks occurred in bacterial specimen as here mineral precipitation occurred predominantly within the crack itself (Fig. 4).

Figure 2. Light microscopic images (40 times magnification) of pre-cracked control (A) and bacterial

VI. CONCLUSION

This revolutionary technique can be very useful in future of concrete. Being the most versatile material, concrete can evolve in such self reliable material, which will improve the life of structures. Self Healing Concrete can change the future of construction in very fashionable manner. The Self healing concrete can be a very effective alternative due to its applicability and healing capacity.

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