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INTRODUCTION TO SELF-HEALING CONCRETE VIA BIOLOGICAL PROCESS

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Abstract:
Concrete is the most important material used in order to construct a building. Malaysia receives extreme variations in rainfall. Due to the rainfall average, water may enter into the cracks occurred in a building. The repairing process of concrete may take some time and the cracks affect the surrounding especially reinforced concrete at a bridge. One of the effective ways to overcome the problem is by applying self-healing concrete that has been used by other countries. The objectives of the research are to understand the concept of self-healing concrete using biological process, to identify the practise of new self-healing concrete process in another country and to propose the concept of biological self-healing concrete that can be adapted to the building in Malaysia. In order to achieve the objectives, the method used to conduct this research is desk study on the relevant topics related to the self-healing concrete in locally and abroad. Therefore, the critical review will become the basis of a new concept for self-healing concrete by biological process to suit local condition. From the review, it was found that mixing the concrete with limestone-producing bacteria may repair any cracks that formed in the concrete.

Keywords: Cracks; Self-healing concrete; Biological process; Bacteria; Limestone.

1.0 INTRODUCTION

Concrete may seem to be a strong component in a building. Nevertheless, there are some disadvantages of using concrete material as the main component. Concrete tend to crack due to drying shrinkage and thermal movement. Besides that, cracks in concrete are a common phenomenon due to the relatively low tensile strength. Though concrete are extremely durable and hard, it is still susceptible to wear and tear damages like overtime or under impact type of cracks t. Last but not least, concrete may also undergo a process known as creep in which material deformity takes place due to mechanical stress.. All of the cracks may lead to high maintenance of building and they also affect other building structures.

According to Patel (2015), in order to help reduce those maintenance costs and make buildings and bridges safer, researchers are now giving concrete the power to heal itself. Extending the lifetime of structures, self-healing concrete could also reduce the use of concrete for rebuilding and cut concrete's impact on the environment (Patel, 2015),. The concept of self-healing concrete by using bio-logical process is one of the purposes behind this study. The concept of biological process is achieved by applying the mix clay pellets containing calcium lactate and spores of limestone-producing bacteria into concrete.

Another purpose is to identify the practice of new self-healing concrete process in another countries. In 2011, Dr Henk Jonkers, a microbiologist who specialises in the behaviour of bacteria in the environment, had developed self-healing concrete in the laboratory and full-scale outdoor testing (Arnold, 2011). Davis (2015) stated that the bacteria, either Bacillus pseudofirmus or Sporosarcina pasteurii, are found naturally in highly alkaline lakes near volcanoes, and are able to survive for up to a staggering 200 years without oxygen or food. He also stated that these bacteria are activated when they come into contact with water and then use the calcium lactate as a food source, producing limestone that, as a result, closes up the cracks.

The application of the self-healing concrete can be adapted to the building in Malaysia. To propose the concept of biological self-healing concrete in Malaysia is also one of the purpose the research is conducted. Due to the extreme variations in rainfall in Malaysia, water may enter into the cracks occurred in a building. Also, there are plenty of bridges, flyovers which are exposed to the local climatic challenges. Therefore, the reducing of cement ratio will be substituted with these two self-healing agent parts that are the bacterial spores and the calcium lactate-based nutrients. This concept may help to reduce the concrete crack as well as maintaining the structure of the building for sustainability in future.

2.0 LITERATURE REVIEW

In order to maintain the sustainability of a building, the properties of material need to bedurable for a long time. Concrete has relatively high compressive strength, but significantly lower tensile strength. Therefore, as an important part of the building, concrete has to be maintained. The maintenance of the concrete can be done by healing the concrete itself.

2.1 The Concept of Self-Healing Concrete

Self-healing concrete can be defined as the process of healing the concrete by itself using various ways to achieve the strength of the concrete. The innovation of self-healing concrete started in Dutch in 2011 by Dr Henk Jonkers, a microbiologist who specialises in the behaviour of bacteria in the environment (Arnold, 2011). According to Snoeck, D et al. (2018)in Belgium, self-healing of cracks in concrete would contribute to a longer service life of concrete structures and would make the material not only more durable but also more sustainable. Snoeck, D et al. (2018)also mentioned that since the costs involved for maintenance and repair of concrete structures are usually high, the development of self-healing concrete shall be the industry's focused. While according to Rathod (2015) in India, self-healing concrete is a concrete which heals itself when it comes in contact with air and water. Different with Arnold (2011), self –healing concrete is a healing agent that works when bacteria embedded in the concrete convert nutrients into limestone.

2.2 The Process of Self-Healing Concrete using Biological Process

From the review, it was found that there are various methods and processes of self-healing using biological process. As stated by Davis (2015), the bacteria, either Bacillus pseudofirmus or Sporosarcina pasteurii, are found naturally in highly alkaline lakes near volcanoes, and are able to survive for up to a staggering 200 years without oxygen or food. Davis stated that the bacteria are activated when they come into contact with water and then use the calcium lactate as a food source, producing limestone that, as a result, closes up the cracks. According to Snoeck, D et al. (2018), there are different healing mechanism that can be used in self-healing concrete. The mechanisms include microfibres, superabsorbent polymers, calcium carbonate precipitating micro-organisms, encapsulated polymers and fly-ash and blast-furnace slag.

In addition, Talaiekhozani, et al. (2013) stated that the microorganism's usage to design self-healing concrete has been suggested. Somehow, Talaiekhozani, et al.(2013) mentioned that the most effective microoganism used is bacteria. Similarly, to Gandhimathi, et al. (2012), the ordinary concrete used in the test program consisted of cementing materials, mineral aggregates and corrosion inhibitor with the specifications of ordinary Portland cement, graded fine aggregates, graded coarse aggregates, water and bacteria types using Bacillus Sphaericus. The process of using bacteria is also applied by cultivation of alkali-resistant spore-forming bacteria, preparation and strength characteristics of bacterial concrete, viability of concrete-immobilized spores and calcite precipitation potential of bacterial concrete as mentioned by Jonkers, et al. (2008).

3.0 METHODOLOGY

Research methodology for this study involves many activities to be performed. Method of study used to obtain information for the research includes secondary sources. Desk study is used to obtain

information on the relevant topics of self-healing concrete by biological process. Apart from that, some information is also obtained through critical review of the process of self-healing concrete. The purpose of the critical review is to propose and differentiate the process and method of self-healing concrete using various ways.

4.0 ANALYSIS AND FINDINGS

The expected finding for the research is the relationship of concrete itself when combinedwith water and bacteria. When there is a presence of water inside of the concrete due to the rain or any other circumstances, the bacteria will activate themselves to repair the crack or closes the flow of water before entering the steel reinforcement bar.

4.1 Concept of Self-Healing Concrete

Basically, the concept of the self-healing concrete by biological process includes the combination of two types of material which are the bacteria and the limestone product. The expected finding for the research is the cement ratio will be reduced to add the precipitation of bacteria and limestone product which will enter the concrete to heal the concrete by itself. As the main purpose of the research is to understand the self-healing of concrete cracks, self-healing concrete is a product that will biologically produce limestone to heal cracks that appear on the surface of concrete structures. According to Arnold (2011), specially selected types of the bacteria genus Bacillus, along with a calcium-based nutrient known as calcium lactate, nitrogen and phosphorus, are added to the ingredients of the concrete when it is being mixed. He also stated that these self-healing agents can lie dormant within the concrete for up to 200 years.

Process of Self-Healing Concrete using Biological Process

The concept of self-healing concrete has been implemented in some other countries abroad such as Dutch by Dr. Henk Jonkers, Belgium as said by Snoeck, D et al. (2018) and India as mentioned by Rathod (2015), where various kind of method has been used. The method of biological process that can be used to suit the Malaysian climate is a product that will biologically produce limestone and specially selected types of the bacteria which is genus Bacillus. Bacillus along with a calcium-based nutrient known as calcium lactate, and nitrogen and phosphorus, are added to the ingredients of the concrete when it is being mixed. According to Arnold (2011), cement and water have a pH value of up to 13 when mixed together, usually a hostile environment for life where most organisms die in an environment with a pH value of 10 or above. Arnold also stated that the trains of the bacteria genus Bacillus were found to thrive in the high-alkaline environment.

Application of Biological Self-Healing Concrete to the Building in Malaysia

Applying the concept that has been invented by other countries such as Belgium and India, the self-healing concrete will help to repair the crack components as well as sustain the building components by itself. Therefore, this concept will be proposed to be adapted to the building in Malaysia. This is due to the amount of rainfalls received in Malaysia and poor condition of bridge which will be improved by applying this concept. As mentioned, one of the material that will be used in this autogenous healing of concrete will be bacteria. According to Gandhimathi, et al. (2012), the design mix of an ordinary concrete may consist of cementing materials, corrosion inhibitor with the specifications of ordinary Portland cement, graded fine aggregates, graded coarse aggregates, water and bacteria types using Bacillus Sphaericus. The combination of the design mix can produce a better workability of concrete to avoid defects of crack.

5.0 CONCLUSION

The application of self-healing concrete in biological process may reduce the probability of concrete with the presence of defect. The process also may ensure that the concrete can be sustained for a long term which will provide benefit in the future. Based on the research, it was found that the combination of the bacteria and the limestone product may produce a great impact to the concrete for them to heal themselves. In fact, the self-healing concrete involves research and implementation abroad. Similar

product can be applied to the building in Malaysia. Hence, the problems of concrete defects which is focused on the cracking of concrete can be solved using the biological self-healing concrete method.

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