EFFECTS OF EFFECTIVE MICROORGANISMS ON PROPERTIES OF BLENDED CEMENT CONCRETE

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"Dedicated to my beloved husband Meor Shahrizan bin Zolkfle,

my son Daniyal Anaqi bin Meor Sharizan, and family for their love,

encouragement and support."

"Special thanks to supervisor, all lecturers, and friends for their motivation, concern and help."

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ABSTRACT

Concrete is an artificial rock that is made with a mixture of cement, aggregates and water with certain proportion. Concrete is one of the material that is most widely used in the construction industry. Cracks that occurs in concrete structure require regular maintenance and special type of treatment which will be very expensive, particularly to the massive concrete structures that bear loads or main structures members. So, to overcome this problem, EM (Effective Microorganism) concrete is introduced to study the potential of EM concrete in filling the cracks. By mixing EM with concrete mixture, the effect on the properties of concrete is assessed whether this EM concrete increase the workability, strength, durability and other properties related. In this study, understanding the function and mechanism of EM in concrete is crucial. Several parameters and concrete properties was tested in the experimental procedure and the effect of EM in concrete were assessed in this study. The performance of EM were measured through its fresh and hardened properties of the concrete. From this experimental study, the optimum EM mix to be added in the concrete is 10%, slump of EM concrete had increase by 11.4%. Compressive strength of the EM concrete also increase and modified compression strength is higher than cube compressive strength by the average of 5%. UPV value were increasing by 4%. The EM concrete had higher shrinkage and expansion strain. Water absorption shows that concrete with dry curing condition does absorb more water. EM concrete shows lower rate of carbonation process than control concrete by 50%. From this study, it can be concluded that the properties and behavior of EM concrete almost similar with the normal concrete. EM concrete does have the potential in filling the crack of concrete and further studied is crucial in understanding the mechanism and reaction of EM in concrete.

ABSTRAK

Konkrit merupakan batuan tiruan yang diperbuat daripada campuran simen, aggregat dan air dengan nisbah yang tertentu. Konkit merupakan salah satu bahan yang digunakan secara meluas di dalam industry pembinaan. Keretakan yang terjadi di dalam struktur konkrit memerlukan penyelenggaraan dan pemuliharaan yang berkala dan mahal, terutamanya kepada struktur konkrit besar yang menanggung beban atau struktur utama. Jadi, bagi mengatasi masalah ini, mikroorganisma efektif (EM) diperkenalkan untuk mengaji potensi EM ini dalam menutupi keretakan konkrit. Dengan mencampurkan EM dalam campuran konkrit, kesan ke atas sifat-sifat konkrit dinilai sama ada konkrit EM ini meningkatkan kebolehkerjaan, kekuatan, ketahanan dan sifat-sifat lain yang berkaitan. Dalam kajian ini, memahami fungsi dan mekanisme EM di dalam konkrit adalah amat penting. Beberapa parameter dan sifat-sifat konkrit telah diuji dalam prosedur eksperimen dan kesan EM di dalam konkrit telah dinilai dalam kajian ini. Campuran optimum bagi spesimen EM yang menyumbang kepada sifat-sifat kekuatan maksimum adalah 10% EM dalam bahan tambah konkrit, ujian penurunan meningkat sebanyak 11.4%, kekuatan kiub konkrit EM lebih tinggi, dan kekuatan mampatan diubahsuai adalah lebih tinggi daripada kekuatan mampatan kiub dengan purata 5%. Bacaan UPV meningkat sebanyak 4%, menunjukkan bahawa EM berpotensi untuk menutupi keretakan konkrit. Konkrit EM mengalami pengecutan dan pengembangan spesimen yang lebih tinggi. Kebolehtepalan air menunjukkan konkrit dalam pengawetan udara menyerap lebih banyak air berbanding konkrit yang diawet di dalam air. Konkrit EM menunjukkan kadar pengkarbonatan yang lebih rendah sebanyak 50%. Daripada kajian ini, dapat disimpulkan bahawa sifat-sifat dan tingkah laku konkrit EM hampir sama dengan konkrit biasa dan berpotensi digunakan dalam bancuhan konkrit.

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LIST OF ABBREVIATIONS/SYMBOLS

ACI	-	American Concrete Institute
ASTM	-	American Society for Testing And Material
BS	-	British Standard
CCRA	-	Cube Control Air Curing
CCRW	-	Cube Control Water Curing
CPRA	-	Cube Pre-Crack Air Curing
CPRW	-	Cube Pre-Crack Water Curing
ECRA	-	EM Cube Control Air Curing
ECRW	-	EM Cube Control Water Curing
EM	-	Effective Microorganism
EPRA	-	EM Cube Pre-Crack Air Curing
EPRW	-	EM Cube Pre-Crack Water Curing
JCI	-	Japan Concrete Institute
PCRA		Prism Control Air Curing
PCRW		Prism Control Water Curing
PEA		Prism EM Air Curing
PEW		Prism EM Water Curing
RILEM		The International Union of Laboratories and Experts in Construction Materials, Systems and Structures
UPV		Ultrasonic Pulse Velocity

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Concrete is one of the important material that is commonly used in the construction industry. Concrete is the main material used for the infrastructure development in every country. Concrete is made from the mixture of cement, water, aggregate and sand with certain proportion to produce a slurry. Cement is a binder that bind other materials together.

In concrete, cracking is a common phenomenon due to the relatively low tensile strength. High tensile stresses can result from external loads, imposed deformations (due to temperature gradients, confined shrinkage and differential settlement), plastic shrinkage, plastic settlement, and expansive reactions (e.g. due to reinforcement corrosion, alkali, silica reaction, sulphate attack. Without immediate and proper treatment, cracks tend to expand further and eventually require costly repair. Durability of concrete is also impaired by these cracks, since they provide an easy path for the transport of liquid and gasses that potentially contain harmful substances. If micro cracks grow and reach the reinforcement, not only the concrete itself may be attacked, but also the reinforcement will be corroded when it is exposed

to water and oxygen, and possibly carbon dioxide and chlorides. Micro cracks are therefore precursors to structural failure (Tittelboom *et al.*, 2013).

Self-healing is actually an old and well known phenomenon for concrete as it possesses some natural autogeneous healing properties. Autogeneously crack-healing capacity of concrete has been recognized in several recent studies. Mainly micro cracks with widths in the range of 0.05 to 0.1 mm have been observed to become completely sealed particularly under wet and dry condition. The mechanism of this autogeneously healing is chiefly due to secondary hydration of non or partially reacted cement particles present in the concrete matrix. One possible technique is currently being investigated and developed was based on application of mineral producing bacteria in concrete.

Although bacteria and particularly acid producing bacteria, have been traditionally considered as harmful organisms for concrete, recent research has shown that species such as ureolytic and other bacteria can actually be useful as a tool repair cracks or clean the surface of concrete. Bacteria can act as catalyst for the metabolic conversion of a suitable organic or inorganic component. The nature of metabolically produced filler materials could be minerals such as calcite (calcium carbonate). These minerals are relatively dense and can block cracks, thus increase some of the concrete properties. The development of a self-healing mechanism of concrete that is based on potentially cheaper and more sustainable material thus be beneficial for both economy and environment.

1.1 Problem Statement

Concrete structures often suffers from cracking that lead to much earlier deterioration and designed service life. To prevent such deterioration, regular inspection of cracks in concrete structures and their repair are usually carried out by means of some kind of human intervention. Cracks in concrete can occur in any stage of the service life of concrete structures due to volume instabilities such as autogenous shrinkage or drying shrinkage since concrete is composed of aggregate of various sizes connected with the hydration process generated by mixing water and cement. Once cracking occurs in reinforced concrete members, not only the stiffness reduced but steel bars corrosion also occurs due to permeation of rain, harsh weather and aggressive substances, reducing structural safety and serviceability. The availability of self-healing concrete would make structures more reliable. For example, if control and repair at the early stage cracks in concrete structures were possible, permeation of factors for deterioration could be prevented, thus extending the service life of the structures. In the meantime, sustainability is now one of the top issues in the field of building and civil engineering from the viewpoint of global ecology. Besides that, precipitation on calcium carbonate due to biochemical action of bacteria has been expected to be one of the new technologies for self-healing concrete that can be applied in the future.

From Jonkers *et al.* (2008), a high crack healing potential of concrete structures is beneficial as it makes the material stronger and above all more durable. A continuous healing of particularly surface cracks results in decreased permeability of the material and a significantly reduced risk of premature matrix degradation and corrosion of the embedded steel reinforcement due to ingress water and aggressive chemicals.

1.2 Objectives

The main purpose of this study is to determine the effects of EM on the properties of concrete including fresh and hardened state. Following are the objectives of the study.

i. To determine the optimum percentage of Effective Microorganism (EM) in blended cement concrete mix.
ii. To determine the effects of Effective Microorganism (EM) on fresh and hardened properties of concrete.
iii. To investigate the effects of Effective Microorganism (EM) on self-healing process of matured concrete.

1.3 Scope of Study

The scope of this study is to focus on applying Effective Microorganism in concrete as the healing agent. Cracks are formed due to plastic shrinkage, drying shrinkage and thermal effects when the concrete are not properly cured. The porosity of concrete produce more voids and the crack allows water and oxygen into the concrete. The idea is that after cracking, mixed in EM on fresh concrete crack surfaces are activated in the presence of water, and then start to multiply and precipitate minerals, such as calcite, and close or seal the crack.

1.4 Significant of Research

Approach of using EM in concrete as self-healing agent makes very beneficial compared to the conventional concrete. Based on these study, if EM concrete does give some effects towards self-healing approach and potential through its reaction mechanism in concrete, then EM concrete could be one of the important material in the future construction. When EM concrete is apply in construction industry, it may become another alternative method to repair concrete cracks internally. The approaches of self-healing concrete can provide ways in reducing maintenance work due to cracking and increase durability of concrete structure, high strength buildings with more bearing capacity, retaining liquid structure which are more detail design especially focused for preventing cracks for a long term period.

REFERENCES

A.M. Neville, J.J. Brooks (1987), "Concrete Technology". Longman.

ASTM. American Society of Testing and Materials. Designation: C 1585 – 04

Dry, C.M. (2000). "Three design for the internal release of sealants, adhesive, and waterproofing chemicals into concrete to reduce permeability." Cement and Concrete research 30 (12), pp. 1969-1977.

E. Schlangen, H. Jonkers, S. Qian & A. Garcia. "Recent Advances on Self-Healing of Concrete." *Fracture Mechanics of Concrete and Concrete Structures*. (2010). Korea Concrete Institute, Seoul.

Edvardsen, C., (1999). "Water Permeability and Autogenous Healing of Cracks in Concrete." *ACI Material Journal*, 96(4), 448-454.

Ghosh, P., Mandal, S., Chattopadhyay, B. D., Pal, S. "Use of Microorganism to Improve The Strength Of Cement Mortar." Cement on concrete Research 35(10): 1980 – 1983 (2005).

Hall, C. "Water Sorptivity of Mortars and Concretes: A Review," Magazine of Concrete Rresearch, Vol 41, No. 147, June 1989. Pp 51-61.

Henk M. Jonkers, Arjan Thijssen, Gerard Muyzer, Oguzhan Coporoglu, Erik Shlangen. "Application of Bacteria as Self-Healing Agent for the Development of Sustainable Concrete". *Ecological Engineering* 36 (2010) 230-235. Elsevier.

Higa, T., 1995, " What is EM Technology", College of Agriculture, University of Ryukyus, Okinawa, Japan.

Homma, D., Mihashi H. and Nishiwaki, T. (2009). "Self-Healing Capability of Fibre Reinforced Cementitious Composites." *Journal of Advanced Concrete Technology*, 7(2), 217-228.

Guim, A.; Andrade, P.; Iturrino-Schocken, R.P. and Malheiros, E.B. (1998): Aerobic Stability of Wilted Grass Silages (Pennisetum purpureum, Schum) Treated with Microbial Inoculant. Fundacao Moki'ti Okada and Universidade Estadual Paulista, Jaboticabal Campus, Sao Paulo, Brazil.

John Newman, Ban Seng Choo. (2003), "Advanced Concrete Technology: Testing and Quality". Elsevier Ltd.

John Newman, Ban Seng Choo. (2003), "Advanced Concrete Technology: Concrete Properties". Elsevier Ltd.

Jonkers HM, Schlangen E. (2007)."Self-Healing Of Cracked Concrete: A Bacterial Approach." *In Proceedings of FRACOS6: fracture mechanics of concrete and concrete structures.* Italy: Catania; 2007. p. 1821–26.

Jonkers HM, Schlangen E. (2008)."Development of a Bacteria-Based Self-Healing Concrete." Tailor Made Concrete Structures – Walraven & Stoelhorst (eds). Taylor & Francis Group, London.

Jonkers HM, (2011)."Bacteria-Based Self-Healing Concrete." Heron Vol. 56 No. ½

Jonkers HM, (2007)."Self-Healing Concrete: A Biological Approach." *Self-Healing Materials. An Alternative Approach to 20 Centuries of Materials Science*, 195-204.

K.A. Shahid, M.F.M. Jaafar & F.M. Yahaya. "Self-Healing Behaviour of Pre-Cracked Pofa-Concretes in Different Curing Conditions." *Journal of Mechanical Engineering and Sciences (JMES)*, Vol. 7, pp. 1227-1235, December 2014.

Klass van Brugel. "Self-Healing Material Concepts as Solution for Aging Infrastructure." *37th Conference on Our World in Concrete & Structure*. 29-31 August 2012. Singapore.

Li, V. C., Sakulich, A. R., Reinhardt, H. W., Shlangen, E. (2013). Recovery Against Mechanical Action : Self Healing Phenomena in Cement based Materials. RILEM.

Khaliq, W. Basit, ehsan. (2016). "crack healing in concrete using various bio influenced self-healing techniques." Construction and Building Materials Journals 102, 345-357

Mario, d. R., Kim, V. Tittelboom, Nele, d. B., Erik, Schlangen. (2014). "Self-Healing Phenomena in Cement-Based Materials – *State-of-the-Art Report of*

RILEM Technical Committee 221-SHC: Self-Healing Phenomena in Cement Based Materials. Vol.11"

Na, S. H., Hama, Y., Taniguchi, M., Katsura, O., Sagawa, T., Zakaria, Mohamad. "Experimental Investigation on Reaction Rate and Self-Healing Ability in Fly Ash Blended Cement Mixtures.

Patel P., (2016). "Helping Concrete Heal Itself".Chemical & Engineering News. Volume 94 Issue 6. Pp. 29 – 30 (online article) http://cen.acs.org/articles/94/i6/Helping-Concrete-Heal-Itself.html

Ramakrishnan, S.K., Panchalan, R. K., Bang, S.S. (2001). "Improvement of Concrete Durability by Bacterial Mineral Precipitation." *11th International Conference on Fracture*, Turin. Italy

Ramm, W. and Biscoping, M., (1998). "Autogenous Healing and Reinforcement Corrosion of Water-Penetrated Separation Cracks in Reinforced Concrete." *Nuclear Engineering and Design*, 179(2), 191-200.

Reinhardt H.W., Jonkers, H., Tittelboom, V. K., Snoeck, D. (2013). Recovery Against Environmental Action. "self – Healing Phenomena in Cement- Based Materials. RILEM

Rooij, M. R., Shlangen, E. and Joseph, C. (2013). "Self-Healing Phenomena. Self-Healing Phenomena in Cement Based Bacteria." RILEM.

Salmabanu Luhar, Suthar Gourav. "A Review Paper on Self-Healing Concrete." *Journal of Civil Engineering Research 2015*, 5(3): 53-58.

Sangadji, S., "Can Self-healing Mechanism Helps Concrete Structures Sustainable?". Procedia Engineering 171 (2017) 238 – 249.

Talaiekhozan, A., Kevyanfar, A., Shafagat, R. Andalib, R. Majid, M. A., Fullazaky, and Marwar, N. F. (2014). A Review of self-healing concrete research development. J*ournal Of Advanced Concrete Techology 2012, Vol 10, 240-253.*.

Th. A. BIER. (1987). "Influence of Type of Cement and Curing On Carbonation Progress and Pore Structure of Hydrated Cement Paste, Materials Research Society Symposium." 85, pp. 123–34

Van Tittelboom K. & Nele De Belie. (2013). "Self-Healing in Cementitious Materials: A Review. *Materials 2013*, 6, 2182-2217.

Victor C. Li & Emily Herbert. "Robust Self-Healing Concrete for Sustainable

Infrastructure. *Journal of Advanced Concrete Technology*. Vol. 10,207-218, June 2012.

Wasim Khaliq, Muhammad Basit Ehsan. "Crack Healing in Concrete Using Various Bio Influenced Self-Healing Techniques." *Journal on Construction and Building Materials*. 102 (2016) 349-357. Elsevier.

Yongzhen N, Waijiong L (1994) Report on the Deodorizing Effect of Effective Microorganisms (EM) in Poultry Production. Beijing, China. 402 - 440.

Zhong, W., Yao, W. (2007). Influence of Damage Degree on Self –healing of Concrete. *Journal on Construction and Building Materials*. 22 (2008) 1137-1142. Elsevier.