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Fresh and hardened properties of concrete containing effective microorganisms

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Abstract:
Nowadays, concrete is popularly used in many areas and applications in construction industry. If designed and manufactured properly it can be one of the most durable construction materials. However, during the life span of the structure the surrounding environment where the structure is built may pose long-term durability problem to concrete such as cracks and corrosion of steel reinforcement. Thus, researchers around the world continue searching for any possible means to improve concrete qualities. This paper presents study on the effects of Effective Microorganism on fresh and hardened properties of concrete. The percentage of Effective Microorganisms (EM) used in this study was 10% and incorporated in the concrete mix by replacing the water content. In this research work, a number of control and EM concrete cube samples were cast, cured in water and tested at the ages of 3, 7 and 28 days. The workability of fresh concrete was measured through the slump test. The effect of EM on hardened concrete was assessed through compression test and ultrasonic pulse velocity (UPV) test. The experimental result shows that the workability of concrete with EM was 67% higher than the control concrete. This may indicate that the EM has the potential to be used as workability enhancer. In terms of compressive strength, the EM concrete recorded 8% higher strength at 28 days compared to concrete without EM. In addition, the early strength of EM concrete was found to be higher by 41% and 27% at 3 and 7 days compared to control, respectively. The UPV result for EM concrete also shows higher value than control concrete indicating denser concrete. All experimental results indicated that the use of EM has positive effects on concrete properties.

1.0 Introduction
Concrete is a vital and comparatively common construction material nowadays. It is consequently the most used building material around the world because of its durability and cheapness. In terms of

compression, concrete is very strong but it is weak in tension. Although concrete is good for resisting the compressive load of structure up to a certain limit, but it will crack if the applying load exceed the limit of resisting load. Beside this, some of the other reasons for micro crack is temperature shrinkage, thermal contraction, and subgrade settlement. Crack may reduce the durability of concrete. Also it will cause corrosion to the reinforcement if the crack width is become too large.

To overcome these problems occurring in concrete, researchers around the world continue searching for any possible means to improve concrete qualities. One of the methods studied is by introducing microorganisms or bacteria in concrete mix to enhance the concrete properties This study focuses on the effect of Effective Microorganisms on the properties of fresh and hardened concrete.

2.0 Previous Study

"Effective Microorganisms" is the abbreviation for EM discovered by Professor Teruo Higa. EM consist of mixed cultures of beneficial microorganisms such as lactic acid bacteria (LAB), photosynthetic bacteria and yeast [1]. Originally, EM was developed as microbial inoculants to increase microbial diversity and improve the quality of soil in agriculture [2]. Since1986, the application of EM has immensely expanded to other fields such as construction industry and water treatment works. However, the use of EM in cement based material is still new to be used in construction industry. Only few research studies have been conducted to find out the effects of EM products on mechanical properties, durability and microstructure of concrete [3, 4]. Figure 1 shows the Effective Microorganisms.

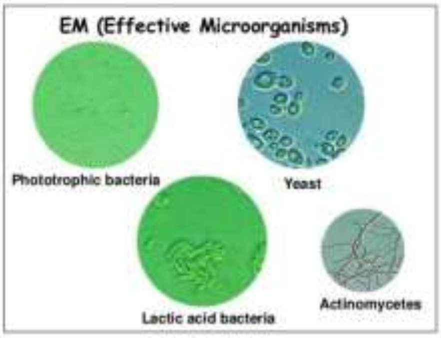

Figure 1. Effective Microorganisms [5].

The lactic acid bacteria are an anaerobic group of Gram-positive non sporulating cocci with rod shaped morphology. It is a group comprising of 11 genera of diverse nature. Lactic acid bacteria (species of genus Lactobacillus) have been used as probiotic in food industry [6]. Lactic acid bacteria are known as aerotolerant anaerobe, which survives in the presence of oxygen but does not use it for growth. Rich nutrients such as carbohydrates, minerals and nitrogen compounds are necessary for growth of lactic acid bacteria [7].

Photosynthetic bacteria are a special type of microorganisms, which produce food for other microorganisms by consuming carbon dioxide and other oxidizable compounds such as Hydrogen Sulfide in the absence of oxygen in suitable environment and therefore act to purify the environment and find effective application in wastewater treatment [8]. Yeasts are classified as single-celled microorganisms belonging to fungus kingdom. Saccharomyces cerevisiae is a common species of yeast. This yeast has many applications in manufacturing of food products. Yeast produces ethanol by using glucose through metabolism in slightly acidic environment [9].

It is an era of green construction and the incorporation of these microorganisms in concrete systems has the potential of reducing the carbon footprint since Effective Microorganisms consume carbon dioxide and nitrogen compounds for their growth. EM technology has found some applications in concrete structures. It increases to some extent the workability of concrete, enhances the strength and improves its durability [10].

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Some researchers observed the effects of the effective microorganism (EM) as the admixture in concrete [11]. They prepared a number of samples and exposed to different environments (acidic, clayey soil, wastewater, marine, alkaline, outdoor (tropical) and indoor environments). The cubes were tested for the compressive strength after 7, 28 and 91 days. Results indicated that concrete containing EM had higher compressive strength and better resistance to many environments. It shows that EM could be used as an admixture in concrete for most types of environment to improve strength and durability.

Other researchers [12] conducted their research to assess the influence of Effective Microorganisms made from locally available fruit and vegetable wastes on compressive strength of concrete. The Effective Microorganisms were produced locally through the process of natural fermentation of fruits and vegetable wastes. The locally made effective microorganism was added in 3%, 5%, 10% and 15% to replace the mixing water required. A total of 60 cubes were produced for compressive strength tests. The results of the tests indicated that the concrete specimens with 3% content of locally made EM-A possessed the highest compressive strength of 28.5N/mm^2 and 34.35N/mm^2 at 28 and 56 days, respectively over the control and other specimens.

3.0 Methodology

This research focuses on the effect of effective microorganism (EM) consolidated with ordinary Portland cement (OPC). Concrete sample without EM is prepared as control concrete (CONC). The fresh properties of concrete were tested for its workability. The compressive strength test, ultrasonic pulse velocity test and temperature increase test were conducted for the hardened properties of concrete.

3.1 Materials

Ordinary Portland cement was used for this study. The locally available sand in the laboratory was used as fine aggregate. For coarse aggregate, crushed granite aggregates with the nominal size of 10 mm was used in this research. The coarse aggregate was air dried to ensure that the water cement ratio will not be affected. Water is very important ingredient of concrete that will contribute to hydration of the cement which lead to strength of concrete. Potable tap water was used for casting concrete. The mix design was prepared with 0.55 w/c ratio. Effective microorganism (EM) was used as water replacement and it was obtained from the EM Malaysia Groups Sdn Bhd.

3.2 Concrete Mix Design

The effect of EM in concrete, two type of concrete mixes were cast, namely EM concrete and control concrete. The concrete was designed for compressive strength of 30 MPa based on the DoE method. The quantity for EM used in the concrete mix was 10% by replacing the amount of total water content. Concrete mix proportions for control concrete (without EM) and EM concrete is shown in Table 1.

Table 1. Mix proportions for concrete.

Kg/m^3				W/C
Cement	Water	Fine Aggregate	Coarse aggregate	0.55
455	250	740	904	

3.3 Preparation of Sample

In this study a total number of twenty-two cube specimens (100 x 100 x 100 mm) was cast. Using concrete drum mixer, the concrete was mixed uniformly. After finish casting, the test specimens were left undisturbed for about 24 hours in the laboratory to set and harden. After that the specimen was demoulded and cured in water tank. The test specimens were cured in water until their compressive strength test determined at 3, 7 and 28 days.

4.0 Results and Discussion

The data and results collected from the experiment are discussed in this section. The results presented in this section are workability, compressive strength, value of UPV and temperature increase of the concrete.

4.1 Workability

The slump was measured to determine the workability of the concrete mix. Results for the slump test of the concrete mixes are shown in the Figure 2. The average slump recorded for control sample was 60 mm and 100 mm for EM sample. It has been clearly seen that EM sample recorded higher value of slump that means EM sample was more workable than control sample. Moreover, from Figure 3, the addition of the EM in the concrete makes the sample slightly darker than normal control sample. It can be said that to improve the workability of the concrete, EM was found to be beneficial.

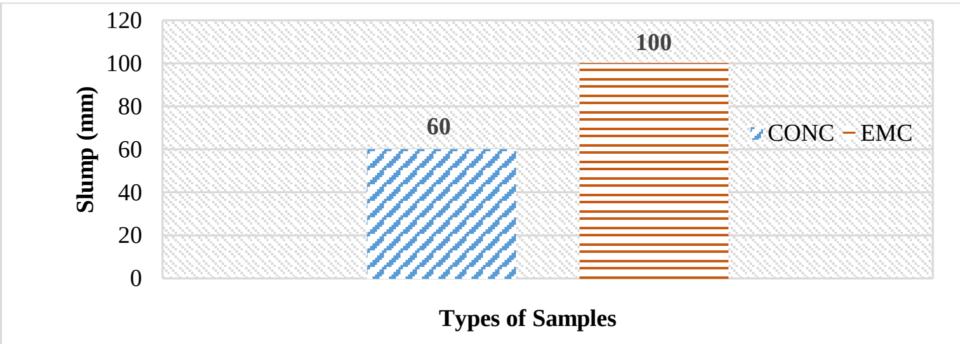

Figure 2. Workability of EM and control concretes.

(a) (b)

Figure 3. Types of slump for (a) CONC mix and (b) EMC mix.

4.2 Compressive Strength

Both type of samples was tested for the compressive strength at the age of 3, 7 and 28 days. A constant rate of 6 kN/s load has been applied by using compression machine until the specimen crushed at the maximum load. For the calculation of the density of the samples the weight of all samples were recorded before testing for the compressive strength. The average strength of the concrete for both type of mixes is shown in Table 2 and Figure 4. Figure 5 shows the mode of failure for CONC and EMC concretes at 28 days.

Table 2. Compressive strength for EM and control concretes.

Types of mixes	Cube Strength (MPa)			Strength ratio	
	3 Days	7 Days	28 Days	3/28 days	7/28 days
CONC	24.24	32.51	44.10	0.55	0.74
EMC	34.50	41.50	47.60	0.73	0.87

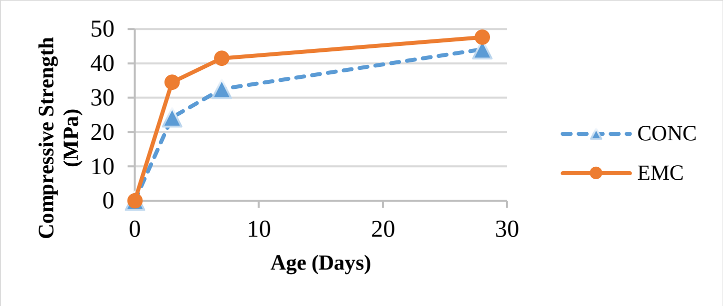

Figure 4. Compressive strength development for EM and control concretes.

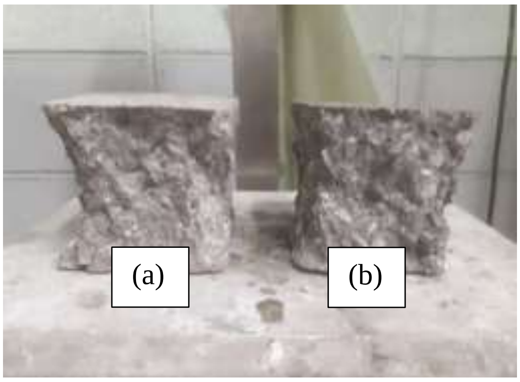

Figure 5. Mode of failure for (a) CONC and (b) EMC at 28 days.

It can be seen from the Table 2 and Figure 4, the EM sample had higher compressive strength than control sample for 3, 7 and 28 days. As shown in Table 2, the strength ratios of 3 to 28 days and 7 to 28 days for EM sample which is 0.73 and 0.87 were also higher compared to control sample which is 0.55 and 0.74, respectively. At the beginning, the control sample had lower strength value of 24.24 MPa at 3 days but it increased dramatically to 32.51 MPa at the age of 7 days and end up with 44.1 MPa. In contrast, the EM sample start with a very good result which is 34.5 MPa at 3 days and it increased slowly to 41.5 MPa and 47.6 MPa for 7 and 28 days, respectively. However, more than 40% of concrete strength had been achieved by both types of samples at the age of 3 days although their mode of failure was the same at the age of 28 days. The results show that both type of concrete samples had achieved their targeted strength. It can be said that the use of EM has good effect on concrete strength properties.

4.3 Ultrasonic Pulse Velocity (UPV)

At a certain age of concrete, the UPV test on cubes were conducted. Table 3 shows the UPV value for CONC and EMC samples for 3, 7 and 28 days. From Table 3, it can be seen that there is not much difference between control and EM sample for the value of pulse velocity except at the age of 3 days. The pulse velocity for EM was higher than control sample. Higher 3 to 28-day ratio for EM concrete compared to control concrete was higher indicating that the EM concrete gain higher early strength than control. Thus, the EM may contribute to enhance the reaction between cement and water during the hydration process.

Figure 6 shows the comparison of UPV for all sample. Based on Figure 6 the CONCP and EMCP have slightly similar value of UPV. However, the EMC has the highest value of UPV over all ages.

Table 3. UPV for CONC and EMC.

Types of mixes	UPV (km/s)			Ratio 3/28 days	Ratio 7/28 days
	3 Days	7 Days	28 Days		
CONC	2.27	4.11	4.60	0.493	0.893
EMC	3.85	4.18	4.67	0.824	0.895

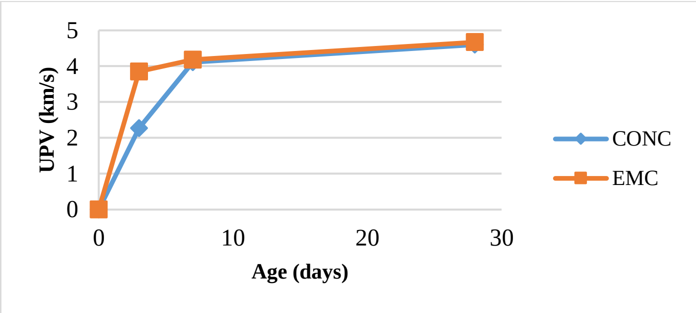

Figure 6. Comparison of UPV for all samples.

4.4 Temperature increase

Figure 7 shows the relationship between temperatures with time for all sample. At the time of casting the temperature for control sample was slightly higher than EM sample. The temperature measured for up to 4 days. It can be clearly seen from Figure 7, during 4 days monitoring the control sample had higher temperature compared to EM sample. However, after four days there was no significant changes had been observed which means the temperature remains constant.

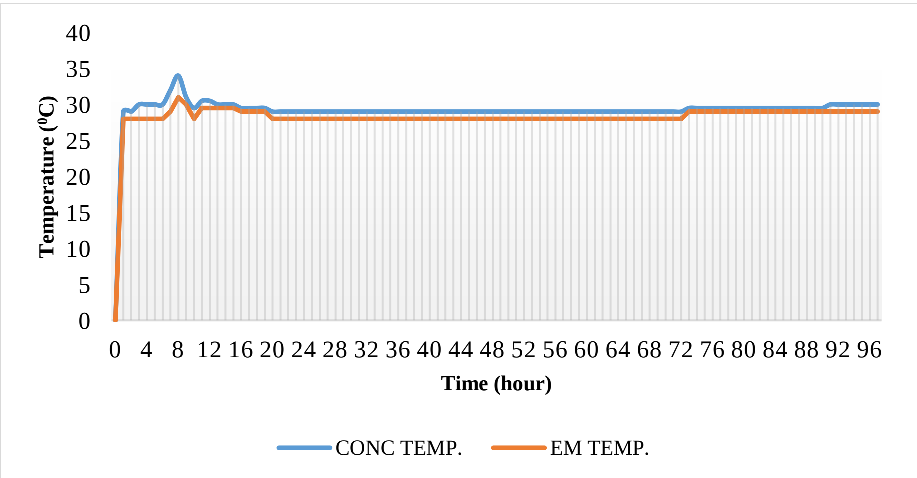

Figure 7. Relationship between temperatures and time.

5.0 Conclusion

The following conclusion can be made from this research based on the experimental results:

i. The workability of concrete has been increased of about 67% by using EM in the concrete mix compared to control sample.
ii. The compressive strength was found to be higher by 8% for EM sample compared to control sample indicating the use of EM has contribution to the enhancement of the compressive strength of concrete.
iii. The UPV results were higher for EM concrete compared to control. This is an indication the EM has an effect on the concrete properties by making concrete denser than control.
iv. From the results of temperature increase test, it was found that the EM sample recorded lower temperature between 1 to 2 °C during its hydration process compared to control sample. This shows one of the benefits of using EM in concrete mix.

6.0 References

[1] T. Higa, *Effective microorganisms: A biotechnology for mankind*. In Proceedings of the first international conference on Kyusei nature farming. US Department of Agriculture, Washington, DC, USA, pp. 8- 14, (1991).
[2] T. L. Chew, M.N. Ismail, F. Razali, I.I. Muhamad, M.R. Sarmidi and A.K. Khamis, *Application of effective microorganisms on soil and maze*. Journal Chemical and Natural Resources Engineering, Special Edition: 1–13, Universiti Teknologi Malaysia.Web:ttps://www.academia.edu/707492/ Application of effective microorganisms on soil and maize. (2008).
[3] W. De Muynck, D. Dieter, D. B. Nele, and V. Willy., *Bacterial carbonate precipitation improves the durability of cementitious materials. Cement and Concrete Research,* 38, no. 7: 1005-1014. (2008)
[4] S. Nobuyuki, S. Masami, and S. Syuichi. *Investigation on concrete rust preventive agents using microorganisms (mechanisms*). In 29th Conference on Our World in Concrete & Structures, Singapore, pp. 25- 26. (2004).
[5] Effective Microorganisms (EM) Market 2017- EMRO, EMNZ, SCD Probiotics, Efficient Microbes, Asia Plant, VIOOO Biology.
[6] Ibourahema, C., *Characterization of lactic acid bacteria isolated from poultry farms in Senegal*. African Journal of Biotechnology, **7**(12), (2008).
[7] F. Yanagida, Y.S. Chen, and M. Yasaki, *Isolation and characterization of lactic acid bacteria from lakes.* Journal of basic microbiology, **47**(2): p. 184-190, (2007).
[8] L. M. Proctor, *Nitrogen-fixing, photosynthetic, anaerobic bacteria associated with pelagic copepods*. Aquatic Microbial Ecology 12, no. 2: 105-113, (1997).
[9] Y. Chen, K. Jeff, H. Weimin, M. Rich, and G. Vik, *Anaerobic yeast fermentation for the production of ethanol in a versatile lab fermentor.* Nature Methods 5, no. 12, (2008).
[10] N. Sato, H. Teruo, S. Sugita, and M. Shuya, *Some properties of concrete mixed with effective microorganisms and the on-site investigation of the completed structures.* In Proceedings of the 28th International conference, our world in concrete and structures, 28-29 August, 2003, Singapore, (2003).
[11] J.M. Yatim, I. Mohamad, W.A.W.A. Rahman, and V.Y. Chiew, *Performance of concrete containing effective microorganisms (EM) under various environments*. In Joint Conference of 7th Asia Pacific Structural Engineering and Construction Conference, (2009).
[12] M.N. Isa, M.G. Magaji, and L.K. Adama, *Influence of locally made effective microorganisms on the compressive strength of concrete*. J. of Multidisciplinary Engineering Science and Technology 3, no. 4: 4425-4429, (2016).

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