Recent Trends in Civil Engineering and Built Environment Vol. 3 No. 1 (2022) 965-975
© Universiti Tun Hussein Onn Malaysia Publisher's Office

RTCEBE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rtcebe
e-ISSN :2773-5184

Mechanical Properties and Internal Microstructure of Concrete Brick with Addition of Effective Microorganisms

Meor Muhamad Fitri Meor Hamzah[1], Noorli Ismail[1]*

[1]Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn, Parit Raja, Johor, 86400, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/rtcebe.2022.03.01.111
Received 4 July 2021; Accepted 13 December 2021; Available online 15 July 2022

Abstract: Effective Microorganisms (EM) technology is rapidly evolving, with applications in a wide range of sectors. However, the use of EM as an additive in concrete bricks is still in its early stages, and the microstructure image of EM containing concrete brick specimens must be assessed. As a result, study into the effects of admixing EM in concrete bricks is necessary in relation to the influence on concrete bricks performance. EM dilution is necessary to construct the EM concrete brick, EM dilution are made of 10% of EM No.1, mixed with 2% of molasses and diluted into distilled water which consists 88% of total mixture. In this study, three (3) proportions EM dilutions which is 5%, 10%, and 15% of the total mixing were added to the concrete bricks, along with a control concrete specimen without EM. All specimens are curing for seven (7) and twenty-eight (28) days before being tested for compressive strength. The analysis indicates with addition of 10% EM dilution as the optimal amount in concrete. This is shown by the increased of compressive strength of the 10% EM concrete bricks compared to control concrete brick specimen by 13.9%. Scanning Electron Microscope (SEM) micrograph examined the concrete brick 10% of EM dilution is denser and less void compared to the others brick. Based on X-Ray Diffraction was showing that 10% EM concrete brick consist the higher proportions of Portlandite $Ca(OH)_2$, Calcite $CaCO_3$ and Silicon Oxide SiO_2 compared to other specimens. I can be concluded that the optimum proportion of EM dilution can be added in concrete brick is 10% EM dilution.

Keywords: Effective Microorganisms, Molasses, Distilled Water, Compressive Strength, Scanning Electron Microscope (SEM), Xray Diffraction (XRD)

1. Introduction

Concrete bricks are the most flexible heterogeneous construction material and the driving force behind any country's infrastructure development. Concrete bricks are used extensively in civil engineering and building projects all over the world. Because of its characteristics, it is the most commonly used in construction world. Concrete bricks are made up mostly of water, gravel, and cement.

*Corresponding author: noorli@uthm.edu.my

To obtain the desired physical characteristics of the finished material, additives and reinforcements are usually used improve the properties. When these components are combined, a fluid mass forms that can be readily shaped into the required shape. Concrete bricks are the most popular construction material widespread commercial production. Continuous study in the field of concrete has led in the creation of many different forms of concrete, including self-compacting concrete, lightweight concrete, precast concrete, green concrete, and many more. To meet the present building industry need, each of these kinds has its own distinct characteristics.

Concrete bricks' strength and durability may be altered by altering their materials, such as cement, aggregate, and water, as well as adding some unique additives. Also known as an admixture, an admixture is a material used as a component in concrete that is applied to the batch directly before or during mixing, aside from cement, water, and aggregates [1]. This study focuses on admixture which is long-lasting, cost-effective, easy to access, environmentally friendly, and manufactured locally. Effective Microorganisms was the name given to admixture in this study. The term "Effective Microorganism" (EM) was originated by Teruo Higa, a professor of horticulture from College of Agriculture, University of the Ryukyus in Okinawa, Japan. EM is a liquid made up of a wide range of functional, helpful, and non-pathogenic microbeds that are generated naturally rather than chemically or genetically manufactured [2].

The results demonstrated that the EM is relevant and beneficial in the agricultural and aquaculture industries. EM was utilized as a fertilizer to improve agricultural output by providing plant nutrients [3]. In previous study, the use of EM resulted in increased shoot height, stem diameter, leaf number, and leaf area [4]. The usage of EM can be utilized in both wastewater treatment and septic tank treatment to minimize the volume of sewage sludge discharge [5]. The addition of EM to concrete has been shown to enhance the strength and durability of the concrete. The inclusion of 5% EM as the optimal amount to be put in concrete resulted in a significant increase in the compressive strength of the concrete [6]. While [1] it was discovered that using 3% locally produced EM-A in concrete resulted in a better compressive strength after 28 days. The performance of concrete containing 5% EM was tested in a variety of settings to determine the full capability of EM-added concrete [7]. However, the use of EM in concrete brick has yet to be investigated. The impact of EM on the internal microstructure of concrete attributed to EM presence has to be thoroughly investigated.

As an outcome, a little amount of EM is added to the concrete brick mix to see if it has the ability to improve the concrete brick compressive strength. In this investigation, high-grade concrete with 5%, 10%, and 15% EM content was used.

2. Materials and Methods

2.1 Concrete brick material.

- Ordinary Portland Cement (OPC) meets the requirement highlighted by BS EN 12390-1:2009.
- Fine aggregates passing No.4 (4.75mm) sieve and retained on the No.200 (75pm).
- Distilled water.

2.2 Fermentation EM dilution.

- EM No-1 Bio-Booster was obtained from Pertubuhan Peladang Tangkak, Johor
- Molasses (sugar cane base) from the Pertubuhan Peladang Tangkak.
- Distilled water

The group of bacteria existed in EM-1 Bio-Booster were lactic acid, yeast and phototrophic bacteria. In fermentation process, the molasses was added into the distilled water and EM for the mixing. During this fermentation process, sugar cane molasses is broken down and Effective Microorganisms multiply. In this study, the distilled water was used in fermentation because the chlorine substances in tap water can give the bad effect to the bacteria contain EM.

In this study, ten percent (10%) of EM No-1 was mixed with two percent of molasses (2%). The combination of EM No-1, molasses and distilled water was called Effective Microorganism Mixed Solution (EM dilution). Table 1 tabulates the five percent (5%) of EM No-1 was mixed with the two percent (2%) of molasses and ninety three percent (93%) of distilled water for main mix proportion of EM dilution. The weight amount of EM, molasses and distilled water depend on ratio of water needed for concrete design.

Table 1: Percentage EM dilution for preparation

Material	Percentage (%)	Preparation of 1000mL of EM Dilution (mL)
Distilled water	93	930
Effective Microorganisms	5	50
Molasses	2	20

After all the content was well blended, then the main mix proportion of EM dilution also known as EM dilutions was diluted into different percentages to add into the concrete as shown in Table 2. The percentage used were 5%, 10% and 15% of EM. As an example, the designation name of EM 5 defined as five percent (5%) from the main proportion of EM dilution. The several dilutions of EM were introduced to investigate the effect of the EM dilution to the compressive strength of concrete.

Table 2: The replacement of EM dilution with distilled water

EM Dilution	EM Dilution (mL)	Distilled Water (mL)
Control	0	2052
EM Dilution 5%	62	1990
EM Dilution 10%	124	1926
EM Dilution 15%	186	1864

The EM dilutions were stored in the plastic bottles in room temperature for fermentation. The fermentation of EM dilutions was carried at seven (7) days to achieve less than four (4) of the pH values like been shown in Table 3. Only the active solution can be mixing together with the concrete.

Table 3: The pH value for fermentation EM dilution

Day	pH
1	4.72
2	4.41
3	4.27
4	4.24
5	4.19
6	4.10
7	3.99
8	3.88

In this study, the cement sand ratio that been applied is 1:3 and the water content is 0.5. Table 4 show the ratio mixture of the concrete brick in this study.

Table 4: Ratio mixture of concrete bricks

	Cement (kg)	Fine Aggregate (kg)	Distilled water (L)	EM dilution (L)
Control Bricks	4.104	12.312	2.052	0
EM 5% dilution	4.104	12.312	1.990	0.062

EM 10% dilution	4.104	12.312	1.926	0.124
EM 15% dilution	4.104	12.312	1.864	0.186

2.3 Sample preparations.

Concrete bricks were mixed using a hand tool. This because the quantity of mix concrete is enough by using hand tool. At first, all fine aggregate put into the mixing place. Then, putting the ordinary Portland cement was added into the mixing place. Next, all the component of concrete was mixed with the distilled water and EM dilutions. Therefore, after casting the concrete, the concrete will be left to harden. It was left for one day or 24 hours. Curing is described as the processes for enhancing the hydration of cement, and it requires temperature management as well as the transfer of moisture from and into the concrete. After 24 hours of casting, all specimen was demolded and need cured. The bricks were cured in the tank for 7 and 28 days as required.

In this study, after 7 and 28 days of curing, the 24 bricks were removed. Each brick was then positioned in the compressive machine. The size of the bricks was produced is 103mm x 65mm x 215mm. These procedures were applied onto the samples and the average reading were taken according to BS EN 12390-3-2009. In this study, after applied the compressive testing on the specimens, the crushed samples were analyzed by the SEM machine to capture microstructure image of microbed concrete and control concrete. Then for XRD analysis, concrete brick specimens will be crushed into fine powder that passing a 65-micrometer sieve. XRD is a method for analyzing and identifying materials based on their diffraction patterns.

3. Results and Discussion

3.1 Compressive Strength.

The brick has been tested using compressive machine by referring to BS EN 12390 3:2009 Testing hardened concrete - Part 3: Compressive strength of test specimens. All the specimens with different percentage of EM dilution were tested with curing process at 7 and 28 days. The result based on the average value of the specimens. From the data obtained, the compressive strength for control specimen was recorded as 29.7MPa.

Table 5: Compressive Strength at 7 Days

EM Dilution (%)	Average Compressive Strength (MPa)	Increment / Decrement (%)
0%	29.7	0
5%	31.8	7.07
10%	32.2	7.76
15%	30.3	1.98

While, other specimens added with 5%, 10 % and 15% were 31.8MPa, 32.2MPa and 30.3MPa respectively. Table 5 shows the highest compressive strength achieved about 32.2 MPa within 10% of EM Dilution while the lowest compressive strength was 29.7MPa which is control specimens. On this aging also the value of compressive strength increases gradually from control to 10% EM specimen. Then, the graph decreased when 15% of EM dilution added into the concrete. The specimen with 10% EM dilution had higher compressive strength compared to the control. The compressive strength of concrete for 10% of EM dilution added was 32.2 MPa where the control specimen was only 29.7MPa. The specimen with 10% EM dilution shows an increment in compressive strength over the control specimen with 7.76%. All the remaining specimens had high compressive strength compared to the control specimen but lower than 10% of EM dilution.

Table 6: Compressive Strength at 28 Days

EM Dilution (%)	Average Compressive Strength	Increment / Decrement (%)
0%	37.4	0
5%	39.5	5.32
10%	42.6	13.9
15%	39.1	4.55

Table 6 shows the result on the compressive strength of concrete tested in laboratory for age 28 days (maturity age). From the data obtained, the compressive strength for control specimen was recorded as 37.4MPa. While, other specimens added with 5%, 10% and 15% were 39.5MPa, 42.6MPa and 39.1MPa respectively. Table 6 shows the highest compressive strength achieved about 42.6MPa within 10% of EM dilution while the lowest compressive strength was 37.4MPa which is control specimens. The value of compressive strength increases slowly from control to 10% of EM dilution. Then, the graph decreased when 15% of EM dilution added into the concrete. The 28-days compressive strength of the specimens within 10% of EM dilution and the control specimen had achieved the compressive strength higher than control specimen compressive strength of concrete. The specimen with 10% EM dilution shows an increment in compressive strength over the control specimen with 13.9%. Addition of chemical admixture by the contractor to increase the compressive strength was not environmental-friendly and cost effective but using Effective Microorganism (EM) technology, any hazard to environment was not apply [6]. This show that within 10% of EM dilution added into the concrete specimen, it can improve the compressive strength of the microbe concrete.

Figure 1 was clearly demonstrating that throughout all ageing days, the concrete specimen within 10% of EM dilution had the maximum compressive strength compared to others. When compared to the control concrete specimen, the concrete contained 10% more EM dilution enhanced strength. The development of compressive strength for 10% of EM dilution inclusion into concrete was rapid compared to others percentage of EM dilution.

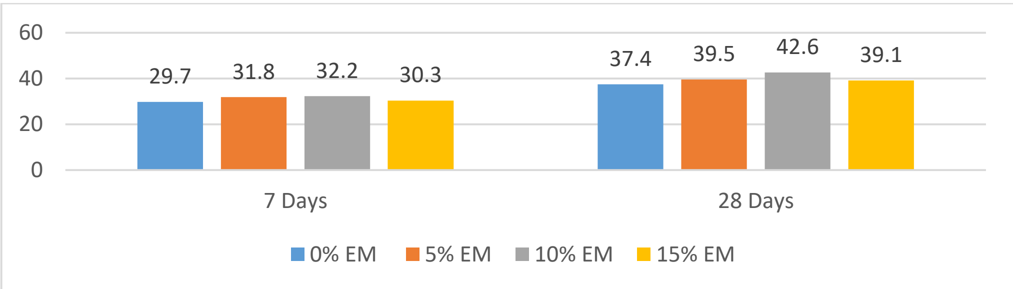

Figure 1: Comparison of Compressive Strength at Aging Day (7 and 28 days) between different percentages of EM dilution

According to the graph above, one of the impacts of EM on concrete performance is to improve the compressive strength of concrete. Based on [8] the biological interaction that happens between the alkaline cement paste and the acidic EM to generate a new material is thought to be one of the causes that improves strength. The new properties and behavior comparable to pozzolanic materials, is intended to fill gaps in concrete and enhance internal connections in the future.

Another theory is that instead of the EM inside the concrete reacting with the cement paste, the EM inside the concrete uses up the air inside the concrete for its aerobic activities. [8] state that the EM living inside the concrete utilizes the internal air, causes the overall volume of air spaces decreases, and the concrete becomes denser, exhibiting stronger compressive strength and improved resistance to the harmful impacts of the environment. The aerobic actions of EM are responsible for the increase in compressive strength. As the internal air utilized by the EM inside the concrete is used up, the total volume of air voids will decrease. As a result of this condition, the concrete has gotten denser and has a higher compressive strength.

3.2 Scanning Electron Microscopes.

The function using Scanning Electron Microscope (SEM) was to capture the micrograph image of concrete specimen containing EM and without EM. The concrete specimens containing dilution of 0%, 5%, 10% and 15% of EM dilution were analyzed for the microstructure examination. The SEM micrograph were captured on the 7 and 28 days within magnification 500x. When different proportion EM dilution was added to the concrete, the slightly different on structure of concrete are determining compared to the control concrete specimen as illustrate in Figure 2, Figure 3, Figure 4, and Figure 5.

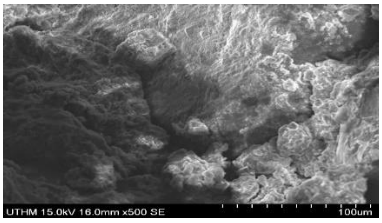

Figure 2: EM dilution 0%

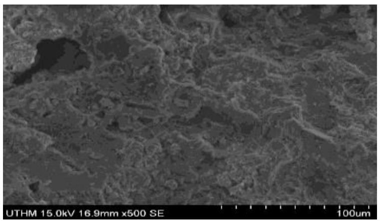

Figure 3: EM dilution 5%

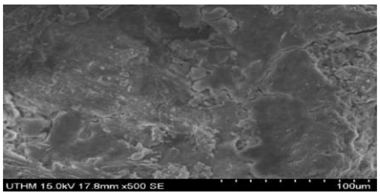

Figure 4: EM dilution 10%

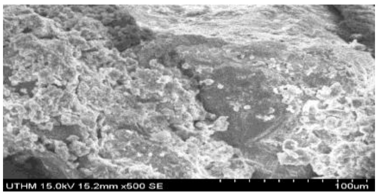

Figure 5: EM dilution 15%

From the SEM micrograph, the concrete containing 10% EM dilution was less pores and less in diameter holes compared to the other concrete specimens including the control specimen. These concrete specimens were also examined the microstructure image on the maturity day (28 days). The SEM micrograph are shown in Figure 6, Figure 7, Figure 8 and Figure 9.

Based on previous study held by [10] state that Bacillus Subtilis Bacterial strains derived from locally produced EMs were introduced partly into the concrete pores. Bacterial strains were placed into concrete pores to reduce hole sizes and increase compressive strength performance. In a similar vein, [11], by replacing the water content with 5%, 10%, and 15% EM dilution, researchers were able to create a self-compacting EM-based concrete. The presence of EM dilution was found to affect plastic viscosity, delay plastic setting times, modify hydration kinetics, and disturb concrete volume stability.

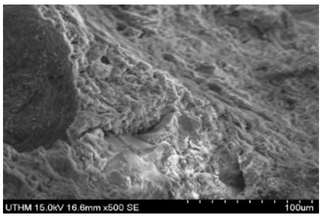

Figure 6: EM dilution 0%

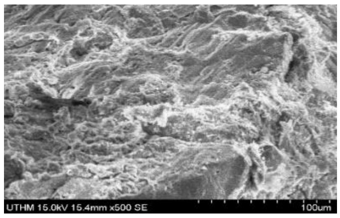

Figure 7: EM dilution 5%

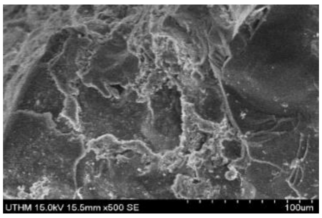

Figure 8: EM dilution 10%

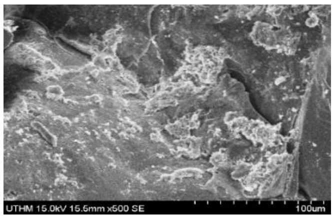

Figure 9: EM dilution 15%

Based on SEM micrograph on the maturity day (28 days), the concrete containing 10% of EM dilution reconciled the pore of the structure due to improvement deposition of calcite $CaCO_3$ in cement-sand matrix in microbial concrete**.** This is showing that 10% EM dilution is the optimum value to achieved higher compressive strength. This also led to the denser of microbial concrete compared to the control concrete.

3.3 X-Ray Diffraction.

The main purpose to applied X-Ray Diffraction analysis (XRD) in this research is to identifies the crystallographic structure of a specimen with addition EM and without EM. In this lab, specimens are taken place with a major different value of compressive strength. After 7 days and 28 days of water curing, the fine powder of crushed cement specimens was collected, pressed into a sample container, and analyzed. The XRD scans were taken with the position of 2θ from 10º to 100º. The control specimens are being choose because least value and been compared with addition 10% EM specimens with the higher value of compressive strength. This being illustrate in Figure 10 and Figures 11.

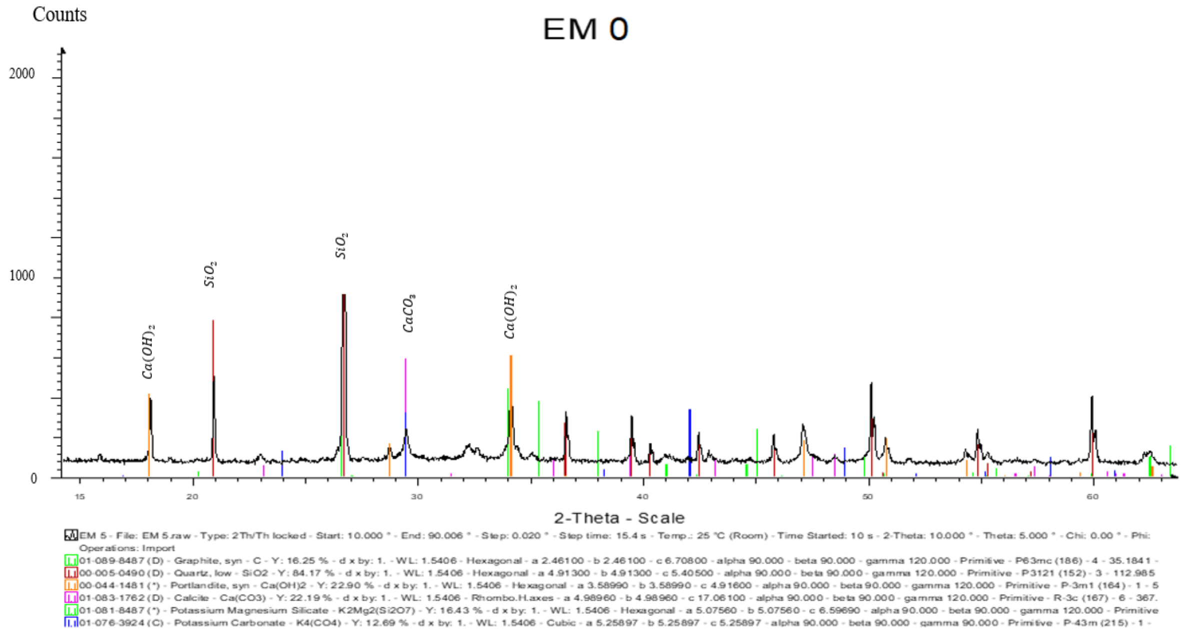

Figure 10: EM dilution 0%

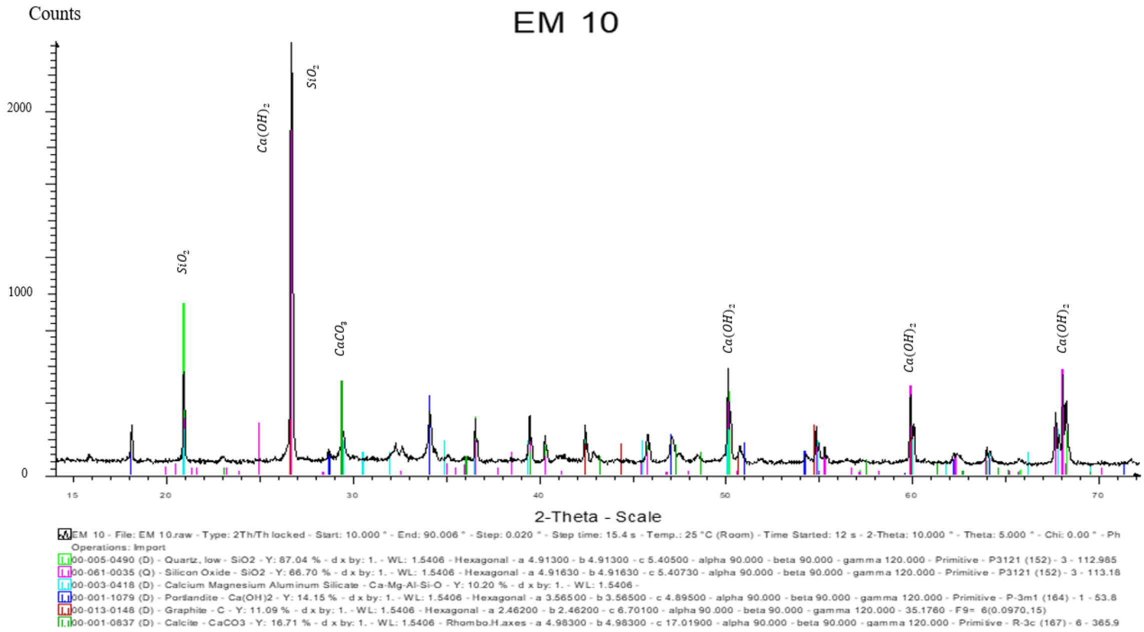

Figure 11: EM dilution 10%

From the XRD analytical graph, the concrete containing 10% EM dilution was recorded the higher amount of Portlandite $Ca(OH)_2$, Calcite $CaCO_3$ and Silicon Oxide SiO_2 compared to control specimens. The XRD analytical graph were recorded on the 7 days curing. These concrete specimens were also recorded the analytical graph on the maturity day (28 days). The XRD analytical graph are shown in Figure 12 and Figure 13.

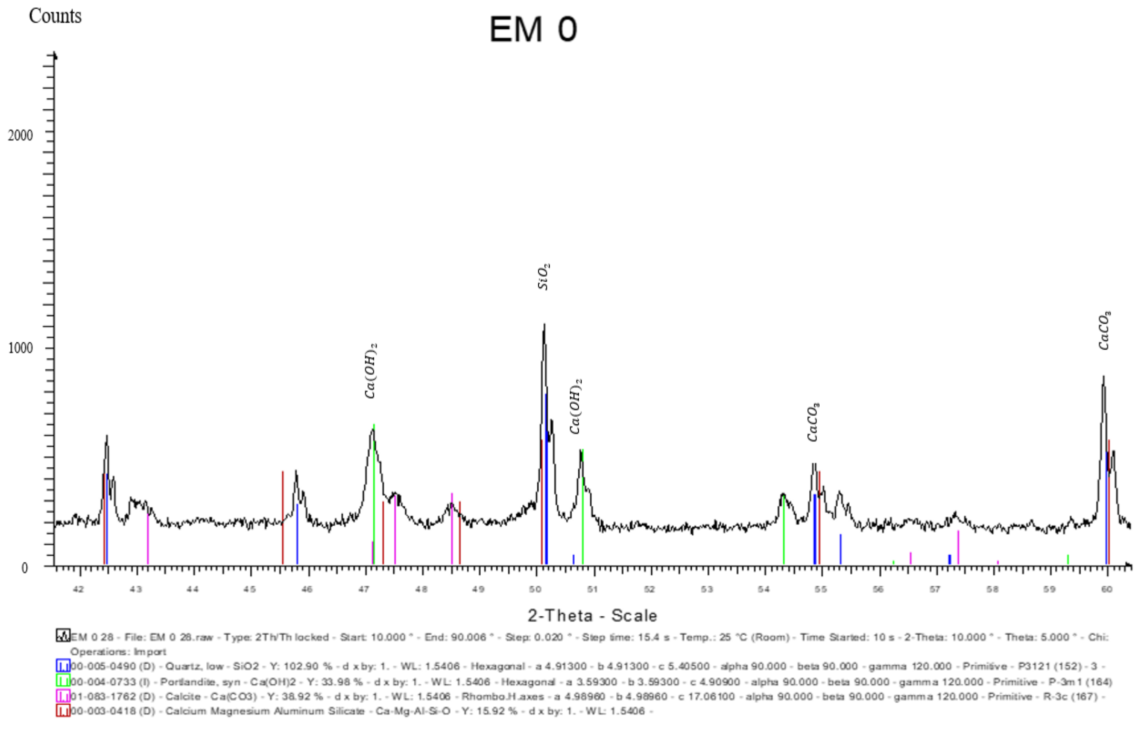

Figure 12: EM dilution 0%

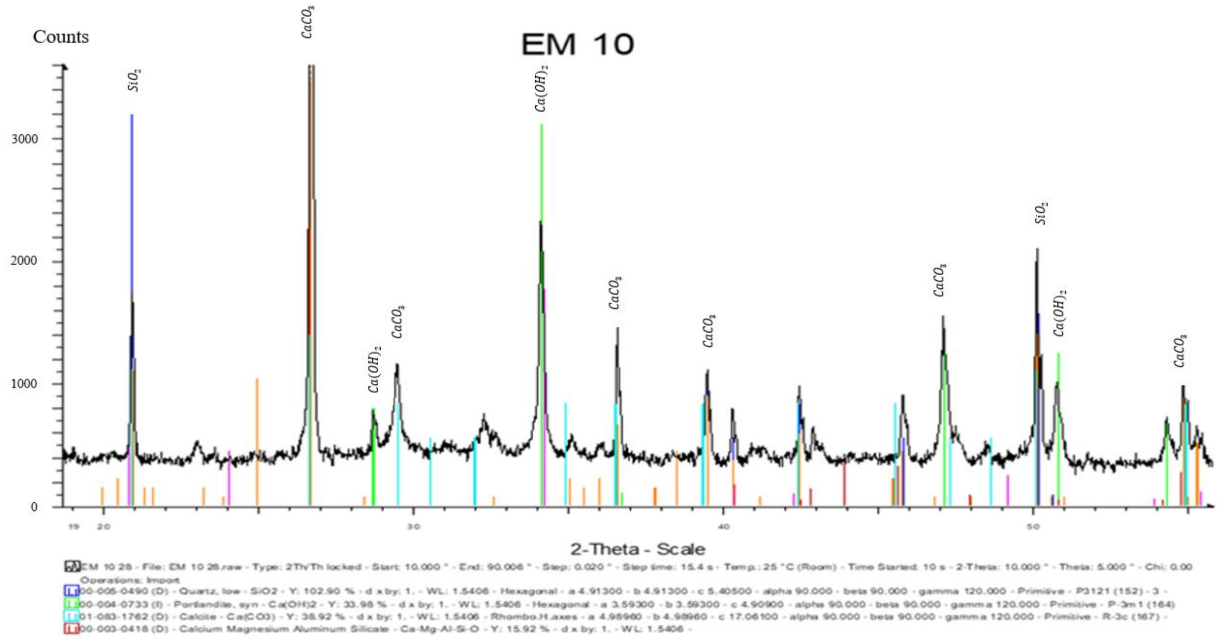

Figure 13: EM dilution 10%

Based on XRD analytical graph on the maturity day (28 days), the concrete containing 10% of EM dilution improvement deposition of Calcite $CaCO_3$ where the higher concentration of Ca ions reconciled the pore of the structure due to in cement-sand matrix in microbial**.** $CaCO_3$ fresh concrete was also more cohesive, owing to the filler effect of fine $CaCO_3$ particles, which promotes complete hydration and increases the cohesiveness and homogeneity of the fresh concrete by providing adequate water absorption of cement particles. Also, because water absorption rate is low, it can be argued that the presence of extremely small $CaCO_3$ particles reduces the pores inside the concrete owing to improved particle packing between cement and $CaCO_3$. [11]

Based on Figure 4.5 (b) Calcium hydroxide $Ca(OH)_2$ is one of the primary components of hydrated Portland cement paste, and it is found in greater amounts in EM concrete bricks. Its content can be used to track the progress of cement hydration or as a gauge of pozzolanic reaction severity. With the help of Calcium hydroxide $Ca(OH)_2$, it will help to because of its strong pozzolanic activity, form is an important component of blended binders used in concrete manufacturing. While the chemical formula for portlandite is $Ca(OH)_2$, it is important to consider the cement hydration process. [12] This will increase the compressive strength of the concrete bricks. The present of higher]] Silica Oxide SiO_2 in EM concrete bricks are compared to control concrete bricks, the reaction activity of silica with Portland cement minerals results in a make some minor in porosity and an improvement in cement concrete's mechanical resistance

This is showing that 10% EM dilution is the optimum value to achieved higher compressive strength. This also led to the denser of microbial concrete compared to the control concrete.

4. Conclusion

The results of the investigation were analyzed to determine the compressive strength of concrete when various percentages of EM dilution were applied, which were 5%, 10%, and 15%. The optimal proportion of EM dilution was then calculated as the suitable percentage of EM dilution applied to the concrete to increase compressive strength. The comparison of the control concrete specimen and the experimental EM concrete specimen. The micrograph images of concrete specimens were then examined within different percentages of EM for early strength (7 days) and mature strength (28 days). As a result, the following is a summary of the conclusion:

I. It was discovered that all of the specimens exhibited compressive strength that was greater than the control concrete specimen at varied percentages of EM dilution. Only concrete within EM

10% acquired the higher compressive strength greater than all the specimen on all ageing days, with a compressive strength increase of 13.9%. Other percentage which was 5% and 10% of EM dilution had compressive strength exceed the control concrete specimen which is 5.32% and 4.55% respectively.

II. The best proportion of EM dilution in the concrete was 10%, which resulted in the maximum compressive strength and was also economical. The compressive strength of 10% EM dilution was 121.4% higher than the design strength.

III. The micrograph image of concrete specimens with and without EM was examined between early strength and maturity age to examine the microstructure of physical properties.

IV. The analytical graph of concrete specimens been compared from the higher compressive strength which is EM 10% with the control specimen. Analytical graph been analyzed in early strength in 7 day and maturity age at 28 days.

Acknowledgement

The authors would also like to thank the Faculty of Civil Engineering and built Environment, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] Isa,M.N., Garba, M.M. & Kawu, A.L. (2016). Influence of Locally Made Effective Microorganisms on The Compressive Strength of Concrete. *Journal of Multidisciplinary Engineering Science and Technology (JMEST), 3(4), pp.4425-4429*

[2] Isa,M.N., Garba, M.M. & Usman N. (2015). Durability of Harden Concrete Containing Locally Made Effective Microorganisms Under Different Environmental Condition. *ADRRI JOURNALS*, 6(1), pp. 1-9.

[3] Javaid, A. (2006). Foliar application of Effective Microorganisms on pea as an alternative fertilizer. *Agronomy for Sustainable Development, Springer Verlag,* 26(4), pp. 257-262.

[4] Muthaura C., David M.M., Joseph A.O and Samuel V.O. (2010). Effective Microorganisms and their influence on growth and yield of pigweed (Amaranthus dubians). ARPN Journal of Agricultural and Biological Science, 5(1), pp. 17-22.

[5] Karthick S.R.N., Narendrakumar G., and Arvind Kumar J. (2011). Evaluation of Effective Microorganism (EM) for treatment of domestic sewage. *Journal of Experimental Sciences,* 2(7), pp 30-32

[6] Andrew, T.C.S., Syahrizal, L.I. & Jamaluddin, M.Y. (2012). Effective Microorganisms For Concrete (EMC) -Its Effect On The Mechanical Properties of Concrete. *Awam International Conference on Civil Engineering (AICCE 12)*. Park Royal Penang Resort, Malaysia: Geohazard Information Zonation (GIZ'12).

[7] Jamaludin, Y. M., Abd Rahman, W. and Sam, A. M. (2012). Characterization and Effect of The Effective Microorganisms (EM) and Industrial waste (lW) Materials as Partial Mixture of Concrete. Retrieved on January 12, 2017

[8] Jamaludin, M.Y.,Ismail, M., Wan, A.W.A. Rahman & Chiew, V.Y. (2009). Performance Of Concrete Containing Effective Microorganisms (EM) Under Various Environments. Joint Conference of 7th Asia Pacific Structural Engineering and Construction Conference 2009 (APSEC2009) and 2nd European Asian Civil Engineering Forum (EACEF 2009).Awana Porto Malai, Langkawi, Malaysia.

[9] Ghasan F.H., Zahraa H.J., Nur H.A.K., (2021), Durability performance of modified concrete incorporating fly ash and effective microorganism, *Construction and Building Materials,* Volume 267

[10] Rizwan S.A., Hasnain K., Thomas A.B., (2017) Use of Effective Micro-organisms (EM) technology and self-compacting concrete (SCC) technology improved the response of cementitious systems, *Construction and Building Materials*, Volume 152

[12] Ali, M., Abdullah, M. S., & Saad, S. A. (2015). Effect of Calcium Carbonate Replacement on Workability and Mechanical Strength of Portland Cement Concrete. *Advanced Materials Research*, *1115*(June 2020), 137–141.

[13] Ismail, N. & Saman, H.M (2014). Microstructure Examination and Strength Characteristics of Effective Microbed Cement. *International Conference on Biological, Civil and Environmental Engineering*. Dubai. pp. 82-87.