Effective Microorganisms for Concrete (EMC) Admixture – Its Effects to the Mechanical Properties of Concrete

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Abstract

Effective Microorganisms for Concrete (EMC) is now being produced locally and used in the construction industry to promote sustainability. Fermentation is the main concept in EMC in which the process will not produce harmful substances. Previous works in Japan found that EMC improved the concrete strength and also durability. This research was carried out to determine the optimum percentage of EMC to be added into concrete and to what extend EMC is able to enhance the mechanical properties of concrete. 11 sets of sample in the increment of 5% till 50% were prepared. Compressive, tensile and flexural strength tests were carried out. The finding shows that when adding 5% of EMC into the concrete, the compressive, tensile and flexural strength were 143.90%, 25.23% and 19.17% of the design compressive strength respectively. However, study also shows that by adding 25% EMC and beyond, the tensile strength was higher compared to the lower dosage. Therefore, the study concludes that the most economical and optimum percentage of EMC added into the concrete is 5% in which enhancing its design strength.

***Keywords*:** Effective Microorganisms for Concrete (EMC); Effective Microorganisms (EM); Admixture; Concrete Technology.

1. Introduction

Concrete is the most widely used material and consumes a great amount of resources (Zongjin L., 2011) [1]. To promote sustainability, the approach has to be such that all aspects of concrete structures are taken into account (Neville A., 2006) [2]. Concrete-technology research has been continuously providing us with up-to-date technologies whereby the usages and functions of various admixtures and additives have been discovered. ASTM C 125 defines an admixture as a material other than water, aggregates, hydraulic cements, and fibre reinforcement that is used as an ingredient of concrete or mortar and added to the batch immediately before or during mixing (Kumar Mehta P., Paulo Monteiro J. M., 2006) [3]. We are able to enhance the physical, chemical and mechanical properties of the concrete just by adding admixtures or additives into the concrete. This is in contrast to the early days of whereby practitioners faced a vast number of problems such as durability, workability, early strength gain and carbonation. These properties are important to prolong the service life of building. Prolonging the service life of a concrete structure not only saves the resources of raw materials for new building, but also reduces construction waste due to the demolishing of the existing buildings and infrastructures (Zongjin L., 2011) [1]. Micro-cracks in concrete will propagate 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 chloride (Tittelboom, K.V., et. al., 2009) [4].

Concrete technology is life-long research. The technology strives to discover the best additives or admixtures that are able to produce good concrete in terms of physical, chemical and mechanical properties in a more economical, sustainable, environmental-friendly and obtainable. In this research, the newly discovered admixture namely Effective Microorganisms for Concrete (EMC) is studied. In the case of adding EMC to concrete, it is still at an early stage. Hence, it is necessary to conduct detailed research to determine the actual effects on the physical, mechanical and chemical properties of the concrete after adding EMC.

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EMC is a product from Effective Microorganisms (EM). EM is the abbreviation for "Effective Microorganisms" and was discovered by Professor Teruo Higa. EM had broad applications such as in agriculture, environmental treatment, household usage, medicine healthcare, disaster treatment and construction industry. In agriculture, EM technology makes it possible to increase crop yields to twice or three times what they are at present, and to do so without the use of agricultural chemicals or artificial fertilisers (Higa T., 1994) [5]. Thus, Higa (1993) [6] stated "I believe I have identified a way of tackling and solving the primary problem of the food supply, and it lies in making use of the tiny creatures I called it as effective microorganisms". The potential of EM to assist in resolving problems of environmental pollution is dependent upon the action of two types of microorganisms: zymogenic EMs, effective microorganisms which produce the anti-oxidizing agents known as antioxidants, and certain synthesizing strains of anaerobic microorganisms (Higa T., 1993) [6]. Apart from that, EM is also able to prevent the "Sick House Syndrome" especially for the newly constructed building. Adding EM in concrete has already been practiced in Japan.

In this experimental work, 11 sets of samples with different EMC proportions (in the increment of 5% till 50%) were studied. Each set of proportions of EMC consists of twelve cubes with 150 mm × 150 mm × 150 mm dimensions, three prisms with 100 mm × 100 mm × 500 mm dimensions, and three cylinders with 150 mm diameter × 300 mm length. The strengths of the concrete with different proportions of EMC such as compressive, splitting tensile and flexural were determined.

2. Research Methodology

2.1 EMC

EMC was supplied by the Effective Microorganisms Research Organisation (EMRO), Japan and was fermented locally at the laboratory located at Taman Sutera Utama, Johor Bahru, Malaysia.

EM is produced through a natural fermentation process and is not chemically synthesized nor genetically engineered. EMC is based on EM Technology and fermented by EM with organic materials. The fermentation period for EMC is about 7 to 10 days depending on the temperature. In order to check the quality of the EMC produced, the following items must be checked:

a) pH should drop below 4.0 (ideally 3.5)

b) Sweet-sour fermented smell should be produced

c) No foul odour

d) The mixture colour should turn from dark brown to lighter brown

The storage of EMC must be in an airtight container as the microorganisms in EM are anaerobic.

After the fermentation process has completed, EMC should be stored in a cool dark place and used within 1 month. However, it is advisable to conduct the above procedures whenever EMC is required for mixing with concrete to ensure the quality of EMC added. Figure 1 below shows the EMC was stored in an airtight container and was labelled to prevent confusion in laboratory.

Fig. 1. Storage of EMC in an airtight container in a cool dark place

2.2 Design Mix for Concrete with EMC Admixture

The grade of the concrete was maintained at 30 N/mm^2. EMC was gradually added into the concrete to replace the water content. The procedures for the design mix for concrete with EMC admixture was in compliance with the Department of Environmental (DOE) Method. Table 1 shows the proportions of cement, water, fine aggregates and coarse aggregates for the design mix.

Table 1. Proportions of cement, water, fine aggregates and coarse aggregates for the design mix

Quantity (m^3)	Cement (kg)	Water (L)	Fine Aggregates (kg)	Coarse Aggregates (kg)
1.0	375	205	1010	785

2.3 Concrete with EMC Admixture

For each percentage of EMC added in concrete, cubes, cylinders and prisms were prepared. The percentage of EMC was gradually increased from 0% to up to 50%, replacing the water content. The dimensions and the calibrations of the concrete samples and moulds were in accordance with BS EN 12390-1:2000 [7]. The total volume of concrete required for each percentage of EMC added in concrete was $0.09m^3$ inclusive of 30% wastage.

Twelve cubes were prepared to determine the compressive strength at 1 day, 7 days and 28 days. Three cylinders were prepared for the indirect tensile test whereas three prisms were used for the flexural strength test.

For the control specimens, the proportions are in accordance to Table 2 whereas for the concrete samples with EMC admixture, the percentage of EMC added was calculated based on the water quantity needed. This meant that EMC acts as the substituent for the water content required.

Table 2. Proportions of cement, water, fine aggregates and coarse aggregates required for $0.09m^3$ of concrete (control set)

Quantity (m^3)	Cement (kg)	Water (L)	Fine Aggregates (kg)	Coarse Aggregates (kg)
0.09	33.75	18.45	90.9	70.65

Table 3 below shows an example of concrete mixing proportions for 5% EMC admixture addition.

Table 3. Proportions of cement, water, fine aggregates and coarse aggregates required for 0.09m^3 of concrete with 5% EMC

Cement (kg)	Water (litre)	EMC (litre)	Fine Aggregates (kg)	Coarse Aggregates (kg)
33.75	17.53	0.92	90.9	70.65

2.4 Curing Environment

All the concrete samples were cured in water with the addition of EMC with the dilution of hundred times as advised by the personnel from EMRO. Rainwater was used in the dilution to ensure that it is chlorine free to prevent EMC from encountering death. All samples were fully immersed in the curing tank until the test day. All the curing procedures were in accordance with BS EN 12390-2:2009 [8]. Figure 2 shows the curing tank filled with 100 times dilution of EMC ready for curing concrete samples.

Fig. 2. Curing tank filled with 100 times dilution of EMC

3. Results

3.1 Development of Concrete Compressive Strength

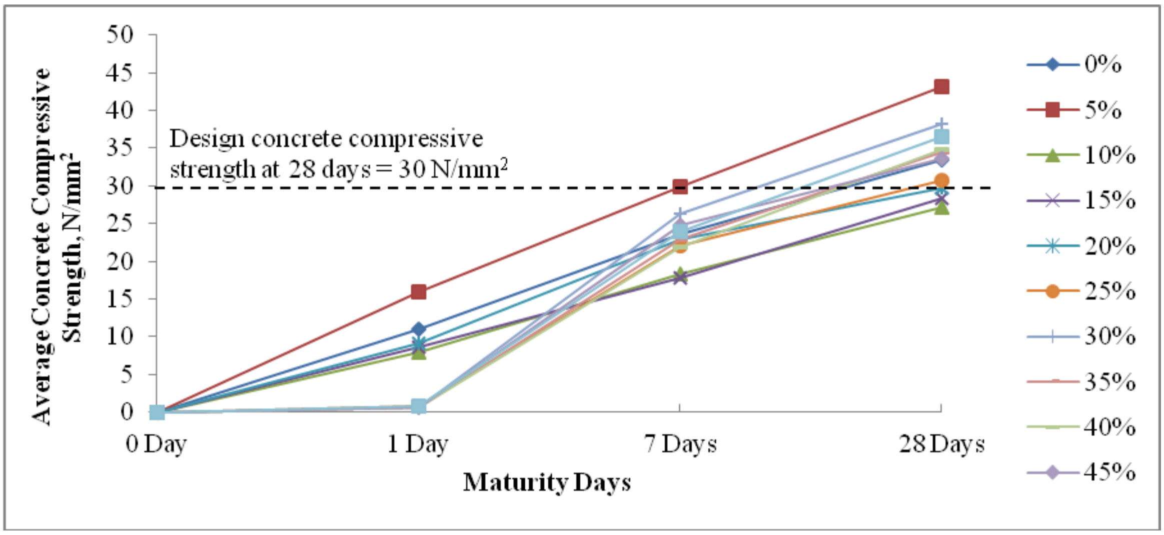

Fig. 3. Relationship between the average concrete compressive strength and maturity days

Refer to Fig. 3, it was clearly shown that the concrete will 5% had the highest compressive strength compared to others in all maturity ages. The development of compressive strength for the concrete with 5% of EMC added was faster compared to others. At the addition of 25% of EMC and beyond into concrete, the development of compressive strength was retarded compared to 5% of EMC. This scenario was much visible for 1-day compressive strength.

3.2 1-Day Concrete Compressive Strength

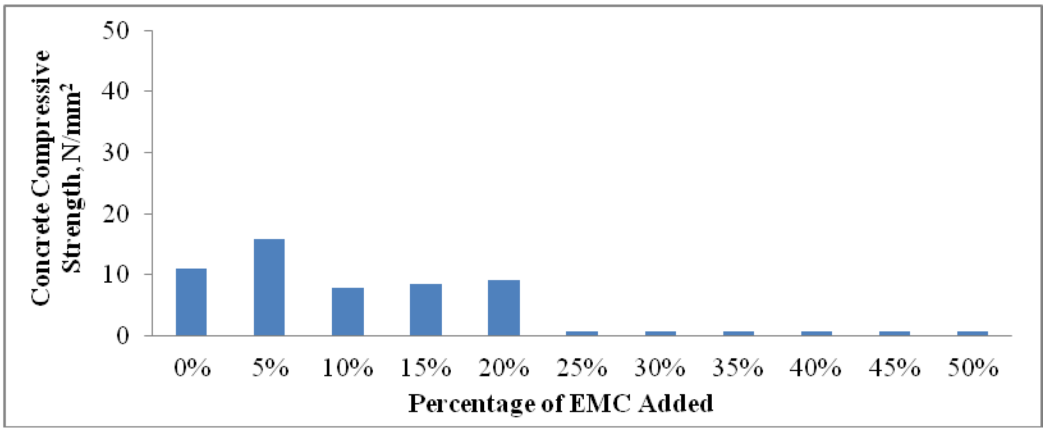

Fig. 4. Relationship between 1-day concrete compressive strength and percentage of EMC added

As refer to Fig. 4, the development of early strength (1-day) was higher compared with the control set. 1-day compressive strength for 5% of EMC added into concrete was 15.92 N/mm^2 (53.07% of the design compressive strength) whereas the control set which was only 10.96 N/mm^2 (36.53% of the design compressive strength). Except for 5% of EMC added, other concrete samples with different percentages of EMC added had lower 1-day compressive strength compared to the control set. This proved that, beyond 5% of EMC added had affected the hydration process and hence caused lower compressive strength. The effect was more distinct when beyond 20% of EMC was added into concrete at which the strength were below 1 N/mm^2. pH of the concrete was decreased (EMC was acidic whereas concrete was alkaline) and the hydration process was interrupted. These results are fascinating to the construction industry at which the formwork removal process can be shortened and this eventually expedites the whole construction period. Usually, in order to achieve high early strength, contractors will add chemical admixture to the concrete which is relatively expensive compared to EMC. Moreover, using chemical admixtures are not environmentally-friendly.

3.3 7-Days Concrete Compressive Strength

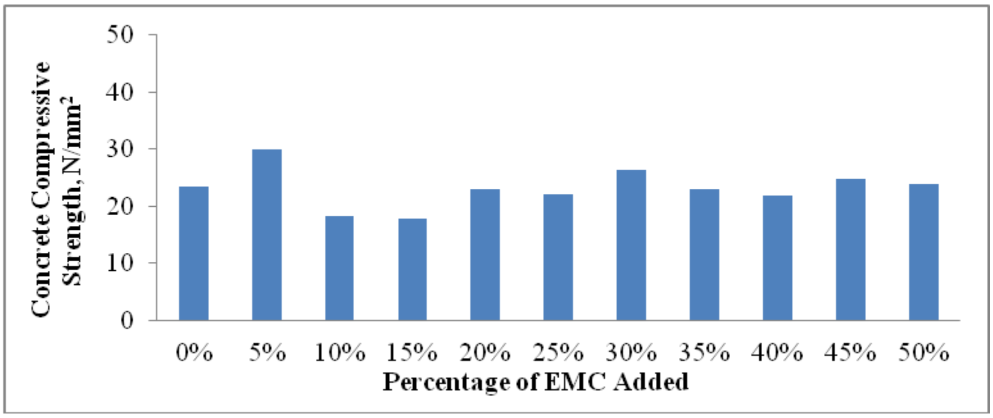

Fig. 5. Relationship between 7-days concrete compressive strength and percentage of EMC added

As refer to Fig. 5, concrete with the addition of 5% EMC had a higher compressive strength compared to control set and other percentages of EMC added. The compressive strength of concrete for 5% of EMC added was 29.84 N/mm^2 (99.47% of the design strength) where as the control set was only 23.52 N/mm^2 (78.40% of the design strength). Except for concrete with 10% and 15% of EMC, all samples having the compressive strength exceeding $\frac{2}{3}$ of the designed strength.

3.4 28-Days Compressive Strength

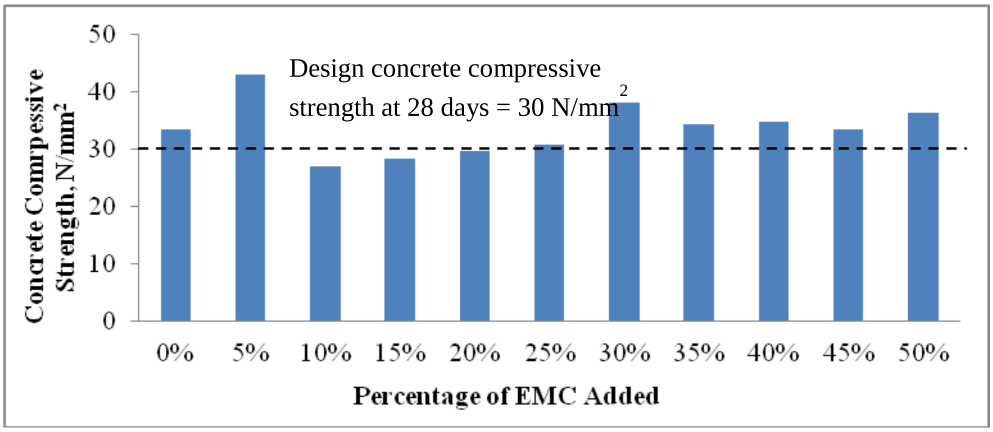

Fig. 6. Relationship between 28-days concrete compressive strength and percentage of EMC added

As refer to Fig. 6, all samples achieved the design compressive strength except for concrete with 10% and 15% of EMC which were only 27.11 N/mm^2 and 28.34 N/mm^2, respectively. Concrete with 5% EMC had the highest compressive strength which was 43.17 N/mm^2 (143.90% of the design strength). This shown that with 5% of EMC added into concrete, it can improve the compressive strength tremendously.

3.5 Indirect Tensile Strength of Concrete Cylinder

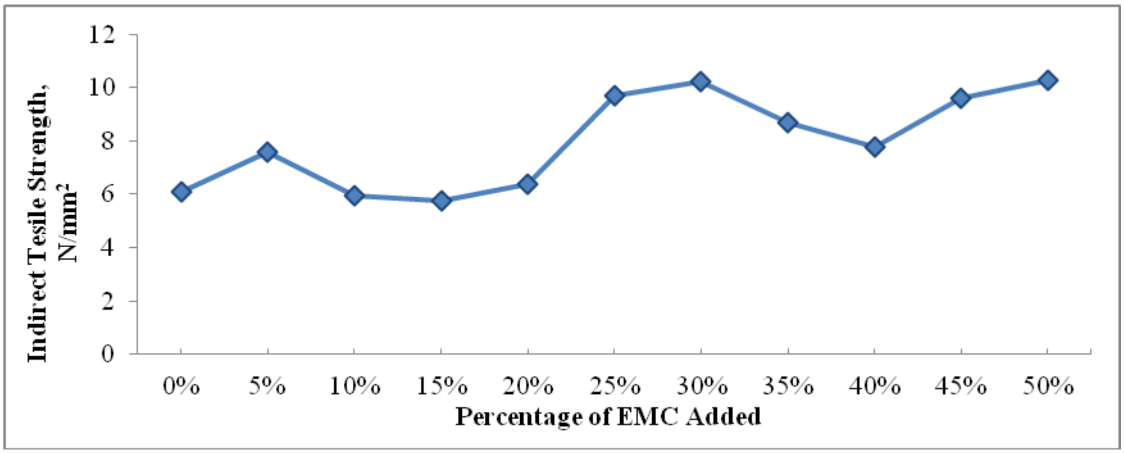

Fig. 7. Relationship between indirect tensile strength and percentage of EMC added

The tensile strength develops more quickly than the compressive strength and is usually about 10% to 15% of the compressive strength at ages of up to about 14 days, falling to about 5% at later ages (Orchard D. F., 1979). Considering the design tensile strength taken as 10% of the compressive strength, i.e. 3 N/mm^2, all samples achieved its minimum requirements in terms of design and construction purposes. Refer to Fig. 7, the tensile strength of concrete generally increased with the addition of EMC into concrete. The highest indirect tensile strength was 10.27 N/mm^2 (34.23% of the design compressive strength) in concrete with 50% of EMC whereas the lowest indirect tensile strength was 5.75 N/mm^2 in concrete with 15% of EMC. The tensile strength for concrete with 5% of EMC added was 7.57 N/mm^2 (25.23% of the design compressive strength).

3.6 Flexural Strength of Concrete Prism

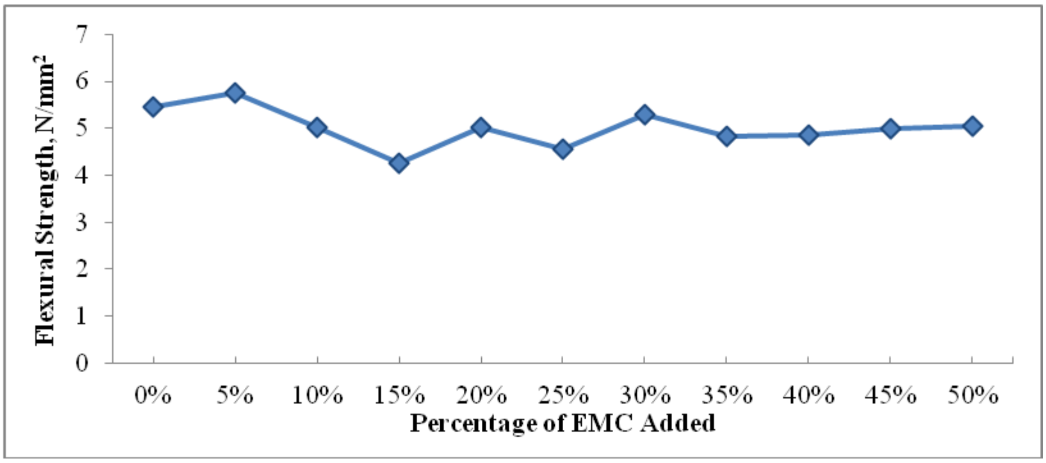

Fig. 8. Relationship between flexural strength and added percentage of EMC

The EMC's effect to flexural strength to all percentages of EMC added was indistinct. According to Fig. 8, the highest flexural strength was 5.75 N/mm^2 (19.17% of design compressive strength) in concrete with 5% of EMC where as the lowest flexural strength was 4.26 N/mm^2 (14.20% of design compressive strength) in concrete with 15% of EMC.

4. Discussions

Concrete with 5% EMC admixture shows an enhanced strength compared to the control set. The 1-day compressive strength for 5% EMC admixture is able to achieve 53.07% of the characteristic strength (30MPa) compared to the control set which is only achieved 36.53% of the characteristic strength (30MPa) in 1 day. These results are fascinating to the construction industry at which the formwork removal process can be shortened and this eventually expedites the whole construction period. In pre-cast industry, high early strength is crucial. This is mainly due to the tight schedule and the limited formwork in the casting yard. High early strength of concrete enables the contractors to remove the formwork early and proceed to the next casting. In tradition, in order to achieve high early strength, the contractors will add chemical admixture to the concrete which is relatively expensive compared to EMC. Moreover, using chemical admixtures are not environmentally-friendly. The low 1-day compressive strength for the cases with 25% EMC and beyond are mainly due to the hydration processes which was interrupted by EMC as concrete is in alkaline whereas EMC is in acidic state.

The 28-day compressive strength of concrete with 5% EMC (43.17MPa) is able to enhance the Grade C30 concrete by 43.90% compared to the designed characteristic strength. The contractors will usually add chemical admixtures into concrete in order to achieve higher compressive strength which is not environmentally-friendly and cost-effective. Leakage of chemical admixtures may cause pollution or hazards to the environment but leakage of EMC will not cause such problems because Effective Microorganisms (EM) technology was initially formulated to enhance the growth of plants in the agricultural industry and disaster treatment. Hence, even though EMC leaks to the environment, it will not possess any hazard to the environment but in contrasts, it will benefit to our environment as beneficial microbes found in the food industries are used in EM and the material is made locally.

The indirect tensile strength of the concrete and the addition of EMC had a positive relationship generally. The tensile strength develops more quickly than the compressive strength and is usually about 10 to 15 percent of the compressive strength at ages of up to about 14 days, falling to about 5 percent at later ages (Orchard D. F., 1979) [9]. In the case of adding EMC, the tensile strength is able to achieve 10.27MPa in 50% EMC which is 34.23% of design compressive strength. 50% of EMC is able to increase the indirect tensile strength by 68.09% when compared to the control set.

5. Conclusion

EMC was able to enhance the mechanical properties of concrete if an optimum dosage (5%) was added into concrete. The finding showed that when adding 5% of EMC into the concrete, the compressive, tensile and flexural strength were 143.90%, 25.23% and 19.17% of the designed compressive strength respectively. However, study also showed that by adding 25% EMC and beyond, the tensile strength was higher compared to the lower dosage. Therefore, this concluded that the most economical and optimum percentage of EMC added into the concrete was 5% in which enhancing its design strength. EMC admixture is environmental friendly and offers a relatively cheaper and better concrete admixture.

6. Acknowledgement

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