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JUDUL : **EFFECTS OF THE ENVIRONMENTS ON THE PERFORMANCE OF CONCRETE CONTAINING EFFECTIVE MICROORGANISMS (EM)**

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EFFECTS OF THE ENVIRONMENTS ON THE PERFORMANCE OF CONCRETE CONTAINING EFFECTIVE MICROORGANISMS (EM)

CHEW VOON YAU

A thesis submitted in partial fulfillment of the
requirements for the award of the degree of
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APRIL 2007

KESAN PERSEKITARAN TERHADAP PRESTASI KONKRIT YANG MENGANDUNGI MIKROORGANISMA EFEKTIF (EM)

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I declare that this thesis entitled "*Effects Of The Environment On The Performance Of Concrete Containing Effective Microorganisms (EM)"* is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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To my dearest family

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ABSTRACT

Nowadays, many materials have been tried to be applied as the admixtures of concrete to improve the performance of concrete. The admixtures were proven to improve the strength and durability of concrete. This study was conducted experimentally to observe the effects of the effective microorganism (EM) as the admixture in concrete. Concrete cube samples with the size of 100mm by 100mm by 100mm were prepared and exposed to different environments. The environments were 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 the concrete containing EM had higher compressive strength and better resistance to many adverse environments. However, as compared to normal concrete, the concrete containing EM had lower strength in marine environment. It showed that EM could be used as the admixture in concrete for most types of environment to improve strength and durability.

ABSTRAK

Pada masa kini, banyak bahan telah digunakan sebagai bahan tambah konkrit untuk mempertingkatkan lagi prestasi konkrit. Bahan tambah telah dikenalpasti berupaya mempertingkatkan kekuatan mampatan dan kelasakan konkrit. Tujuan projek ini dijalankan ialah untuk mengkaji secara ujian makmal kesan penggunaan mikroorganisma efektif (EM) sebagai bahan tambah konkrit. Sampel-sampel kuib konkrit yang bersaiz 100mm x 100mm x 100mm telah disediakan dan didedahkan kepada tujuh jenis persekitaran yang berbeza. Tujuh jenis persekitaran itu ialah asid, alkali, air laut, air sisa, tanah dan persekitaran luaran (tropika) dan dalaman. Sampel kuib telah diuji untuk memperoleh kekuatan mampatannya selepas 7, 28 dan 91 hari. Keputusan menunjukkan bahawa konkrit yang mengandungi EM mempunyai kekuatan mampatan yang lebih tinggi dan kelasakan yang lebih baik dalam pelbagai jenis persekitaran. Walaubagaimanapun, apabila dibandingkan dengan konkrit biasa, konkrit yang mengandungi EM mempunyai kekuatan yang lebih rendah dalam air laut. Secara umum, EM boleh digunakan sebagai bahan tambah bagi konkrit dalam kebanyakan jenis persekitaran untuk mempertingkatkan lagi kekuatan mampatan dan kelasakannya.

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LIST OF ABBREVIATIONS

EM	-	Effective Microorganism
EMAS	-	Effective Microorganism Activated Solution
HCL	-	Acidic environment; Hydrochloric acid
INDR	-	Indoor environment
NaOH	-	Alkaline environment, Sodium hydroxide
OUTDR	-	Outdoor environment, Tropical
SOIL	-	Soil environment, Clayey soil
SWTR	-	Marine environment, Seawater
WWTR	-	Wastewater environment

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CHAPTER 1

INTRODUCTION

1.1 Background

The early use of cementing materials dates back several thousand years by the old Romans and Egyptians. In 1824, Joseph Aspdin was granted a patent of his “improvements in the modes of producing an artificial stone.” Aspdin named his new product as *Portland Cement* because it resembled in color of a building stone found on the Isle of Portland. Cement is mixed with aggregates and water to produce concrete which is a good construction material. Nowadays, the most commonly used cement is the *Ordinary Portland Cement (OPC)*.

The use of concrete as the major material in the present construction is due to its outstanding properties, which outdo other materials. First of all, concrete has excellent resistance to water and is the cheapest material that is available in most places. Besides that, the plastic property of fresh concrete enables it to be formed into various shapes and sizes with great flexibility. This makes fantastic ideas of architects realized in the actual construction.

Uncountable researches on cement and concrete have been performed to enhance their properties over the years. When it comes to researches of hardened concrete, the main concerns are the strength and durability of concrete. Popular researches such as the uses of admixtures, the actions of aggressive agents and the application of new technology into the production of concrete have been done, to find out how all these affect the strength and durability of concrete. Researchers always find ways to increase the strength and improve the durability of concrete.

Ever since the development of a new technology, namely the effective microorganisms (EM), numerous researches have been carried out and the results have proved that the EM is useful and applicable in many industries. Thus, it is worthwhile and interesting to find out how the use of EM as an admixture in concrete can benefit the construction industry.

1.2 Problem Statement

Undoubtedly, concrete is an ideal material for construction industry which can provide desired strength and durability in the condition that everything is done properly from the early stage of concrete mix design, materials selection, mixing process, concrete placement to the stage of curing the concrete. In short, the performance of concrete is directly related to the design, workmanship and environment of the concrete. However, in actual construction, not all these stages can be done perfectly especially in the aspect of workmanship.

Aggressive agents harmful to the durability of concrete exist everywhere. In any environment, it is always at least one or more destructive agents existing there to attack concrete, leading to certain degree of deterioration. Soon or later, as the concrete becomes more permeable, the strength becomes reduced. The concrete at such condition is no longer durable. As a result, the deterioration of concrete is inevitable because there seems to be neither any safe environment for concrete nor perfect workmanship. Nevertheless, the deterioration can be minimized by slowing down the rate of deterioration. This explains why there are many types of cement in the market. By using suitable type of cement in certain environment, the deterioration of concrete can be minimized and even in some circumstances, it can be avoided.

The technology of EM is growing tremendously and its usage is widespread. From the study of Mohd. Firdaus (2005), the result showed that with the use of EM as an admixture of concrete, it increased the strength of concrete. Now, the questions are *"What is the significance of EM in concrete?", "What are the effects of various aggressive environments on the performance of concrete containing EM?"*, *"Is there any reaction between the EM and existing aggressive agents?"* and *"How will the outcome of the reaction be, favorable or not?".* These are to be answered and become the main interests of this study.

1.3 Objectives Of Study

The focus of this study was to find out the effects of environment on the performance of concrete containing EM, especially the compressive strength. The objectives of the study were:

1) To observe the effects of EM on the performance of concrete

2) To investigate the effects of environments on the compressive strength of concrete containing EM. The environments in this study were as follow:
   a. Acidic liquid
   b. Alkaline liquid
   c. Sea water
   d. Soil environment
   e. Wastewater
   f. Outdoor environment
   g. Indoor environment

1.4 Scope Of Study

The scope of this study was limited to find out the compressive strength of the concrete containing EM under the effects of specified environments and to rank the significance of the use of EM in the concrete of different environments. Concrete cube test was carried out to find out the compressive strength after 7, 28 and 91 days after the making of cubes.

The concrete cubes were prepared according to the specification of the previous study of Mohd Firdaus (2005). The same specification of concrete mix design with the optimum dosage of EM which was 10% (by the percentage of water required in the concrete) was adopted. The specification of the concrete mix design was of Grade 30, size of 100mm by 100mm by 100mm and the raw materials consisted of OPC, coarse aggregate with maximum size of 10mm, fine aggregate (sand) of 40% passing 600μm sieve and EM functioning as an admixture. The curing method of the concrete cubes was by dry curing for three days before the samples were put into the assigned environments.

The scope of studying the effects of the assigned environments on the compressive strength of concrete containing EM was limited by exposing the concrete cubes as directly as possible to the natural environments so that the results were closer to the actual situation. The main purpose of the adoption of natural environments instead of simply having simulation of those environments in laboratory was to allow the EM to mingle and react with the complex of physical, chemical and biotic factors of the ecosystem in the environments. This adoption was applied in the sea water, soil (clay), wastewater, outdoor (tropical) and indoor environments.

However, the scope for acidic and alkaline environments could be various and widespread. Therefore, solutions with pH values ranging from 1.5 to 2.5 for acid and from 11.5 to 12.5 for alkali were used as the testing environments.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, facts and information of some research subjects that will support the research question and hypothesis are defined and explained.

The first subject to be defined is the concrete. The constituents of concrete, the properties of fresh and hardened concrete and their respective tests are explained to provide an overview of the fundamental material used in this study. Next is the information on the admixtures which can be categorized into chemical and mineral admixtures. Then, it is followed by the literature review on the new technology, namely the effective microorganisms (EM) and its uses especially in being an admixture of concrete. The last subject is the environments and only the environments within the scope of this study are detailed.

At the end of this chapter, a hypothesis will be made based on the literature reviews of these subjects.

2.2 Concrete

2.2.1 Introduction

Concrete, as quoted by A. M. Neville, in the broadest sense, is any product or mass made by the use of a cementing medium. In general, the cementing medium is the product of reaction between hydraulic cement and water. As mentioned early, ever since the introduction of concrete until today, it remains as the most frequently used material in the construction industry due to its lower cost and better overall performance. Therefore, a thorough understanding of concrete is essential for all the people involving in the world of construction.

2.2.2 The Constituents Of Concrete

2.2.2.1 Cement

In general, cement is an adhesive and cohesive bonding material and its chemical composition mainly consists of 54.1% tricalcium silicate (C_3S), 16.6% dicalcium silicate (C_2S), 10.8% tricalcium aluminate (C_3A) and 9.1% tetracalcium aluminoferrite (C_4AF).

Both C_3S and C_2S are responsible for the development of strength that C_3S contributes most of the early strength and C_2S influences the later gain of strength. The presence of C_3A in cement is not desirable due to its reaction with sulfates to form expansive calcium sulphoaluminate (ettringite) which may cause disruption. C_4AF may accelerate the hydration of the silicates.

The chemical composition of cement can be modified to produce different cement with various desired properties. Modification can also be done by mixing other materials during the production of cement. The modification of cement is to ensure good durability of concrete under a variety of the construction conditions. Below are the general types of cement and their applications in different conditions and environments of construction.

i) *Ordinary Portland Cement (Type I)* for normal construction where there is no extreme exposure to aggressive agents
ii) *Modified Cement (Type II)* for the type of construction which moderately low generation of heat is desirable or where moderate sulfate attack may occur
iii) *Rapid-hardening Portland Cement (Type III)* for construction which requires early development of strength so that formwork can be removed early for reuse or further construction is required quickly
iv) *Low-heat Portland Cement (Type IV)* for mass construction to limit the release of heat of hydration to minimize expansion of concrete and cracking
v) *Sulfate-resisting Cement (Type V)* for type of construction where sulfate attack is severe
vi) *Portland Blast Furnace Cement (Type IS)* which is also known as slag cement, exhibits properties of better resistance to sulfate attack, lower heat of hydration and better performance in marine construction
vii) *Portland Pozzolanic Cement (Type IP, P and I(PM))* which contain pozzolanic materials, exhibits properties of lower early strength, lower heat of hydration but higher later strength

Other than the types of cement mentioned above, there are also some types of cement less commonly used such as *high alumina cement* and *white and colored cement*. In addition, there are also some special types of cement such as *anti-bacterial cemen*t, *hydrophobic cement*, *masonry cement*, *expansive cement*, *oil-well cement* and *natural cement*.

2.2.2.2 Water

The quantity and quality of water as part of the mixing material in producing concrete are of vital consideration and they must be controlled properly.

The quantity of water influences the strength of concrete. In general, with higher water/cement ratio, the strength becomes lower. The quality of water affects the durability of concrete. Water containing excessive sulfates, chlorides, clay, silt and undesirable substances and aggressive chemical ions should not be used as the mixing water.

No standards explicitly prescribing the quality of mixing water are available but in many project specifications, the quality of water is covered by a clause saying that water should be fit for drinking.

2.2.2.3 Aggregate

The use of aggregate may limit the strength and affect the durability of concrete because almost three quarters of the volume of concrete are occupied by aggregate.

Among the important properties of aggregate which are of main concerns are its shape, texture, mechanical properties (bond, strength, toughness and hardness), physical properties (specific gravity, bulk density, porosity, absorption, moisture content, bulking of sand and soundness) and thermal properties. In general, a strong concrete requires aggregates which are angular and rough to increase the bonding with cement and interlocking among aggregates.

The cost of aggregate is cheaper than cement and therefore it is economical to put as much as of the former into a concrete mix and as little of the latter as possible. In addition, higher percentage of aggregate in concrete increases the volume stability and durability of concrete.

2.2.3 Properties Of Fresh Concrete

2.2.3.1 Workability

The ACI defines workability as “that property of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished”.

There is one term which is always confused with and taken as interchangeable with workability is consistency. ACI defines consistency as “the relative mobility or ability of freshly mixed concrete or mortar to flow”. In other word, consistency is more to the degree of wetness. Wet concretes are more workable than dry concretes but concretes of the same consistency may vary in workability.

The primary importance of workability is its influence on the compaction and density of the concrete. A workable concrete facilitates the compaction to achieve a denser and less permeable concrete. The strength of concrete increases with higher density and its durability better with lower permeability.

Workability of concrete is greatly affected by water content. Other additional factors are the aggregate type and grading, aggregate/cement ratio, presence of admixtures and fineness of cement.

2.2.3.2 Setting Time

The setting time of concrete can be determined by a penetration test using Proctor probe. The *initial set of concrete* occurs when it is able to sustain a penetration of 3.5 MPa and by then, the concrete has become too stiff to be made mobile by vibration. On the other hand, the *final set of concrete* is indicated when the concrete is able to support penetration of 27.6 MPa.

It is important to understand that the setting time of concrete is distinct from the setting time of cement. Setting time gives an indication of the degree of stiffening of concrete.

2.2.3.3 Segregation

Segregation can be defined as separation of the constituents of a heterogeneous mixture so that their distribution is no longer uniform. In the case of concrete, it is the differences in the size of particles that are the primary cause of segregation. The strength of segregated concrete is no longer uniform. However, segregation can be controlled by the choice of suitable grading and by care in handling.

2.2.3.4 Bleeding

Bleeding is also known as water gain. It is another form of segregation in which some of the water in the mix tends to rise to the surface of fresh concrete. This