CHARACTERIZATION AND EFFECTS OF THE EFFECTIVE MICROORGANICS (EM) AND INDUSTRIAL WASTE (IW) MATERIALS AS A PARTIAL MIXTURE OF CONCRETE

CHARACTERIZATION AND EFFECTS OF THE EFFECTIVE MICRO-ORGANICS (EM) AND INDUSTRIAL WASTE (IW) MATERIAL AS PARTIAL MIXTURE OF CONCRETE

(Keyword: Effective Microorganisms, Industrial Waste, Concrete Technology)

Researchers keep renewing and updating the concrete technology from day to day. There are a lot of added materials in concrete mixture. The main objective in this study is to investigate the admixture or filler that are economical, environment-friendly, sustainable, and easily obtained. This research focused on two type of material which is locally produced that is material based on Effective Microorganisms (EM) and Industrial Waste (IW) which are used as a partially in concrete mixture. The scope of study only focused on laboratory work to obtain the results. The result indicated in that the application of 10%, 20% and 30% of EM in concrete mixture, can be applied in concrete technology and improve the concrete properties while the application of IW in this study indicated the reduction in concrete properties as the content of IW increased and showed that it cannot replace the conventional material in concrete mixture as filler. This study recommend to extend the research especially concrete containing IW that heated in high degree of temperature (above 500 ^{o}C) because this study indicated it was improved the concrete properties on 500 ^{o}C. The outcome of the study has developed of new technology in achieving sustainability for affordable concrete structure.

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SIFAT DAN KESAN BAHAN MIKROORGANISMA BERKESAN (EM) DAN SISA INDUSTRI (IW) MENJADI SEBAHAGIAN DARI CAMPURAN KONKRIIT

(Kata Kunci: Effective Microorganisms, Industrial Waste, Concrete Technology)

Penyelidik sentiasa memperbaharui dan menigkatkan teknologi konkrit dari hari ke hari. Terdapat bayak bahan tambah di dalam campuran konkrit. Objektif utama kajian ini ialah mengkaji bahan tambah atau pengisi yang ekonomi, mesra alam, senang dihasilkan dan sebagainya. Kajian ini menumpukan dua jenis bahan yang disediakan secara tempatan iaitu Miroorganisma Berkesan (EM) dan Sisa Industri (IW) sebagai sebahagian campuran konkrit. Skop kajian hanya tertumpu pada kerja makmal untuk memperolehi keputusan. Keputusan menunjukkan penggunaan 10%, 20% dan 30% EM di dalam campuran konkrit boleh digunakan di dalam konkrit teknologi dimana ia boleh meningkatkan sifat-sifat konkrit manakala penggunaan IW di dalam kajian ini menunjukkan semakin tinggi penggunaan IW maka semakin rendah sifat-sifat konkrit dan ini menunjukkan ia tidak boleh menggantikan bahan biasa yang digunakan di dalam campuran konkrit tetapi kajian ini mencadangkan suatu kajian diteruskan terutamanya konkrit yang mengandungi IW yang dipanaskan pada suhu yang tinggi (lebih 500 ^{o}C) di mana ia menunjukkan ia mampu meningkatkan ciri-ciri konkrit pada suhu 500 ^{o}C. Hasil kajian mampu mencapai suatu teknologi baru yang mampan untuk mencapai suatu struktur konkrit yang lebih ekonomi.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOL/ABBREVIATIONS/TERMS

EM - Effective Microorganisms

EM – AS - Effective Microorganisms Activated Solution

C3S - Tricalcium Silicate

C2S - Dicalcium Silicate

C3A - Tricalcium Aluminoferrite

C4AF - Tetracalcium Aluminoferrite

Ca (OH)2 - Calcium Hydroxide

OPC - - Ordinary Portland Cement

FTIR - Fourier Transform Infrared Spectroscopy

KBr - Potassium Bromide

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

PE - Polyethylene

XLPE - Cross-linked Polyethylene

PET (poly (ethylene terephthalate)

LDPE (low density polyethylene)

P0-C - Cement paste with 0% waste addition

E5-C - Cement paste with 5% elastomer waste addition

E10-C - Cement paste with 10% elastomer waste addition

E15-C - Cement paste with 15% elastomer waste addition

X5-C - Cement paste with 5% XLPE waste addition

X10-C - Cement paste with 10% XLPE waste addition

X15-C - Cement paste with 15% XLPE waste addition

P0-M - Mortar cube with 0% waste addition

E5-M - Mortar cube with 5% elastomer waste addition

E10-M - Mortar cube with 10% elastomer waste addition

E15-M - Mortar cube with 15% elastomer waste addition

X5-M - Mortar cube with 5% XLPE waste addition

X10-M - Mortar cube with 10% XLPE waste addition

X15-M - Mortar cube with 15% XLPE waste addition

P0-MC - Mortar cylinder with 0% waste addition

E5-MC - Mortar cylinder with 5% elastomer waste addition

E10-MC - Mortar cylinder with 10% elastomer waste addition

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X5-MC - Mortar cylinder with 5% XLPE waste addition

X10-M C - Mortar cylinder with 10% XLPE waste addition

X15-MC - Mortar cylinder with 15% XLPE waste addition

List of Table

List of Figure

Acknowledgement

All praises be to Allah S.W.T, The most Gracious and The Most Mercifull for His guidance and Blessing, because without it, the author never finish this research.

The author would like to express a heartfelt gratitude to his researcher members; Assoc. Prof. Dr. Mohammad Ismail, Assoc. Prof Wan Aizan bt Wan Abd Rahman, for being researcher and friend, advice, brilliant ideas and constructive comments has brought light to this study.

A word of thanks goes to staff of Material Laboratory of Faculty of Civil Engineering for providing assistance willingly in many ways and for their friendliness. Not to forget a word to thanks also to Dr. Wan Aizan Bt Wan Abdul Rahman from Faculty of Chemical Engineering, UTM in her helpness and sharing ideas and opinion to undergraduate and post graduate who directly involve in this study. Without her provided waste materials and information, this project will not toward successful.

A word of thanks also goes to Assistant Research Officer; Liew Shan Chin and Nur Hafizah Bt Abd Khalid who involve in writing and preparing a part of this report and also indirectly involve in secretariat work with Research Management Centre, RMC. Their patience, time, co-operation and understanding are highly appreciated.

To his wife, family and beloved friends, the author owes a debt of gratitude for their encouragement, prayers, moral support throughout the whole duration of research. Without their continuous words of caring, it would have been difficult to complete this report. Thank you.

CHAPTER 1

INTRODUCTION

1.1 General

Since the early of nineteenth century, the importance of Portland cement in civilizing the nation is undeniable as it is one of the crucial ingredients in concrete.

Nationwide has been using concrete as their main material in construction as concrete is notorious for its strength, durability and affordable price. As the time goes by, lots of research and development have been done in order to produce better quality of concrete. Earlier generation faced a lot of problems in handling concrete. These involved the workability, early strength and later strength of the concrete. In order to cater the problems, they had improved the technology of the concrete. One of the most important contributions of this ingenious people was the introduction of admixtures in concrete. It is used to modify particular properties of concrete by enhancing them in terms of strength and durability.

Researchers keep renewing and updating the concrete technology from day to day. There are a lot of material add in concrete mixture. Their main aim is to search for admixtures or filler that are economical, environment – friendly, sustainable, easy to obtain and so on. Furthermore, it will be such a great advantage if the admixture or filler is locally produced. This report focused on two types of additives which are locally produced. They are Effective Microorganisms (EM) and Industrial Wastes (IW).

Ever since the development of a new technology, namely the effective microorganisms (EM), numerous researches have been carried out. The results have proved that the EM is useful and applicable in agriculture and aquaculture industries. Recently, there are research using EM in irrigation and construction and the results indicated application on EM in both fields are beneficial.

A lot of future potential of the industrial waste utilization in replacing or improving qualities of some conventional construction materials are foreseen as the waste are easily available. Follow on this project is to recognize the polymer-based industrial wastes to produce a more flexible concrete with an adequate strength. It is believed that the material can replace the conventional concrete, without coarse aggregate.

Thus, it is worthwhile to find out how the use of EM and polymer-based industrial waste as an admixture in concrete can benefit the construction industry in future.

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. As the time goes by, the demand for greater performance of concrete in construction arises. Admixtures have become essential ingredients in concrete mixture to provide high performance concrete. It is proven that by adding admixtures into the concrete mixtures will increase the quality of concrete in terms of strength and durability.

One of the interested additives is Effective Microorganisms. The technology of Effective Microorganisms is growing tremendously and its usage is widespread in many industries. Unfortunately, the usage of EM as an admixture in concrete is still at minimum stage. The practice is still at minimum level as the knowledge about the existence and advantages of EM is still limited. EM can be easily obtained from local - Pertubuhan Peladang. Therefore, research about the properties of EM is vital in order to understand the effect on the concrete performance.

Another attractive material which can be added in the concrete mixture is polymer based industry waste. Wastes produced from production industrial sector is increasing, especially polymer-based industrial waste, most of this kind of waste is in low recycle rate and disposed by using landfill method (H.H. Krause, J.M.L.Penninger,1994). One of the wastes to be used was rubber-based adhesive by-product from Raflatac Sdn. Bhd. 10 tones of this waste are sent to prescribe premise in Bukit Nanas per month. Big amounts of cost to manage the by-product are needed to be paid by the company. Besides, another waste used in this study also seems as a low recycle rate waste, cross-linked Polyethylene (XLPE). Therefore, it is better to predict possible development in the utilization of this kind of waste as additive or raw material in cement and concrete instead of disposed them by landfill.

The knowledge about the existence and advantages of these materials in concrete is still limited. The questions arise, “What is the significance of the EM or polymer based industrial waste in concrete?”, “What are the effects of various aggressive environments on the performance of concrete containing the EM or polymer based industrial waste?”, “Is there any reaction between the EM, polymer based industry waste 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 main objectives of the study are:

1) To study the effect of additives – Effective Microorganisms (EM) and polymer based industrial waste (IW) in both concrete and mortar on the physical and mechanical properties in fresh and hardened state,

2) To investigate the long-term effects durability of hardened concrete and mortar containing Effective Microorganisms (EM) or polymer based industrial waste (IW),

3) To obtain the optimum percentage of the additives in concrete and mortar in terms of its mechanical and physical performance.

1.4 Scope of Study

The scope of the study was established to fit into the desired objectives. The study was mainly focused on experimental work in laboratory. All testing activities are carried out in compliance with specified and relevant standards.

In the study, concrete and mortar are control medium and act as main material. The first additive in interest is EM which can be produced locally. Another material is polymer based industry waste, by-product from Raflatac Sdn. Bhd. Certain amounts of the admixtures are mixed with concrete and mortar for the laboratory testing to investigate the effect of the additives in concrete and mortar.

Basically, the experimental work was divided into three major parts. The first part of the experimental work is to study on the effect of the additives in concrete and mortar in fresh and hardened state. Workability measurement on fresh concrete and fresh mortar was carried out in accordance with specified fresh concrete standard. The hardened concrete and hardened mortar cube test were carried out to find out the early and later compressive strength. The second part of the experimental work is to find out the compressive strength of the concrete containing EM and polymer based industrial wastes under the effects of specified environments and to rank the significance of the use of EM and polymer based industrial wastes in the concrete of different environments. Concrete and mortar cube test was carried out to find out the compressive strength after 7, 28 and 91 days after the making of cubes. Laboratory tests for the purpose were normal consistency, compression and chemical analyzer. The comparison between samples were observed and recorded.

CHAPTER 2

LITERATURE REVIEW

2.1 General

In this chapter, facts and information of some research subjects that will support the research question and hypothesis are defined and explained. Apparently, this chapter will divide three parts according to the background of the material being studied. 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 literature review on Effective Microorganisms (EM) and its uses especially in being an admixture of concrete. The following topic is about industrial waste with more specified explanation on polymer-based industrial waste.

2.2 Concrete

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.

2.2.1 The Constituents of Concrete

2.2.1.1 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*.

2.2.1.2 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.

2.2.1.3 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

2.2.2 Properties of Fresh Concrete

2.2.2.1 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.

2.2.2.2 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.

2.2.2.3 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.

2.2.2.4 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 is caused by the inability of the solid constituents of the mix to hold all the mixing water when they settle downwards, water having the lowest specific gravity of all the mix constituents. Bleeding affects the strength and durability of concrete by forming voids in the concrete, a weaker wearing surface, incomplete hydration of cement paste and cracking due to plastic shrinkage. Bleeding can be reduced by using a rich mixes, addition of pozzolanas or fine materials into the mix and air-entraining admixture.

2.2.3 Tests For Fresh Concrete

The primary test for fresh concrete is the workability tests. Numerous attempts have been made to correlate workability with some determinable physical measurement but none of these is fully satisfactory. Anyhow, they may provide useful information within a range of variation in workability. The available workability tests are:

i) Slump test

ii) Compacting factor test

iii) ASTM flow test

iv) Remolding test

v) Vebe test

vi) Flow test

vii) Ball penetration test

viii) Nasser’s K-tester

ix) Two-point test

2.2.4 Properties of Hardened Concrete

2.2.4.1 Strength

The primary consideration for concrete is its strength and it is the parameter to indicate the quality of concrete. Generally, the strength of concrete becomes higher with the increase in degree of compaction and age and the decrease in water/cement ration and porosity. Other factors are the aggregate/cement ratio, quality of aggregate and maximum size of the aggregate.

2.2.4.2 Durability

The durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack and abrasion while maintaining its desired engineering properties. Different concretes require different degrees of durability depending on the exposure environment and the properties desired. The concrete ingredients, proportioning of those ingredients, interactions between the ingredients and placing and curing practices determine the ultimate durability and life of the concrete.

2.2.5 Tests for Hardened Concrete

2.2.5.1 Destructive Test

To test for the quality of concrete, concrete specimens of a certain mix design can be made in laboratory. Then, the specimens are tested to their failures to obtain its ultimate strength. The common tests for compressive strength of concrete are cube test, cylinder test and equivalent cube test. On the other hand, tests for tensile strength are flexural strength test and splitting tension test. Besides obtaining merely the strength of concrete, other parameters such as the deflection, influences of size, rate of loading and shape of specimens on the strength of concrete can also be determined.

2.2.5.2 Non Destructive Test (NDT)

Non destructive test (NDT) is usually performed onsite to test for the quality of existing concrete structures. A concrete may suffer from minor damage internally although its performance and appearance must not be impaired. In such situation, NDT is very useful for re-testing the concrete without causing any damage to the structure. Other than the strength, NDT can also determine the voids, cracks and deterioration of concrete.

2.2.6 Compressive Strength of Concrete Cube Test

The most frequently used test to acquire the compressive strength of concrete cube test. The specimens are usually 150 mm cubes, cast in steel or cast-iron moulds. A thin layer of mineral oil should be applied to the mould to ease the dissembling of the specimen later. BS 1881: Part 108: 1983 prescribe to fill the mould in three layers. Each layer of concrete is compacted by not fewer than 35 strokes of a 25mm square steel punner. Ramming should continue until full compaction because the test result is to be representative of the properties of fully-compacted concrete. After the top surface of the cube has been finished by means of a float, it is stored undisturbed for 24 ±4 hours at a temperature of 20 ±5 °C and a relative humidity of not less than 90%. At the end of this period, the mould is stripped and the cube is further cured in water at 20 ±2 °C.

In the compression test, the cube, while it is still wet, is placed with the cast faces in contact with platens of the testing machine and loading should be applied at a constant rate of 0.2 to 0.4 MPa/sec. Owing to the non-linearity of the stress-strain relation of concrete at high stresses, the rate of increase in strain must be increased progressively as failure is approached, that is the speed of the movement of the head of the testing machines has to be increased.

The compressive strength, also known as the crushing strength, is reported to the nearest 0.5 MPa; a greater precision is usually only apparent.

2.3 Effective Microorganisms (EM)

Since in the early 1980s, the world has been concerned with the intensive use of chemical fertilizers and pesticides in agriculture. The health of human consuming such agricultural products may deteriorate due to accumulative chemical. Thus, the world has started to look for alternative agriculture that is sustainable.

In 1982, Teruo Higa, professor of Agriculture at the University of Ryukus in Okinawa, Japan, introduced to the world a breakthrough in the field of microbiology. After more than 20 years of researching beneficial microorganisms for use in agriculture, Dr. Higa discovered a specific group of naturally-occurring beneficial microorganisms with powerful antioxidant and anti-putrefactive properties. In other words, microorganisms with an amazing ability to revive restore and preserve. He named this group as EM, an abbreviation for Effective Microorganisms.

2.3.1 The Constituents of EM

Teruo Higa originally stated that one could use up to 83 different species of microorganisms to formulate EM. However, as Teruo Higa and his researchers further studied EM, they discovered that there were only 15 or fewer classes of primary microorganisms being the primacy and central role in EM. There are many types of EM and not all the primary microbes are used to produce an EM. Various combinations of these microbes are used to formulate different EM to suit different applications. However, the three general classes of microbes being the core of all EM are *lactic acid bacteria, phototrophic bacteria* and *yeasts*.

2.3.1.1 Phototrophic Bacteria

Phototrophic bacteria are also known as Purple Non-Sulfur Photosynthetic Bacteria (PNSB). The photosynthetic or phototropic bacteria are a group of independent, self supporting microbes. These bacteria synthesize useful substances from secretions of roots, organic matter and harmful gases, by using sunlight and the heat of soil as sources of energy. Useful substances developed by these microbes include amino acids, nucleic acids, bioactive substances and sugars, all of which promote plant growth and development. The metabolites developed by these microorganisms are absorbed directly into plants and act as substrates for increasing beneficial populations.

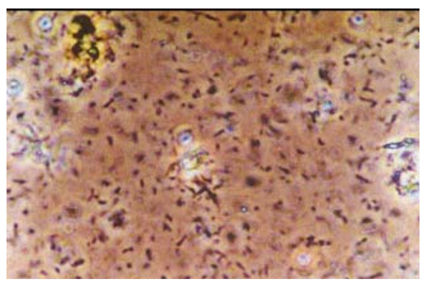

Figure 2.1: Phototrophic Bacteria

2.3.1.2 Lactic Acid Bacteria

Lactic acid bacteria produce lactic acid from sugars and other carbohydrates, developed by photosynthetic bacteria and yeast. Therefore, some foods and drinks such as yogurt and pickles have been made with lactic acid bacteria for decades. However, lactic acid is a strong sterilizing compound and suppresses harmful microorganisms and enhances decomposition of organic matter. Moreover, lactic acid bacteria promote the decomposition of material such as lignin and cellulose. In addition, the lactic acid bacteria ferment these materials, thereby removing undesirable effects of undecomposed organic matter.

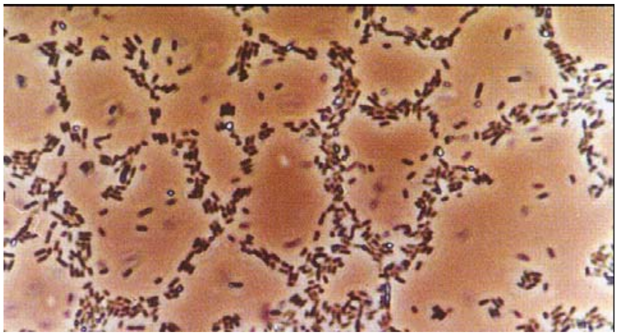

Figure 2.2: Lactic Acid Bacteria

2.3.1.3 Yeasts

Yeasts synthesize antimicrobial and other useful substances required for plant growth from amino acids and sugars secreted by photosynthetic bacteria, organic matter and plant roots. The bioactive substances such as hormones and enzymes produced by yeasts promote active cell and root division. These secretions are also useful substrates for effective microbes such as lactic acid bacteria and actinomycetes.

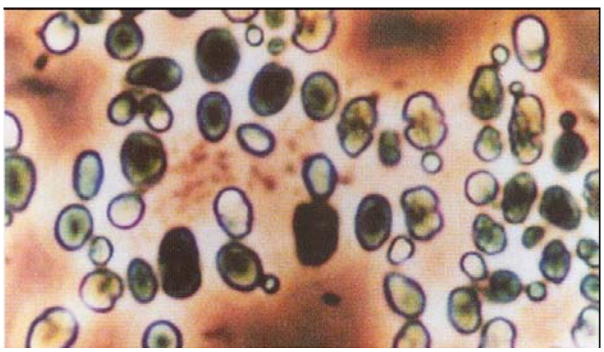

Figure 2.3: Yeast

2.3.2 Types Of EM And Their Particular Applications

Presently, the popular and frequently used EM and their particular applications are as below.

i) EM-1: Soil improvement
ii) EM-2: Wastewater treatment
iii) EM-3: Garbage decomposition
iv) EM-4: Rice growing
v) EM-5: Fruit growing
vi) EM-6: Sludge treatment
vii) EM-X: Health product

Other applications are odor control, pets control, toxic waster remediation and so on. More types of EM are being introduced such as EM-Ceramics which is used in the pre-treatment of water.

2.3.3 Application Of EM As An Admixture In Concrete

In Japan, researchers have studied the application of EM (EM-1, EM-3, EM-X and EM-Ceramics) as an admixture in concrete. The result showed changes on some properties of concrete. Firstly, EM contributes to a powerful surface activity. Secondly, by adding EM into the fresh concrete mixture, the compressive strength after 3 and 7 days of the concrete cubes is increased to 30 – 50% rather than ordinary concrete cubes. The compressive strength of the concrete based on different percentage and types of EM is summarized in Table 2.1 below. While, the suppression of carbonation based on types and percentage of EM is tabulated in Table 2.2. Furthermore, the application of EM reduced the effect of carbonation in concrete and formed a neutral environment inside the concrete.

Other than using EM, there is also a research of the use of microorganisms to improve the strength of cement mortar, carried out by P. Ghosh, S. Mandal, B.D. Chattopadhyay, S. Pal (2003). The result showed that with addition of 10_5/ml cell concentration of *Shewanella* anaerobic microorganisms could increase the compressive strength of concrete to its maximum.

Table 2.1: Compressive Strength Based on EM Percentage and Types
(After N. Sato et al, 2000)

Types of EM	**EM percentage**	**Compressive strength**
EM – 1	5%	20% > control concrete
EM – 3	5%	10% > control concrete
EM – X	5%	20% > control concrete
EM Ceramics	10%	20% > control concrete

Table 2.2: Suppression of Carbonation Based on EM Percentage and Types
(After N. Satoet al, 2000)

Types of EM	**EM percentage**	**Compressive strength**
EM – 1	5%	70% < control concrete
EM – 3	5%	60% < control concrete
EM – X	5%	70% < control concrete
EM Ceramics	10%	70% < control concrete

2.3.4 Effective Microorganisms (EM) in Malaysia

In Malaysia, EM is mainly used for agriculture and aquaculture purposes. The appliance of EM in other activities is still at minimum rate. This is caused by lack of exposure and research about the importance and benefit of EM in Malaysia. Nowadays, universities in Malaysia have started their own research on using EM in few activities such as in irrigation and construction. EM is used in irrigation to cater the pollution that occurred in water ways. By using EM in agriculture sector, the production rate and quality of vegetables and fruits are increased.

2.4 Industrial Wastes

Basic perceptions of industrial wastes that can be introduced into cementitious materials are separated into two: solid waste and liquid waste (Ravindra K. Dhir, Trevor G. Jappy, 1999). Solid waste could be use either as aggregate or filler. If used as aggregate, density of the solid waste should be lower than the density of the normal aggregate used in the mix design. In other way, it will contribute and benefit to concrete properties by act as filler. On the other hand, liquid waste contributes as bonding agent to improve the properties by act as binder. Some examples of extenders of Portland cement are pozzolanic material and mineral like fly ash, silica fume. However, this study will focus more on the solid wastes utilization in mortar mixes.

2.4.1 Classification

According to waste material and combination of the statistical waste classification, there are chemical compound wastes, chemical preparation wastes, other chemical wastes, health care and biological wastes, metallic wastes, nonmetallic wastes, discarded equipment, animal and vegetal wastes, mixed ordinary wastes, common sludge, mineral wastes and finally, solidified, stabilized or vitrified waste.

The chemical industry deals with petrochemicals, fibers and polymers, agrochemicals, pharmaceutical products, fine chemicals, catalysts, adhesives, waxes and pigments, and soaps and detergents. Regarding to industry is the most obvious source of chemical waste; some of them are also hazardous chemicals. Each of the classification has their own characteristics and examples.

2.4.2 Polymer

The simplest polymer definition is something made of many units. It can be defined as a large molecule built by the repetition of small, simple chemical unit. Polymeric material usually have high strength, possess a glass transition temperature, exhibit rubber elasticity, and have high viscosity as melts and solution (Anil Kumar. Rakesh K. Gupta, 2003).

There are 10-12 main polymer types and thousands of different resin grades and blends. Besides, polymers have become increasingly multi-component through the use of multi-layers, laminates and composites. In addition, they also contain a surplus of additive and modifiers (fillers, pigments, antioxidants and flame retardants).

2.4.2.1 Polymer Structure

Polymer structure can be varying in two ways, e.g. the geometric arrangement of the bonds and the physical structure of the chain, as shown in Figure 2.4. The terms of configuration and conformation are used to describe the geometric structure of a polymer. Configuration refers to the order that is determined by chemical bonds while conformation refers to order that occurs from the rotation of molecules about a single bonds (Rebeiz, K.S. Fowler, D.W. and Paul, D.R. 1993).

On the other hand, there are some chain structures that can divide polymers to several groups which are linear polymer, branched polymer, star polymer, dendrimer polymer and cross-linked polymer. A branched polymer is formed when there are "side chains" attached to a main chain. However, there are also many ways a branched polymer can be arranged. One of these types is called star-branching. Star branching results when a polymerization starts with a single monomer and has branches radically outward from this point. Dendrimers are polymers with a high degree of branching, in these molecules, branches themselves have branches. This tends to give the molecule an overall spherical shape in three dimensions.

In addition to the bonds which hold monomers together in a polymer chain, many polymers form bonds between neighboring chains. These bonds can be formed directly between the neighboring chains, or two chains may bond to a third common molecule. Though not as strong or rigid as the bonds within the chain, these crosslinks have an important effect on the polymer. Polymers with a high enough degree of cross-linking have "memory." When the polymer is stretched, the cross-links prevent the individual chains from sliding past each other. The chains may straighten out, but once the stress is removed they return to their original position and the object returns to its original shape (Anil Kumar. Rakesh K. Gupta, 2003).

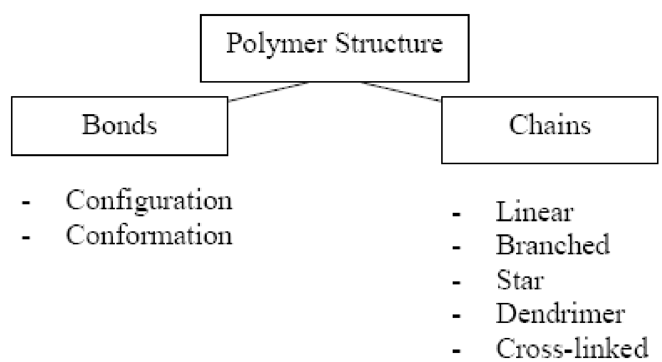

Figure 2.4: Classification of Polymer Structure

2.4.2.2 Classes of Polymers

The two major polymer classes:

1) Elastomers, or rubbery materials, have a loose cross-linked structure. This type of chain structure causes elastomers to possess memory. Natural and synthetic rubbers are both common examples of elastomers.
2) Plastics are polymers which, under appropriate conditions of temperature and pressure, can be molded or shaped (such as blowing to form a film). In contrast to elastomers, plastics have a greater stiffness and lack reversible elasticity. All plastics are polymers but not all polymers are plastics. Some plastics, such as nylon and cellulose acetate, are formed into fibers (which are regarded by some as a separate class of polymers in spite of a considerable overlap with plastics). Every day plastics such as polyethylene and poly (vinyl chloride) have replaced traditional materials like paper and copper for a wide variety of applications (J.A. Brydson, 1975).

2.4.2.3 Applications of Polymers

It is difficult to find an aspect of our lives that is not affected by polymers. With further advances in the understanding of polymers, and with new applications being researched, there is no reason to believe that the revolution will stop any time soon. This section presents some common applications of the polymer.

Rubber is the most important of all elastomers. Natural rubber is a polymer whose repeating unit is isoprene. This material, obtained from the bark of the rubber tree, has been used by humans for many centuries (Richard Heggs, 1990). It was not until 1823, however, that rubber became the valuable material we know today. In that year, Charles Goodyear succeeded in "vulcanizing" natural rubber by heating it with sulfur. In this process, sulfur chain fragments attack the polymer chains and lead to cross-linking.

Much of the rubber used in the United States today is a synthetic variety called styrene-butadiene rubber (SBR) (Clear, K.C. 1978). Initial attempts to produce synthetic rubber revolved around isoprene because of its presence in natural rubber. Researchers eventually found success using butadiene and styrene with sodium metal as the initiator. During World War II, hundreds of thousands of tons of synthetic rubber were produced in government controlled factories. After the war, private industry took over and changed the name to styrene-butadiene rubber. Today, the United States consumes on the order of a million tons of SBR each year.

More than rubber, Americans consume approximately 60 billion pounds of plastics each year. Among the most important and versatile of the hundreds of commercial plastics is polyethylene. Polyethylene is used in a wide variety of applications because, based on its structure, it can be produced in many different forms. The first type to be commercially exploited was called low density polyethylene (LDPE) or branched polyethylene. This polymer is characterized by a large degree of branching, forcing the molecules to be packed rather loosely forming a low density material. LDPE is soft and flexible and has applications ranging from plastic bags, containers, textiles, and electrical insulation, to coatings for packaging materials. Another form of polyethylene differing from LDPE only in structure is high density polyethylene (HDPE) or linear polyethylene. This form demonstrates little or no branching, enabling the molecules to be tightly packed. HDPE is much more rigid than branched polyethylene and is used in applications where rigidity is important. Major uses of HDPE are plastic tubing, bottles, and bottle caps. Other forms of this material include high and ultra-high molecular weight polyethylene, HMW and UHMW, as they are known. These are used in applications where extremely tough and resilient materials are needed.

Nevertheless, fibers represent a very important application of polymeric materials, including many examples from the categories of plastics and elastomers. Natural fibers such as cotton, wool, and silk have been used by humans for many centuries. In 1885, artificial silk was patented and launched the modern fiber industry. Man-made fibers include materials such as nylon, polyester, rayon, and acrylic. The combination of strength, weight, and durability has made these materials very important in modern industry. Nylon (a generic term for polyamides) was developed in the 1930's and used for parachutes in World War II. This synthetic fiber, known for its strength, elasticity, toughness, and resistance to abrasion, has commercial applications including clothing and carpeting. Nylon has special properties which distinguish it from other materials. One such property is the elasticity. Nylon is very elastic, however after elastic limit has been exceeded the material will not return to its original shape. Like other synthetic fibers, Nylon has a large electrical resistance. This is the cause for the build-up of static charges in some articles of clothing and carpets (Rebeiz, K.S. Fowler, D.W. and Paul, D.R., 1993).

2.4.3 Polymer-based Industrial Wastes

Nowadays, polymers at the end of its useful live are less and less regarded as the beginning of a waste problem but more and more as an unconventional raw material for new products. Utilization of fossil resources starts with the production of the resource (natural gas, oil or coal). These resources are committed first to supplying of the raw materials for the manufacturing of chemicals (monomers ethylene, propylene, styrene, adipic acid, vinylchloride). These monomers are subsequently processed into polymers (large variety of products). These products are collected and prepared for recycling when they do not function any more.

Processes which can be used for recovery of mixed polymer waste are shown in Figure 2.5. It is obvious that these processes give different products and have different economic and environmental characteristics (John Scheirs, 1998). Mechanical recycling involved collection, size reduction and extrusion of mixed prior-used polymers. This was the method used to recycle wastes in this study. While chemical recycling is subjected to the principles of thermodynamics as a transformation of chemical nature. This is compensated by energy input, by converting part of the products. One option could be the conversion of these materials back into polymer feed stocks. Energy recovery is an integrated approach to plastics recycling, which includes feedstock recycling and incineration.

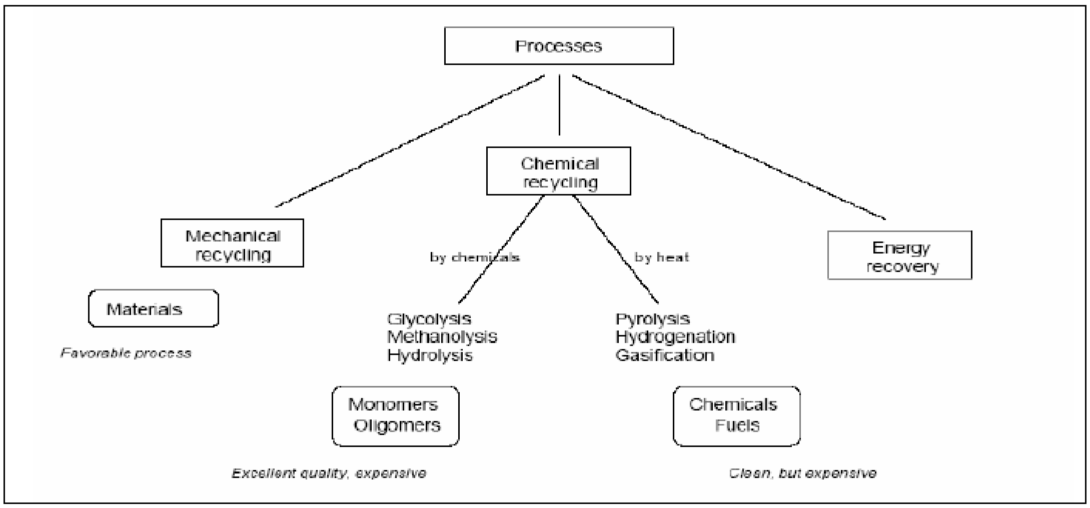

Figure 2.5: Processes for Mixed Polymer Waste Recovery

2.4.3.1 Elastomer-based Adhesive Waste

Besides only focus on the synthetic elastomer-based materials application, there are also wastes from the same class of the polymer. In this study, this waste was provided by Raflatac. Sdn. Bhd. in Pasir Gudang, Johor, Malaysia. The material was from the excess material used in coating purpose, which is non-hazardous and originally in liquid condition. In order to make it easy to handle and send to prescribe premise in

Bukit Nanas, it was extracted by using calcium carbonate, ($CaCO3$ 12%) and poly (aluminum) chloride (PAC 20%) to become solid form. This becomes a problem for the company as a burden to manage the waste because there is a big amount being produced, which are 10 tones every month.

The waste is concluded as thermoset silicone rubber type polymer which has bonding types of carbon-hydrogen (C-H) as alcohol-phenol (O-H), methane (C-H), Esther (C=O), methyl (C-H or C-C) and vinyl (C=CH). Thermogravimetric analysis of the waste concluded that there were three ranges of changes when increased in temperature on it which can be explained as material degradation process included in the waste. When temperature increased until 330.7°C, there were only impure materials being degraded. Then, continued with polymer at 439.9 °C and carbon at 789.9 °C (Siti Aishah Binti Mohd Hashim, 2006).

2.4.3.2 Cross-linked Polyethylene (XLPE)

First of all, polyethylene (PE) is a thermoplastic polyolefin manufactured by the polymerization of ethylene and has excellent chemical resistance, good water vapor barrier, good electrical properties and good impact resistance. PE do not ordinary link to one another within the polymer matrix. XLPE then is the product resulted from the formation of bonds between the molecules of PE as shown in Figure 2.6. These bonds could be direct carbon to carbon bond or chemical bridge linking two carbon atoms. When PE molecules not free to move or slide freely from each other, this interconnection of molecules creates a 3 dimensional network of molecule known as XLPE.

XLPE is thermoset and has high temperature properties, it operational between 50 °C to 100 °C, suitable for usage under cold and hot condition. It can be used for subsoil heating, marine installation, chemical application, etc, due to not affected by corrosion, electrolysis actions and resist building up to scale. Besides, it remains operational even after many year of usage without compromising the quality. All of those properties made it to become a non-recyclable material, thus, this study is observing the silane-based XLPE, as illustrated in Figure 2.7, to contribute in cementitious construction material.

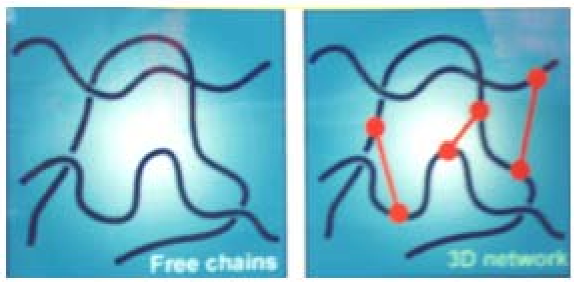

Figure 2.6: Connections Between Chains of PE and XLPE

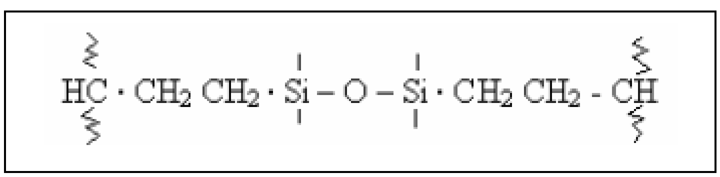

Figure 2.7: Structure of XLPE

2.4.3.3 HDPE rice husk waste

HDPE rice husk waste which is a bio-composite material. Bio-composites are materials formed by a matrix (resin) and reinforcement of natural fibers. The development of composites using agro wastes of ligonocellulosic materials as reinforcing fillers and thermoplastic polymers as matrices is currently gaining popularity nowadays.

The main uses of this bio-composite material is as a wood replacement material which has many advantages such as resistance to termite and fungal attack, weather proof, no warp/splintering, smoother texture to particle board and plywood. It can also be veneered of painted and the production does not cause wastage. This bio-composite material is extremely environmentally friendly and easy to install. The applications include automotives where it can be used for doors, headliner and ducting. For the industrial/infrastructure sector, it can be used as handrails, railings and signage. Besides that, for the building and construction industry, timber, stairs and roofs can be replaced by this biocomposite material.

2.4.4 Polymer-based Industrial Wastes Application

Due to excellent properties and contribution to the reduction of fuel and air pollution, polymer materials have found broad application in the automotive industry. However, this created new problem – waste recovery. The main characteristic of automotive polymers is low recycling rate (S. Krstic, 2001). Another source of mixed polymer waste is electronics, which are composed of 17-33 % of polymer materials. However, just a small portion of it is suitable for reprocessing. Materials used for packaging products such as PET (poly (ethylene terephthalate), HDPE (high density polyethylene), LDPE (low density polyethylene) are considered to be suitable for recycling.

2.4.4.1 Poly (ethylene terephthalate) (PET)

Post-consumer PET is widespread use, particularly in the beverage industry. PET is condensation polyester, produced by the reaction of a di-acid and a di-alcohol. The first step involved in PET synthesis is either an esterification of terephthalic acid (TPA) and ethane diol (ED) or the trans-esterification of dimethyl terephthalate (DMT) and ED, performed under pressure. In either case, the result is the di-ester (BHET). The second reaction is the poly-condensation polymerization of BHET to form PET and the regeneration of ED, conducted under vacuum (Rebeiz, K.S. Fowler, D.W. and Paul, D.R., 1993).

Unsaturated polyester based on this waste can be used as a source of resin for the manufacture of polymer concrete and polymer mortar. The recycled PET is first converted to low molecular weight oligomers by a glycolysis reaction in the presence of a trans-esterification catalyst. The glycolysis reaction is a reaction that performed under nitrogen, involves the propylene glycol replacing the EG from PET by a process of chain scission and glycol exchange. The oligomers are then used as raw materials in the production of unsaturated polyester (H.H. Krause, J.M.L. Penninger, 1994).

2.4.4.2 Expended Polystyrene (EPS)

EPS is formed by the addition of a hydrocarbon blowing agent (5-8 wt. % isomeric pentanes) to PS. EPS typically possesses bulk densities in the range 15-50 kg/m3, is widely used in applications like building insulation, vegetables and fish crates, boxes etc. The major source of waste EPS is from manufacturing, industrial and commercial operation. Graded PS foam fragments from EPS waste can be used in various construction applications due to their reduced weight, thermal conductivity and increased sound insulation.

When size of EPS foam reduced to a particle size of 1-4 mm, can be used as ground fragment incorporated into concrete mix, becomes encapsulated in the concrete matrix upon hardening, in the production of light-weight concrete. Through the used of it as aggregate, the densities produced of the concrete are in the range of 300-1000 kg/m3, which can be called floating concrete. A range of building materials of varying weight, thermal insulation capacity and degree of noise insulation can be manufactured with this technology. Besides, ultra light-weight but strong concrete panels and concrete that prevent seasonal frost damage also can be produced (H.H. Krause, J.M.L. Penninger, 1994).

2.4.4.3 Rubber Tire

This kind of waste encompasses a range of rubber types. Approximately 94% of all the rubber consumed in the world being thermoset in nature, other 6% is thermoplastic elastomers. There are 4 main steps to convert scrap tires into ground rubber crumb in mechanical grinding processes: shredding, separating, granulating and classifying. High-quality rubber particles (1.7 mm diameter) that 98-99% of steel and textile fiber removed can be produced.

One of the applications of the rubber tire waste is in producing rubber modified concrete. Ground tires have even been mixed with concrete to produce a building material known as ‘Rubcrete’. 10% ground rubber tires in a mixture has been shown to have adequate strength and stiffness to replace conventional concrete in bridge overlays, sidewalks, sound barriers and highway dividers. Unclear long term environment implications and lack of specifications for size-reduced rubber are resistances that met by application of this kind of technology in civil engineering (H.H. Krause, J.M.L. Penninger, 1994).

2.4.4.4 Test Results: Compressive Strength and Deflection

The results of the average compressive strength for control and rubber tire concrete specimens are shown in Table 2.3. Losses in compressive strength were up to 75% depending on the volume percentage of rubber chips. The specimens containing rubber exhibited post failure compression loads and underwent significant displacement before failure as shown in Figure 2.9. The specimens were able to withstand some of the ultimate load although they were highly cracked. The large displacement and deformation which were observed are due to the fact that rubber aggregate has the ability to withstand large deformations. They seem to act as springs and cause a delay in widening the cracks and preventing the catastrophic failure which is usually shown by plain concrete specimens. (H.A. Toutanji, 1996)

Table 2.3: Compressive Strength of H.A. Toutanji Research on the Rubber Modified Concrete

Volume of chip rubber aggregate (%)	Compressive strength (MPa)
0	31.9
25	19.6
50	13.8
75	9.9
100	7.5

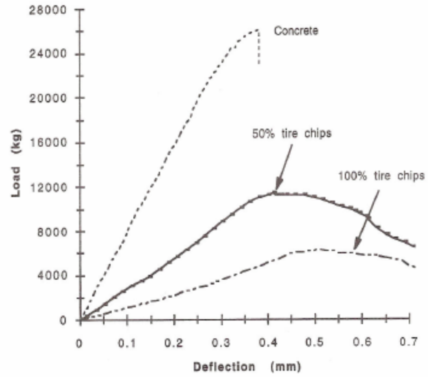

Figure 2.9: Load- Deflection Curves for Plain and Rubber Tire Concrete Cylinder (H.A. Toutanji, 1996)

2.5 The effect of concrete in high temperature

Previous experimental studies on concrete under high temperatures have mainly concentrated on the reduction of stiffness and strength properties. Various experimental parameters have been examined such as maximum temperature, heating rate, types of aggregates used, various binding materials, and loading paths (that is, mechanical loading applied before, during, and after high temperature testing). There exist few data on strength, stiffness, and permeability of concrete considering cooling rate after fire damage, however. Particularly, the increase of permeability severely affects the durability properties of concrete and reduces the remaining service life of the concrete structure. The purpose of this study is to investigate strength, stiffness, and permeability properties of concrete cylinders that are subjected to various heating and cooling scenario. The thermal diffusivity, weight losses, color changes, and cracks of the specimens are also reported.

2.5.1 Strength of concrete at high temperature

Report on test intended to established the effect of exposure to high temperature, to about 600^{0}C, give widely varying results. The reason for this include: differences in the length of exposure to the high temperature; and the differences in properties of the aggregate. Moreover, the knowledge of strength of concrete may be required for different practical conditions of exposure; instance, in the case of fire, the exposure to the high temperature is only of few hours' duration but the heat flux is large and so is the mass of concrete. Conversely, in cutting concrete by thermal lance, the exposure high temperature is only of a few seconds' duration and the heat flux applied very low. From many test that been done researcher before the strength of concrete in decreasing when temperature is increase. Many researchers have stated that compressive strength of concrete decreases with temperature. Phan, L. T. [15] (2002) tested 100 x 200 mm cylinders with initial compressive strength ranged from 51 to 98 MPa using unstressed, stressed and residual unstressed test method under high temperatures ranged from 100 °C to 600 °C and reported that compressive strength of concrete are adversely affected by temperature, as shown in Figure 2.10 - 2.12. Loses between 10 to 20% of original compressive strength were observed in normal strength concrete when heated to 300 °C and between 60 to 75% at 600 °C. For high strength concrete, a higher rate of strength loss than normal strength concrete were observed, which is about 40% loss of strength were observed at temperatures below 450 °C. Figure 2.10, 2.11 and 2.12 was showed summary relationship between compressive strength of concrete and temperature.

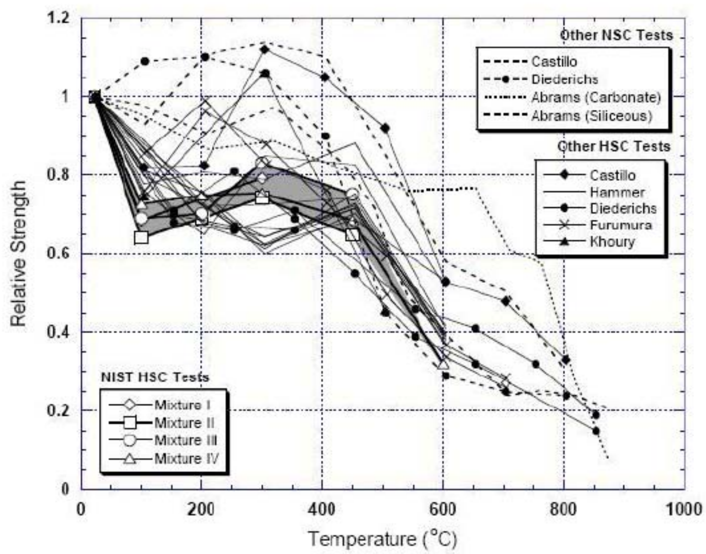

Figure 2.10: Summary of Compressive Strength-Temperature Relationships for Normal Weight Concrete, Obtained by Unstressed Test (Phan, L. T., 2002)

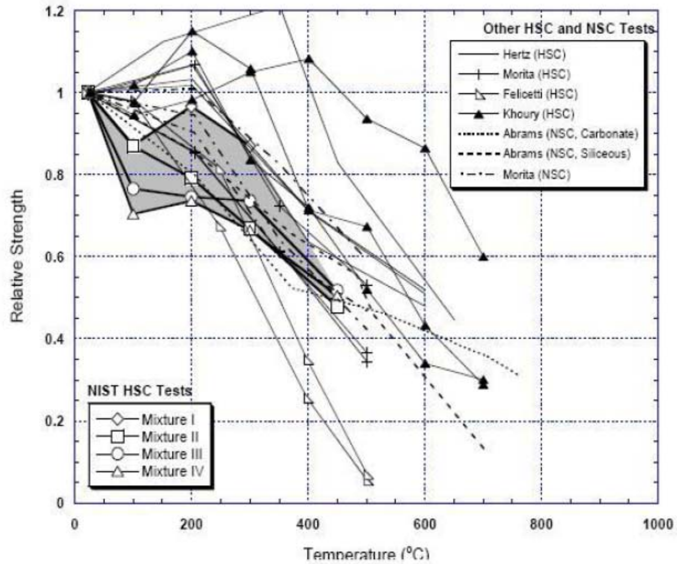

Figure 2.11: Summary of Compressive Strength-Temperature Relationships for Normal Weight Concrete, Obtained by Residual Unstressed Test (Phan, L. T., 2002)
Note: Mixture I, II and III are HSC; Mixture IV is NSC.

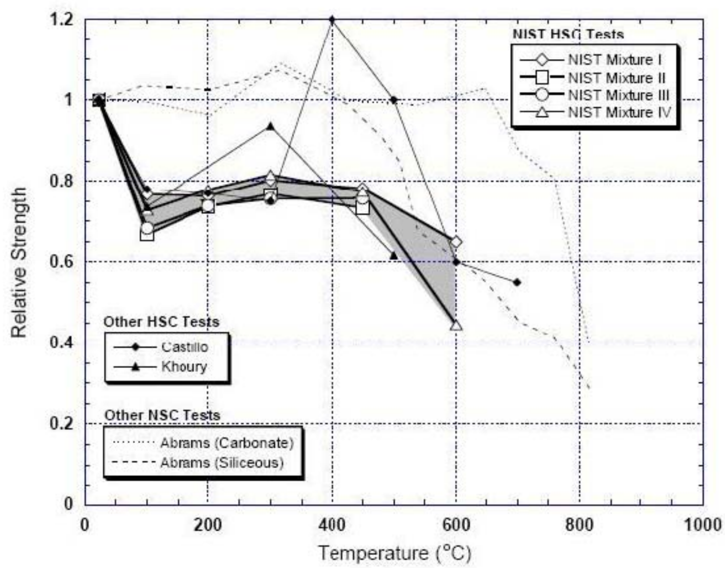

Figure 2.12: Summary of Compressive Strength-Temperature Relationships for Normal Weight Concrete, Obtained by Stressed Test (Phan, L. T., 2002)

2.5.2 Modulus of elasticity at high temperature

In a reassessment done by Khoury, G.A. (1999), strength and elastic modulus of concrete decrease when expose in high temperature. The behavior of structures is often dependent on the modulus of elasticity for the concrete, and this modulus is strongly affected by temperature. The relative modulus of elasticity is decreasing when temperature is increase. The extent of the decrease in the modulus depend the aggregate used, but a generalization on this subject is difficult. In terms, the variation of strength and of modulus with temperature is of the cube form. Figure 2.13 was showed relationship of strength and elastic modulus with temperature.

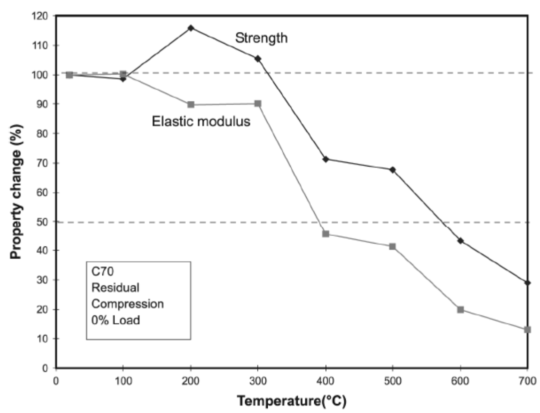

Figure 2.13: Graph of Property Change vs. Temperature

2.5.3 Behavior of concrete in fire

In general, concrete has a good proper with respect to fire resistance; that is, concrete is non-combustible, the period time under fire during which concrete continuous to perform satisfactorily relatively high, and no toxic fumes are emitted. The relevant criteria performance is: load-carrying capacity, resistance to flame penetration resistance to heat transfer when concrete is used as a protective materials for building. Concrete with low thermal conductivity has a better fire resistance so that, for instance, weight concrete stands up better to fire than ordinary concrete.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 General

This chapter discuss in detail on the experimental procedures to achieve the objectives. Basically, experimental procedures are divided in two sub-topics according to the materials used as admixture in concrete. The first sub-topic focuses on Effective Microorganism as admixture in mortar and concrete. The second sub-topic focuses on Polymer Based Industrial Waste as admixture in mortar and concrete. To achieve the objectives, the study will divide into three phase.

First phase is to investigate the effects of admixture – EM and polymer based industrial waste in both concrete and mortar on the physical and mechanical properties in fresh and hardened state. The optimum containing of EM in concrete and mortar in first phase will be used in the second phase and third phase.

The second phase of the study will investigate the long-term effects durability of hardened concrete and mortar containing EM and polymer based industrial waste.

3.2 Studies on Effects of EM in Mortar and Concrete

3.2.1 Material Used in the Study

The raw materials used in the study were cement, aggregate, water and EM. The preparation of the raw material will be discussed in detail in the following chapter.

3.2.1.1 Cement

Ordinary Portland Cement (OPC) is the popular cement used in construction and available in many places. OPC in the Concrete Laboratory of Faculty of Civil Engineering was used. The cement was not tested because it was SIRIM approved and conformed to the Malaysian Standard MS 522: Part 1 2003.

The chemical composition of the cement consisted of 55.3% tricalcium silicate (C_3S), 15.3% dicalcium silicate (C_2S), 9.1% tricalcium aluminate (C_3A) and 10.3% tetracalcium aluminoferrite (C_4AF). Figure 3.1 shows cement bags available in laboratory.

Figure 3.1: Stacks of Cement Bags.

3.2.1.2 Coarse Aggregate

Single-sized coarse aggregate with maximum size of 10mm was used to suit the size of concrete cube, which was 100mm by 100mm by 100mm. The type of coarse aggregate was ground granite obtained from the sieve analysis with grading limits complying with BS 882: 1992 as shown in Table 3.1. The coarse aggregate was air-dried for at least 24 hours before it was used in the mixing.

Table3.1: Grading Limits for Coarse Aggregate as Stated in BS 882: 1992.

Sieve size	Percentage by mass passing BS sieves for nominal sizes							
	Graded aggregates			Single-sized aggregate				
	40 mm to 5 mm	20 mm to 5 mm	14 mm to 5 mm	40 mm	20 mm	14 mm	10 mm	5 mm[1)]
mm								
50.0	100	-	-	100	-	-	-	-
37.5	90 to 100	100	-	85 to 100	100	-	-	-
20.0	35 to 70	90 to 100	100	0 to 25	85 to 100	100	-	-
14.0	25 to 55	40 to 80	90 to 100	-	0 to 70	85 to 100	100	
10.0	10 to 40	30 to 60	50 to 85	0 to 5	0 to 25	0 to 50	85 to 100	100
5.0	0 to 5	0 to 10	0 to 10	-	0 to 5	0 to 10	0 to 25	45 to 100
2.36	-	-	-	-	-	-	0 to 5	0 to 30

[1)]Used mainly in precast concrete products

Figure 3.2: Course Aggregate with Maximum Size 10mm.

3.2.1.3 Fine Aggregate

Fine aggregate of 40% passing 600μm sieve was used. The type of fine aggregate was sand with grading limits complying with BS 882: 1992 as shown in Table 3.2. The fine aggregate was air-dried for at least 24 hours before it was used in the mixing.

Table 3.2: Grading Limits for Fine Aggregate as Stated in BS 882: 1992

Sieve size	Percentage by mass passing BS sieve			
	Overall limits	Additional limits for grading		
		C	M	F
10.0 mm	100	-	-	-
5.00 mm	89 to 100	-	-	-
2.36 mm	60 to 100	60 to 100	65 to 100	80 to 100
1.18 mm	30 to 100	30 to 90	45 to 100	70 to 100
600 μm	15 to 100	15 to 45	25 to 80	55 to 100
300 μm	5 to 70	5 to 40	5 to 48	5 to 70
150 μm	0 to 15[1)]	-	-	-

1) Increased to 20% for crushed rock fines, except when they are used for heavy duty floors.

NOTE. Individual sands may comply with the requirements of more than one grading. Alternatively some sands may satisfy the overall limits but may not fall within any one of the additional limits C,M or F. In this case and where sands do not comply with table 4 an agreed grading envelope may also be used provided that the supplier can satisfy the purchaser that such materials can produce concrete of the required quality.

Figure 3.3: Fine Aggregate was Air Dried At Least 24 Hour.

3.2.1.4 Water

The water used in mixing concrete was of tap water in the Concrete Laboratory. The water was supplied by Syarikat Air Johor (SAJ) that the quality of the water was ensured to be safe for drinking. This conformed to the general requirement of mixing water as stated in many project specifications.

3.2.1.5 Admixture: EM

The admixture used in this study was EM. The type of EM was EM-1 supplied by Peladang Johor Bahru. According to Peladang Johor Bahru, the EM-1 was cultivated in Loji Air Semangar, Kota Tinggi. The original EM-1 was an inoculant that could be activated and extended for economic reasons. Activation involved adding the original EM-1 culture to a mixture of water and blackstrap molasses, its main food source. The mixture was called EM Activated Solution (EMAS) and its mix proportion is shown in

Table 3.3. The EMAS was then allowed to ferment in an anaerobic environment anywhere for 7 to 10 days. Only when the pH of EMAS was less than 4, it was used in mixing together with concrete.

Figure 3.4: EM-1

Figure 3.5: Molasses

Table 3.3: Mix Proportion for 4 Liter EM Activated Solution (EM-AS)

Material	Percentage (%)	Volume (ml)
Water	90	3600
EM-1	5	200
Molasses	5	200

The procedures of preparing the EM Activated Solution (EMAS) were as below:

i. The vessel for mixing and storing the EMAS was prepared.

ii. The mixing water was made sure to be free from chlorine. Distilled water was used for the purpose.

iii. The materials of the mixture were prepared and weighed accordingly as shown in *Table 3.3*.

iv. The materials were put into the vessel carefully.

v. The mixture were mixed until even and then stored properly at room temperature for 7 to 10 days.

vi. After 7 to 10 days, the EMAS was tested for its pH before it was used.

The EMAS must have a pH value less than 4 before it was mixed in the concrete. It was to ensure the effectiveness of the EM because EM was active and effective in acidic environment.

Figure 3.6: Effective Microorganisms Activated Solution (EM-AS)

3.2.2 Design Mixture for the Study on the Effect of EM in Mortar and Concrete

The first objective is to study the effect of EM in mortar and concrete on the physical and mechanical properties in fresh and hardened state. The mixture designs for mortar and concrete are as the following chapter.

3.2.2.1 Mortar Mixture Containing EM

48 with size 50 x 50 x 50 mm are prepared to determine the strength of the mortar at the ages of 3 days and 7 days. The cubes are mixed with EM according to percentage as in Table 3.4. For control specimens, 6 cubes are excluded from the admixture.

Table 3.4: Proportion of Ingredients in mortar

Mortar Cube	Cement (g)	Sand(g)	Water (g)	EM (g)	Number of Cube
Control	500	1500	250.0	0.0	6
EM 5 %	500	1500	237.5	12.5	6
EM 10 %	500	1500	225.0	25.0	6
EM 15 %	500	1500	212.5	37.5	6
EM 20 %	500	1500	200.0	50.0	6
EM 30 %	500	1500	175.0	75.0	6
EM 50 %	500	1500	125.0	125.0	6
EM 100 %	500	1500	0.0	250.0	6

3.2.2.2 Concrete Containing EM

To study the effect of EM in concrete on the physical and mechanical properties in fresh and hardened state, the mix of concrete containing EM was designed by using the procedures issued by Department of Environment (DOE) of United Kingdom, with the grade of concrete as 30 MPa. 18 concrete cubes are prepared which require $0.018m^3$ concrete. The proportion of concrete mixture is shown in Table 3.5.

Table 3.5: Proportion of Ingredients in Concrete.

Quantity	Cement (kg)	Water (kg)	Course Aggregate (kg)	Fine Aggregate (kg)
$1m^3$	410	205	990	810
$0.023m^3$	9.430	4.715	22.770	18.630

3.2.3 Design Mixture for the Investigation on Long-term Effects Durability of Hardened Concrete Containing EM

The second of the objective is to investigate on long term effect durability of hardened concrete containing EM. Therefore, EM was used as the admixture and only one dosage of EM was used, namely the optimum dosage obtained from the previous study. The specimens were put under seven prescribed environments with different conditions. The methods on how the prescribed environments were applied to the test are described.

3.2.3.1 Concrete Mixture Containing EM

The mixing method was by replacing optimum dosage of mixing water with the EMAS. Totally, 63 concrete cubes of 100mm x 100mm x 100mm were needed. Therefore, 0.063m^3 of concrete was required. Additional 30% of wastage was expected and thus the nett volume of concrete containing EM was 0.082m^3. The 63 cubes were made in three batches and each batch of mix consisted of 21 cubes. The number of batch was determined by the number of age of testing, namely at the ages of 7 days, 28 and 91 days. The following Table 3.6 shows the quantities of the materials to prepare for 21 cubes of concrete containing EM.

Table 3.6: The Quantities of the Materials Used for the Preparation of 21 Cubes of Concrete Containing EM

Quantity (m^3)	Cement (kg)	Water (kg)	Aggregate (kg)		EMAS (kg)
			Coarse	Fine	
1	410	184.5	990	810	20.5
0.027	11.070	4.982	26.730	21.870	0.554

The mix of control specimen was designed exactly the same with the mix of concrete containing EM with a minor modification. The modification was to exclude the use of EM as admixture. Basically, the control specimen was of normal concrete with grade of 30 MPa. Table 3.7 shows the quantities of the materials to prepare for 21 cubes of control specimen.

Table 3.7: The Quantities of the Materials Used for the Preparation of 21 Cubes of Control Specimen

Quantity (m^3)	Cement (kg)	Water (kg)	Aggregate (kg)	
			Coarse	Fine
1	410	205	990	810
0.027	11.070	5.535	26.730	21.870

3.2.4 Design Mixture for the Study of Chemical Composition in Cement Paste and Mortar Containing EM

The study carried out to identify the chemical composition in cement paste and mortar containing EM. The materials used in the study are cement paste and mortar.

3.2.4.1 Cement Paste Containing EM

There were 42 cement cubes with the size of 50mm by 50mm by 50mm provided in this study. The water cement – ratio for the cement paste was 0.5. The cement cubes were cured by wet curing process. The cubes were submerged under water for a given period. From the total sum of cement cubes, six of them were ordinary cement paste without EM (control). They were six different percentages of EM - AS (5%, 10%, 20%, 30%, 50%, and 100%) proposed for the study. A number of 21 cubes were tested for compression test after 3 days while the rest were after 7 days.

Table 3.8: Portion of Ingredients in Cement Paste

Cube	Cement (g)	Water (g)	EM (g)	Number of Samples
Control	500	250.0	0.0	6
5%	500	237.5	12.5	6
10%	500	225.0	25.0	6
20%	500	200.0	50.0	6
30%	500	175.0	75.0	6
50%	500	125.0	125.0	6
100%	500	0.0	250.0	6

3.2.4.2 Mortar Mixture Containing EM

For this research, the proportion for mortar was 1:3, which means one portion of cement was mixed together with 3 portion of fine aggregate. The water cement ratio for the mix was 0.5. The Leighton Buzzard Standard Sand which was classified under zone 2 was used in the mixture. By far, this type is the best as its particle size is similar and consistence. During mixing, the cubes were vibrated by machine with 200Hz frequency for 2 minutes.

Figure 3.7: Preparing the Mortar Mix

Figure 3.8: Mixing Cement with Sand

There were 30 samples of mortar cubes that consist of 6 ordinary mortar mixes that acted as controls. For mortar cubes, only 5 types of EM percentages were used. The percentages were selected after the optimum dosage was known based on the compressive strength of the cement cubes. According to MS 17.3 which is equivalent to BS 1881, the minimum compressive strength for the mortar cubes after 3 days and 7 are 15.2 N/mm^2 and 23.4 N/mm^2 respectively.

Table 3.9: Portion of Ingredients in Mortar Mix

Cube	Cement (g)	Water (g)	EM (g)	Quantity
Control	100	50.0	50	6
5%	100	47.5	47.5	6
10%	100	45.0	45.0	6
20%	100	40.0	40.0	6
30%	100	35.0	15.0	6

Table 3.10: Grade Limits for Sand (MS 522)

Passing percentage (%)					
BS sieve size		Zone 1	Zone 2	Zone 3	Zone 4
10 mm	3/8 in	100	100	100	100
5 mm	3/16 in	90-100	90-100	90-100	90-100
2.36 mm	No. 7	60-95	75-100	85-100	95-100
1.18 mm	No. 14	30-70	55-90	75-100	90-100
600 µm	No. 25	15-34	35-59	60-79	80-100
300 µm	No. 52	5-20	8-30	12-40	15-50
150 µm	No. 100	0-10	0-10	0-10	0-15

3.2.5 The Environments (EM)

The environments were set up to serve the purpose of the second objectives – investigation on the long term effects of the mortar and concrete containing EM in different prescribed environments.

3.2.5.1 Acidic Liquid (HCL)

The acid used was hydrochloric acid (HCl) with pH ranging from 1.5 to 2.5. The HCl solution was obtained by adding 5ml of HCl with concentration of FW 36.46 into 1000ml water. The concrete cubes were immersed fully in the hydrochloric acid solution in a vessel. This vessel was kept in the laboratory. The concrete cubes were let to freely react with the physical, chemical and biotic factors available within the acidic environment until the day of compressive strength test.

3.2.5.2 Alkaline Liquid (NaOH)

The alkali used was sodium hydroxide solution (NaOH) with pH ranging from 11.5 to 12.5. The NaOH solution was made by dissolving 10gram of NaOH pellets with concentration of FW 40.00 into 1000ml water.

Figure 3.9: Samples in the Acidic Liquid (left) and Alkaline Liquid (right)

Figure 3.10: Hydrochloric Acid (left) and Sodium Hydroxide (right)

The concrete cubes were also immersed fully in the alkaline sodium hydroxide solution in a vessel. This vessel was kept in the laboratory. The concrete cubes were let to freely react with the physical, chemical and biotic factors available within the alkaline environment until the day of compressive strength test.

3.2.5.3 Sea Water (SWTR)

Sea water from natural ocean was collected and stored in the laboratory. The sea water was obtained from the sea of Danga Bay, Johor Bahru. The pH of the sea water was 8.81.

The concrete cubes were immersed in a vessel containing the sea water. This vessel was kept in the laboratory. The concrete cubes were let to freely react with the physical, chemical and biotic factors available within the marine environment until the day of compressive strength test.

3.2.5.4 Soil (Clay) Condition (SOIL)

The river bank in Kolej Rahman Putra (KRP) was the location where the concrete cubes were buried into. The soil near the river bank was of clayey soil with pH 6.3. The cubes were buried about 300mm under the ground. The concrete cubes were then let to freely react with the physical, chemical and biotic factors available within the clayey soil environment until the day of compressive strength test.

Figure 3.11: Samples in the Sea Water

Figure 3.12: Soil Condition; Cubes Being Buried (left) and Cubes Fully Buried under the Clayey Soil (right)

3.2.5.5 Wastewater Condition (WWTR)

The oxidation pond near KRP was the testing environment. The wastewater in the oxidation pond had pH of 7.3. The concrete cubes were put inside some nets and then immersed fully into the wastewater. The concrete cubes were let to freely react with the physical, chemical and biotic factors available within the wastewater environment until the day of compressive strength test.

3.2.5.6 Outdoor (Tropical) Climate (OUTDR)

For outdoor (tropical) environment, the concrete cubes were placed at open area near the Arked Cengal in UTM campus. The concrete cubes were exposed to the effects of direct sunlight, rain and the other surrounding influences. In addition, the concrete cubes were let to freely react with the physical, chemical and biotic factors available within the alkaline environment until the day of compressive strength test

Figure 3.13: Cubes in Net Immersed into Wastewater

Figure 3.14: Samples Exposed to Outdoor (Tropical) Climate

3.2.5.7 Indoor Environment (INDR)

This was the control for the parameter of environment because indoor environment contained the least aggressive influences to the performance of concrete as compared to other environments. In this environment, the concrete cubes were kept undisturbed inside the Concrete Laboratory, protected from the effects of wetting by rainwater and drying by sunlight. The concrete cubes were let to freely react with the physical, chemical and biotic factors available within the indoor environment until the day of compressive strength test.

Figure 3.15: Indoor Environment

3.2.6 Laboratory Test

3.2.6.1 Normal Consistency Cement Paste Test

The main objective of conducting the test was to determine the water content to produce standard consistency of cement paste. This test was done on neat cement paste of a standard consistency. A cement paste is said to have a standard consistency when a plunger of the Vicat's apparatus penetrates the paste to a point 5 ± 1 mm from the base of the mould. The method of conducting the test was according to MS 7.13: Part 2: 1977. The Malaysian Standard has specified that the test should be conducted at a temperature within 17.7°C and 23.3°C, while the air difference humidity is greater than 90%. The apparatus that were used in the test were 200ml glass graduated measuring cylinder and Vicat apparatus. The procedures of conducting the test are explained below:

1. 500g of dry cement is weighed and will be used in the test.

2. 100g of water (20% of the cement weight) is added to the cement.

3. The cement and water is mixed thoroughly to produce a ball – like shape by tossing from one hand to another.

4. The spherical mass is placed in the cylindrical mould and is shaking forward and backward until the paste has filled up the mould. The excess paste at the top of the mould is sliced off by single oblique stroke of a sharp edged trowel. If necessary, the top of the mould is smoothened by a few light touches of the pointed end trowel. During the operation of cutting and smoothing, take care not to compress the paste.

5. The mould is placed on the base of the Vicat's apparatus, in such a way the plunger is above the center of the mould.

6. The above sequence is completed within 2 minutes from the moment the water was added. The plunger is brought in contact with the surface of the cement paste and released.

7. The reading of the scale of the Vicat's apparatus is recorded 30 second after the plunger being released.

8. The entire procedure is repeated for five times, each using new dry cement and increasing amount of water.

9. Graph that consists of the percentage of water against the distance from the base is plotted.

3.2.6.2 Compression test

Compressive strength is perhaps the most important property of hardened cement, mortar and concrete (Shan Somayaji, 2001). It is customary to estimate the strength properties of a cement or concrete in a structure using tests performed on small samples. In this case, the compressive strength of cement cubes that contained EM –AS was expected to be higher than ordinary cement cubes. Thus, the compression test is conducted to prove the hypotheses. The followings are the procedures in handling compression test for cement cubes:

1. The moulds of size 50mm by 50mm by 50mm were prepared. 6 moulds were for the control cubes while the rest were for cement cubes with different percentages of EM - AS (according to the proportion stated in mixture design).

2. The interior surfaces of the assembled mould were thinly coated with oil or grease to prevent adhesion of cement.

3. Each mould was filled with 2 layers of cement and each layer was tamped 25 times using a 25mm square steel rod.

4. The top surface was smoothened with a trowel and the date of manufacturing was recorded on the surface of the cement paste for identification purpose.

5. The cubes were stored and covered with wet gunny sacks and leave undisturbed for 24 hours.

6. The next day, all the cubes were removed from the mould and placed under water at temperature 19°C to 21°C.
7. 21 cubes were tested for compression test after 3 days while the rest were after 7 days.

8. The cubes were positioned in the compressive machine with the cast faces in contact with the platens.

9. Load was applied at the range of 0.03 N/mm2s to 0.1 N/mm2s until the sample reached the failure point.

10. The maximum load is recorded to the nearest 0.5 N/mm2. The compressive strength of the cubes is calculated by using equation 4:

Compressive strength (N/mm^2) = Load (N) / Cross-section area of the sample (mm^2) (4)

The procedures in making mortar cubes are similar to the cement cubes.However, the number of cubes for mortar is lesser than cement cubes. The procedure for the mortar can be referred to British Methods of Testing Mortar, Screeds and Plaster, BS 4551: 1980.

3.2.6.3 Fourier Transform Infrared Spectroscopy,FTIR – (EM)

Fourier Transform Infrared Spectroscopy (FTIR) is an analytical technique used to identify organic (and in some cases inorganic) materials. This technique measures the absorption of various infrared light wavelengths by the material of interest. These infrared absorption bands identify specific molecular components and structures.

Fourier Transform Infrared Spectroscopy (FTIR) is a powerful tool for identifying types of chemical bonds in a molecule by producing an infrared absorption spectrum that is like a molecular "fingerprint".

FTIR is most useful for identifying chemicals that are either organic or inorganic. It can be utilized to quantitative some components of an unknown mixture. It can be applied to the analysis of solids, liquids, and gasses. The term Fourier Transform Infrared Spectroscopy (FTIR) refers to a fairly recent development in the manner in which the data is collected and converted from an interference pattern to a spectrum. Today's FTIR instruments are computerized which makes them faster and more sensitive than the older dispersive instruments. FTIR can be used to identify chemicals from spills, paints, polymers, coatings, drugs, and contaminants. FTIR is perhaps the most powerful tool for identifying types of chemical bonds (functional groups).

For the purpose of study, FTIR was conducted in order to trace the functional group in the cement and mortar cubes. The main purpose is to compare the resulting graphs with the existing graphs obtain from previous research. If there were any differences between them, it might be a contribution from EM during hydration process. The experiment was conducted at Faculty of Chemical Engineering and Natural Resources laboratory.

Figure 3.16: FTIR Set at FKKSA

Figure 3.17: Closer View of Spectroscopy

EM – AS is an acidic solution while cement is an alkali. When acid reacts with alkali, a particular salt is produced. The resulting salt might influence the performance of cement and this is the main difference between EM – AS and ordinary cement. One of the objectives in the research is to find out the composition in the resulting salt. Thus, the cement cube was crushed and placed in a specific machine that extracted the functional groups of the cube. At the end of the process, the machine produced the spectrum wavelength of the material. The contribution from EM was found out by comparing the output from EM – AS and ordinary cement. The particular fiding might be the factor that contributes to higher strength of cement.

In FTIR, solid specimen needs to be grind together with a certain medium. Dry powdered Potassium Bromide (KBr) is commonly used for taking IR spectrum of solid organic or inorganic compounds. KBr is transparent in the IR region, where most organic molecules exhibit signals. It is used to dilute the solid sample and it is inert. It should be thoroughly mixed with the sample. Sample was prepared by using proportion 1mg of specimen: 1 mg of KBr. The band intensities are expressed in transmittance (T %).

Below are the steps in preparing the solid sample:

1. 1 mg of solid sample was grinded in the provided agate mortar and pestle.

2. 100mg dry pre-ground KBr was added into the agate mortar.

Figure 3.18: Potassium Bromide (KBr)

3. The two powders were mixed together with the spatula first, then with pestle using slight pressure. Grinding at this point introduces moisture into the sample.

Figure 3.19: Grinding Specimen with KBr

4. Any residual KBr was wiped off from the die set.

5. The anvil was placed with the shorter die pin on a bench or other flat surface.

6. The collar was placed on the anvil.

Figure 3.20: Anvil and Mortar Set

7. The prepared sample was place in the collar.

Figure 3.21: Placing the Sample in the Collar

8. The anvil was placed with the longer die pin over the collar so that the die pin comes into contact with the sample.

Figure 3.22: Sample was Ready for Pressing

9. The hand press was hold in the upright position and the handle was lifted to the open position. The pressure dial was rotated at the top of the press counterclockwise until it is at least one revolution from the fully clockwise position.

Figure 3.23: Pressing the Sample using Hand Press

11. The handle was slowly closed. The pressure dial was rotated clockwise until the upper ram of the hand press just touches the upper anvil of the die assembly.

12. The handle was opened and rotated clockwise a few (3 to 5) small divisions.

13. The handle was slowly closed. Then the pallet was checked. It should remain mounted in the collar. The pellet should be relatively clear, although a good

spectrum may often be obtained with an opaque pellet. The pellet can be re pressed after turning the dial clockwise another 3 to 5 divisions

14. The infrared spectrum of the pellet was measured while it is mounted in the collar.

15. The pellet was removed from the collar by poking it with a spatula.

3.3 Studies on Effects of Industrial Waste in Mortar and Concrete

3.3.1 Preparation of Materials

Materials used in all tests of this study were cement, fine aggregate, water, Elastomer-Based Adhesive Waste and. All these basic construction industry used materials were being well prepared before any test therefore tests could be conducted smoothly. Single batch of cement and well graded fine aggregate passing 1.18µm were supplied to minimize variation of results. All materials were checked to be ensured free from any impurity and certain standard were complied in the course of this study.

3.3.1.2 Cement

The cement used was Ordinary Portland Cement provided by material lab of Faculty Civil Engineering, UTM. It was ‘Holcim Top Standard’ brand multi-purpose cement produced by Holcim (Malaysia) Sdn. Bhd or formerly called Tenggara Cement.

Manufacturing Sdn. Bhd, which located at Pasir Gudang, Johor, Malysia. No test to examine the quality of the neat cement because it was approved by SIRIM and complies with MS 522: Part 1 (2003), which in dry powdery form with typical chemical compositions, chemical compounds and physical characteristics listed in Table 3.11, Table 3.12 and Table 3.13 respectively, sources from Holcim (M) Sdn. Bhd.

Table 3.11: The Chemical Compositions of Portland Cement

Chemical Composition	Percentage (%)
Silica, SiO_2	20.0 - 22.5
Alumina, Al_2O_3	4.8 -6.0
Ferum Oxide, Fe_2O_3	2.4 – 2.5
Calcium Oxide, CaO	Min 62.0
Magnesium Oxide, MgO	Max 3.5
Sulphuric Anhydrite, SO_3	2.1 – 2.4
Insoluble Residue, IR	Max 2.5
Loss of Ignition, LOI	Max 2.0
Density	Max 0.4
Lime Saturated Factor, LSF	Max 0.85

Table 3.12: The Chemical Compounds of Portland Cement

Chemical Compound	Percentage (%)
Tricalcium silicate (C_3S)	55.3
Dicalcium silicate (C_2S)	15.3
Tricalcium aluminate (C_3A)	9.1
Tetracalcium aluminoferrite (C_4AF)	10.3

Table 3.13: The Physical Characteristics of Portland Cement

Fineness:	
Surface area (m^2/kg)	290 – 325
90 micron (%)	1.5 – 2.5
45 micron (%)	15.0 – 2.0
Setting time (minute):	
Initial set	90 – 180
Final set	180 – 270
Compressive strength (N/mm^2):	
1 day	20
3 days	30
7 days	40
28 days	50
Soundness (mm)	Max 10

3.3.1.2 Fine Aggregates

Fine aggregates also known as sand and should be complied with the grading requirements of overall limits as specified in BS 882 (1992). The method used in this study to determine the particle size distribution of samples of sand by sieving was according to BS 812 – 103.1 (1985). The first step in conducted with sand was to wash the fine particle before determining particle size distribution by dry sieving. This is used for the sand to free from impurities. After that, the sand was oven dried (Figure 3.24) by heating at a temperature of 105 + 5 °C (Figure 3.25) for 24 hours to obtain a totally dry condition so that the water-cement ratio is constant when used in producing all samples. After oven-dried, the sand was allowed to cool and sieve analysis (Figure 3.26) was done prior in mixing to get the sand which all passed through 1.18 mm sieve and well grading as within overall limits.

Figure 3.24: Sand Dried in Oven

Figure 3.25: Oven Dried to a Temperature of 105 + 5 °C

Figure 3.26: Sieving Machine

3.3.1.3 Elastomer-Based Adhesive Waste

One of the wastes to be introduced into mortar mix designed in this study was an elastomer-based adhesive waste extracted by using calcium carbonate 12% and poly (aluminium) chloride 20%, produced by Raflatac (M) Sdn Bhd, which supplied the waste to polymer lab at N29, Faculty of Chemical and Nature Resource Engineering (FKKKSA), UTM, Skudai, Johor. It is by-product from paper-based and filmic pressure sensitive label stock products which included labeling solutions for demanding applications in product and information labeling in a vast array of enduses, both consumer and industrial.

Original appearance of waste when got from FKKKSA was in the form of pieces, like cake or pastry which impossible to direct mix with mortar. The waste was first cured in oven-dry condition with 105 + 5 °C for 24 hours. After being cured, the waste became elastic and harder. When cool, they were cut into smaller pieces and their density was obtained by using Mettler Toledo digital balance (Figure 3.28), and then pulverized by using 3-Phase Grinder (Figure 3.29) in polymer lab, to become in smaller size, average about 3mm in dimension. Then the sieve analysis was carried out and the particles were sieve to all passed 1.18mm as similar with sand size used in mortar mixes. Figure 3.27 shows the size reduction of elastomer-based adhesive waste from original appearance to ready be used.

Figure 3.27: Size Reduction of Elastomer-Based Adhesive Waste

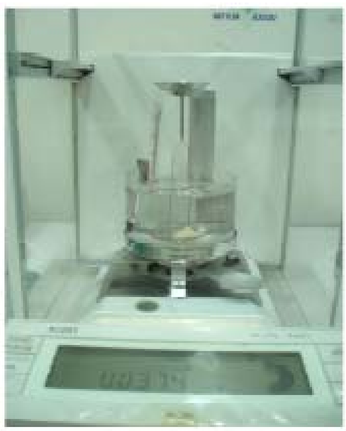

Figure 3.28: Mettler Toledo Grinder

Figure 3.29: 3-Phase Balance

3.3.1.4 Cross-linked Polyethylene Waste

Another waste to be used in this study was cross-linked polyethylene (XLPE) provided by constant temperature lab at N29, Faculty of Chemical and Nature Resource Engineering (FKKKSA), UTM, Skudai, Johor. It was in soft bottle shape originally.

Therefore, some processes to be carried out to make them suitable to mix into mortar mixes. Their density was obtained and shredding process was same as elastomer-based adhesive waste as mentioned above. Figure 3.30 shows the size reduction of XLPE from original appearance to ready be used.

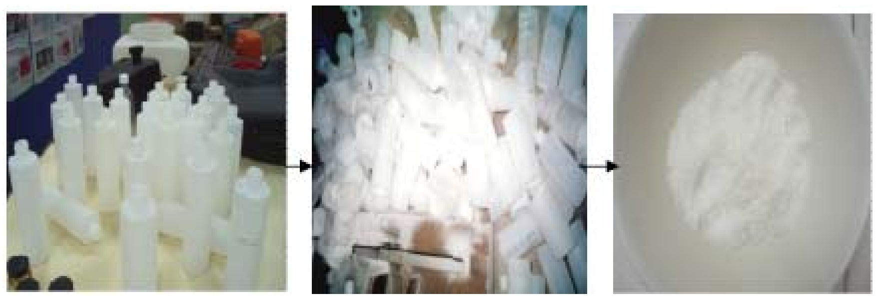

Figure 3.30: Size reduction of Cross-Linked Polyethylene Waste

3.3.1.5 HDPE Rice Husk Waste

Plastic wastes used in this research are made of HDPE rice husk waste which is a bio-composite material. Bio-composites are materials formed by a matrix (resin) and reinforcement of natural fibers. The development of composites using agro wastes of lignocelluloses materials as reinforcing fillers and thermoplastic polymers as matrices is currently gaining popularity nowadays. The main uses of this bio-composite material is as a wood replacement material which has many advantages such as resistance to termite and fungal attack, weather proof, no warp/splintering, smoother texture to particle board and plywood. It can also be veneered of painted and the production does not cause wastage. This bio-composite material is extremely environmentally friendly and easy to install. The applications include automotives where it can be used for doors, headliner and ducting. For the industrial/infrastructure sector, it can be used as handrails, railings and signage. Besides that, for the building and construction industry, timber, stairs and roofs can be replaced by this biocomposite material.

Figure 3.31: Plastic Wastes Made of Biocomposite Used in This Research

The plastic waste (HDPE Rice Husk) to be used was obtained from local manufacturers. It has a shape of a rectangular beam with hollow sections in it. To obtain a fine form of plastic waste, it is cut using a cut-off machine shown in Figure 3.32 and Figure 3.33 into thin slices and the dust is collected to be used as a replacement of fine aggregates in the concrete. A large plastic mat is placed under the cutter so that the fine dust of plastic waste can be collected.

Figure 3.32: Cut-off Machine

Figure 3.33: An example on How the Fine Particles of Plastic Waste is Collected

3.3.2 Mould

Due to both mortar cube and cylinder size used in this study were not a standard size, mould of them was prepared before cast. Mould of mortar cubes were prepared by using layered timber width 18 mm. 30 cubes of 50 mm x 50 mm x 50 mm well designed mould were produced. While for mortar cylinders, PVC pipe was used as a material to produce the moulds in dimension of 45 mm diameter and 90 mm length. In this study, 42 cylinders were being produced. Figure 3.34 and 3.35 show both of the moulds respectively.

Figure 3.34: Moulds of Mortar Cube

Figure 3.35: Moulds of Mortar Cylinder

3.3.3 Cement Standard Consistency Test

Principle according to the test is that cement paste of standard consistence has a specified resistance to penetration by a standard plunger, while the water required for such a paste is determined by trial penetrations of pastes with different water contents (BS EN 196 Part 3, 2005). The objective of this test is to examine effect of the both wastes on the ordinary cement consistence. In this study, the test was done with the method complying with BS EN 196 Part 3 (2005); on a neat cement paste and water content for standard consistence was observed. In addition, the two types of the polymer-based industrial wastes were mixed with cement paste in 5%, 10% and 15% by weight of cement appropriately therefore the effect of each on the cement standard consistence can be observed. Paste with particular water content as the water for standard consistence produce a distance between plunger and base-plate of 6 + 2 mm.

3.3.3.1 Preparation

Well preparation was given attention before any procedure begins. Planner tables were prepared for all samples tests. The purpose was to clearly define all data needed to be recorded. Apparatus used was Vicat apparatus, with the plunger and Vicat mould as shown in Figure 3.36. Vicat's apparatus in good condition was tested; plunger movement truly vertical and without appreciable friction and axis was coincide.

Figure 3.36: Vicat's Apparatus

3.3.3.2 Procedures

Several steps that had been carried out in the tests were stating below:

1. 500 g of dry cement powder was weighted by using a balance with an accuracy of ± 1 g.
2. 125 g of pipe water was measured by volume using the graduated cylinder dispensed to an accuracy of + 1 ml and was added to the cement (said 24 % by weight of cement)
3. Cement and water were thoroughly mixed to produce a ball-like shape by tossing from one hand to another.
4. The spherical mass was placed in the cylindrical mould and it was shacked forward and backward until the paste filled up the mould. The excess paste was sliced off at the top of the muld by single oblique stroke of a sharp edged trowel and smoothed it. During this operation of cutting and smoothing, the paste was not to be compressed
5. The mould was placed on the base of the Vicat's apparatus, in such a way the plunger was above the center of the mould.
6. The above sequences were completed within 2 minutes from the moment the water was added. Plunger was brought in contact with the surface of the cement paste and released
7. 30 seconds after the plunger being released, the reading of the scale of the Vicat's Apparatus was recorded.
8. The entire procedure was repeated for another amount of water with new dry cement powder.
9. Graph of percentage of water against the distance from base was plotted and water content for standard cement consistency was obtained.
10. Step 1 to 9 were repeated with introducing each type of waste in 5%, 10% and 15% by weight of cement, that were 25 g, 50 g and 75 g with thoroughly mixed with dry cement powder before added water.

3.3.4 The Environment (IW)

3.3.4.1 Acidic Solution

The acid used would be of hydrochloric acid (HCL) with PH ranging from 1.5 to 2.5. The HCL solution was obtained by adding 5ml of HCL with concentration of FW 40.00 into 1000 ml of water

Figure 3.37: Cubes Placed in the Acidic Solution

Figure 3.38: Control Cubes in the Acidic Solution

The concrete cubes were immersed fully in the hydrochloric acid solution in a basin. This basin was kept in the lab. The concrete cubes were left to freely react with the acidic environment until the curing reaches the age required, and then the compressive strength test could be done.

3.3.2 Alkaline Solution

The alkali used was sodium hydroxide solution (NaOH) with PH ranging from 11.5 to 12.5. The NaOH solution was made by dissolving 10gm of NaOH pallets into a concentration of FW 40.00 into 1000 ml of water. The concrete cubes were immersed fully in the sodium hydroxide solution in a vessel. This vessel was kept in the lab. The concrete cubes were left to freely react with the acidic environment until the curing reaches the age required and after that the compressive strength test could be done.

Figure 3.39: Control Cubes and Cubes with Plastic Wastes in the Acidic Solution

3.3.4.3 Water

This is done in the laboratory almost equivalent to the curing process where the cubes would be submerged in water for 7 and 28 days instead of the dry curing process where the concrete would be covered with a gunny sack. The concrete would be tested on its compressive strength according to the age of curing.

Figure 3.40: Cubes Immersed in Water under the Water Environment

3.3.4.3 Outdoor Environment

For outdoor environments, the concrete cubes were placed in an open area to test on the weathering effects towards the samples. The cubes were placed at an open area near the Arked Cengal in UTM campus. The concrete cubes were exposed to the effects of direct sunlight, rain and all the other surrounding influences.

Figure 3.41: Cubes Exposed to the Outdoor Environment in an Open Area Near Arked Cengal, UTM

3.3.4.5 Indoor Environment

This environment will be provided as a control for the parameter of environments as the indoor environment contained the least aggressive influences to the performance of concrete as compared to other environments. Inside the laboratory, the concrete cubes would be protected from all types of weathering effects such as rain, sunlight or any other chemical attacks. The concrete cubes would be left unharmed and tested on its compressive strength.

Figure 3.42: Cubes Exposed to the Indoor Environment in the Concrete and Structure Lab, UTM

3.3.5 Mortar Cube Compression Test

Compressive strength is the most important property of mortar. It is contributed by the harden cement paste which contain C-S-H and lying on the adhesion characteristic between the cement hydration product and sand. Therefore the objective of this test conducted in this study was to observe the ultimate compressive strength of ordinary cement mortar cube and effect of the both discrete wastes on the compressive strength of mortar cube. Principle of this test is that hardened mortar cube with certain proportion of constituent has an ultimate strength and the strength was obtained by applying a constant increasing load to the sample until it fail and comparison of different samples are made. The BS 4551 (2005) was used as references to conduct this test. Cement-based mortar cubes with cement-sand proportion of 1:3 and constant water-cement ratio of 0.6 for all specimens with dimension of 50 mm x 50 mm x 50 mm were be used for determining the compressive strength in two curing methods which are wet curing and dry curing. 126 specimens or 7 sets of mortar cube were tested, they were 1 set of control; 3 sets by introducing the elastomer waste with 5%, 10% and 15% each by weight of cement; and 3 sets by introducing the XLPE waste with 5%, 10% and 15% each by weight of cement. Three specimens were being prepared for each constituent proportion and curing condition and tested after 3, 7 and 28 days. 3.4.1 Preparation Size of the mortar cube used in this study was 50 mm x 50 mm x 50 mm. This was not the standard size mould by according to BS. Therefore, 30 moulds were prepared by using layered timber width 18 mm as mentioned before and each was reused for about 4 times. Mortar and modified mortar mix designed were be calculated and listed in a table as shown in Table 3.14. Each set of the mix was calculated to produce 6 specimens for each different age.

Table 3.14: Ordinary Mortar and Modified Mortar Mix Design

Cube	Cement (g)	Sand (g)	Water (g)	Waste (g)
Control	500	1500	300	0
E5-M	500	1475	300	25
E10-M	500	1450	300	50
E15-M	500	1425	300	75
X5-M	500	1475	300	25
X10-M	500	1450	300	50
X15-M	500	1425	300	75

3.3.5.1 Procedures

Steps conducted from mixing to testing all sets of samples were same as listed below. Only 6 cubes were produced for each following procedures to make sure all constituent were thoroughly mixed in equilibrium due to hand mixing method was used.

1. Interior surfaces of 50 mm x 50 mm x 50 mm cubes to be used were coated with a thin layer of mould oil to prevent adhesion of mortar and then covered by a plastic sheet until used.

2. 500 g of dry cement powder, 1500 g of sand passing 1.18 μm and 300 g of water like listed in Table 3.5 row 1 were weighted by using a balance to an accuracy of ± 1 g.

3. Dry materials like cement powder and sand were mixed equilibrium in a dry platen.

4. A hole-like space was made at the center of the dry mix and water was thrown inside and whole mix was thoroughly mixed.

5. Each mould was filled with two layers of mortar and each layer was tempered 25 times with a square steel rod.

6. The top surface was finished with a trowel and the date of manufacturing was recorded on the surface of the cube

7. All cubes were stored undisturbed at a temperature of 18 to 22°C and a relative humidity of not less than 90% by covering with wet gunnysack

8. The mould was striped after 24 hours and cured by immersing in water at temperature 19 to 21°C until the testing date for hydraulic curing; on the other hand, for moist air curing, without immersed in water but stored over water in a closed airtight container

9. Cubes were tested at the age of 3 days

10. Samples with moist air curing were immersed for 4 hours immediately before testing

11. The cube was positioned in the compressive machine with the cast faces in contact with the platens

12. Load was applied at the rate of 0.02 N/ (mm2s) to 0.1 N/ (mm2s) to cube until failure occurs and the maximum value of load was recorded

13. Compressive strength of mortar cube was calculated by using the formula below:

$$\text{Compressive strength } (N/mm^2) = \frac{\text{Load (N)}}{\text{Cross section area } (mm^2)}$$

14. Step 1 to 13 was repeated for mortar cubes at the age of 7 days and 28 days.

15. All steps were repeated all over again for another constituent as shown by other rows in Table 3.14

Figure 3.43: Jack Load Cell Used in Compression Test

Figure 3.44: Hand Pump Jet Used to Apply Load

3.3.6 Mortar Cylinder Compression Test: Elastic Properties

The purpose of mortar cylinder compression test is to determine the static modulus of elasticity in compression of hardened mortar. The principle of the test is the weakness of a cylinder aspect ratio to a control axial compressive load and relating the compressive stress to the longitudinal strain induced by that stress. Method used to conduct the test was referred to those described in MS 7.13: Part 2 (1997). 112 mortar cylinders with dimension of 45 mm diameter and 90 mm length, cement-sand proportion of 1:3 and constant water-cement ratio of 0.6 were prepared. 1 set of control was ordinary cement mortars; 3 sets were samples with elastomer waste filled 5%, 10%, 15% respectively; and 3 sets were samples with XLPE waste filled 5%, 10%, and 15% respectively. Curing was done under two conditions i.e. wet condition and dry condition, both at ambient temperature. One specimen was being prepared for each constituent proportion and curing condition to obtain compressive strength. Three specimens were being prepared for each constituent proportion and curing condition to obtain stress-strain relationship. Test was done at the age of 7 and 28 days.

3.3.6.1 Preparation

Cylinder with dimension of 45 mm diameter and 90 mm length is not a standard mould size; therefore, some steps were being carried out to prepare the moulds. PVC pipe was used as a material to produce the moulds and 42 cylinders were being produced. Besides, ordinary mortar and modified mortar mix designed were be calculated and listed in a table as shown in Table 3.15. Each set of the mix was calculated to produce 6 specimens for each different age.

Table 3.15: Ordinary Mortar and Modified Mortar Cylinders Mix Design

Cube	Cement (g)	Sand (g)	Water (g)	Waste (g)
Control	600	1800	360	0
E5-M	600	1770	360	30
E10-M	600	1740	360	60
E15-M	600	1710	360	90
X5-M	600	1770	360	30
X10-M	600	1740	360	60
X15-M	600	1710	360	90

3.3.6.2 Procedures

Before determination of static modulus of elasticity of all the samples, compressive strength of one specimen of each specimen for each curing condition was be tested. The value of the compressive strength was be used to determine the maximum load applied in the determination of static modulus of elasticity as listed below.

1. The cylinder was positioned vertically in the compressive machine within two thin hard rubber plates at the top and bottom of the sample.

2. The basic stress of 0.5 N/mm2 was applied centrally to the specimen, the Decmec gauge reading was taken at each measurement line.

3. The stress at a constant rate within the range 0.6+ 0.4 N/(mm2s) was steadily increased until the stress equal to one-third of the compressive strength of the mortar specimen.
4. The stress was be maintained for 60s and the strain reading taken during the succeeding 30 s at each measurement line was recorded.

5. Two additional preloading cycles was carried out by using the same loading and unloading rate, the strain readings was recorded at various measurement lines.

6. After all elasticity measurements had been completed, the load was increased on the test specimen at the same rate until failure occurred

7. Modulus of elasticity in compression of mortar cylinder is given by the formula:

$$\text{Modulus of Elasticity (N/mm}^2\text{)} = \frac{\text{Stress (N)}}{\text{Strain (mm}^2\text{)}}$$

8. Step 1 to 7 was repeated for mortar cylinders at the age of 7 days and 28 days.

9. All steps were repeated all over again for another constituent as shown by other rows in Table 3.15

Figure 3.45: Specimens in Wet Curing Condition

Figure 3.46: Specimens in Dry Curing Condition

Figure 3.47: Mortar Cylinder with Decmec Points Ready to be Tested

Figure 3.48: Reading Strain of Mortar Cylinder

Figure 3.49: Screen Showing Applied Load Value

3.4 Compressive Strength of Concrete cube test

The test of compressive strength on the concrete cubes would be defined into 3 stages which is the making, curing and testing of the concrete cube samples. The samples would be divided into control and concrete containing plastic wastes. A number of 60 cubes would be prepared with 30 cubes as a control and another 30 cubes containing plastic wastes. The size of the cubes is all the same which is 100 mm x 100 mm x 100 mm and are produced in 2 batches according to the age of curing which are 7 and 28 days

Figure 3.50: Compression Test Machine

All of the cubes made complied with the methods stated in BS 1881: Part 116 (1983). The samples used are cube samples that are cured using gunny sacks and left in the mould for three days. After three days, the concrete cubes are ensured to be hardened before the moulds could be dismantled. Afterwards, the specimens were then transferred to the six prescribed environments. All of the samples were left at their respective environments to blend and respond to the condition of the environments until the day of the compression test. The compressive strength of the concrete cubes would be tested ate the ages of 7, 28 and 91 days after the making of the samples. This test is done and it complies with the BS 1881: 116 (1983). Three samples would be tested according to the age of curing and the average would be taken based on the results of the samples

3.5 High Temperature Condition

Furnace is provided in Structural and Materials Laboratory. After the wet curing for 28 days, the concrete cube will be test in heat condition before destructive test begins. Before placed into the oven and furnace, the cured concrete needed to be dry. The concrete is placed outside until it already dry. The oven and furnace needed to be function and clean before used. Then, the concrete will be placed in 5 different temperatures. The concrete exposed in room temperature (30 ^{0}C) and high temperature, 50 ^{0}C, 100 ^{0}C, 200 ^{0}C and 500 ^{0}C. In high temperature, the sample cube that exposed is according to duration 1 hour, 2 hour and 3 hour. Handling of cube is using heat glove and scoop for furnace usage. The handling of furnace is under laboratory technician supervision. Table 3.3 was showed the heat condition and quantity of cube for this research.

Table 3.16: Total Sample of Concrete Cube

temperature(^{0}C)	30	50	100	200	500
Control sample	3	9	9	9	9
Sample with plastic waste	3	9	9	9	9

Three concrete that placed in each high temperature, 50 ^{0}C, 100 ^{0}C, 200 ^{0}C and 500 ^{0}C, is taken out when the first hour. Then, the sample is testing with compressive strength test. The procedure will continue for two and three hour duration of exposed.

There are four furnaces available for this high temperature, so this process can completed in 3 hour only. Figure 3.51 was showed furnace that used for high temperature condition.

Figure 3.51: Furnace that Can Achieve 2000 ^{0}C

3.6 Compressive Strength Test in High Temperature Condition

The objective of this test is to determine the compressive strength of concrete cubes. This test is conducted according to BS 1881: Part 116: 1983. The sample used is the sample cube that been curing for 7 and 28 days. After that materials needed to be test under 3 condition, room temperature (as control), oven (60 ^{0}C) and furnace (500 ^{0}C). Then, the sample cube can be test under compressive strength test. Total quantity concrete cube used is 42 cubes. For every test, 3 samples will be test and the result will be the average of 3 data of results. From this test, the result will give compressive strength of the concrete cube. This is the most common test of all hardened concrete partly because it is an easy test to perform, and partly because many, though of all, of the desirable characteristics of concrete are qualitatively related to its strength; but mainly because of intrinsic importance of the compressive strength of concrete in structural design.

3.7 Preparation and Procedures

Test specimens shall be concrete cubes made, cured and stored in accordance with relevant part of this standard. Do not test cubes which have been made in badly assembled moulds or which are clearly misshapen. Remove any projecting fins unless auxiliary platens of the required dimensions are to be used. Then, sample cube is placed in the testing machine. Ensure that all testing machine bearing surfaces are wiped clean and that any loose grit or other extraneous material is removed from surfaces of the cube which will in contact with the platens. Use no packing between the cube and platens, and the spacing blocks if used. Carefully, centre the cube on the lower platen and ensure that the load will be applied to opposite cast faces of the cube. If auxiliary platens are being used, align the top auxiliary platen with the cube. Without shock, apply and increase the load continuously at normal rate within the range 0.2 N / (mm^2.s) to 0.4 N / (mm^2.s) until no greater load can be sustained. On manually controlled machines as failure is operate the controls to maintain as far as possible the specified loading rate. Record the maximum load applied to the cube. To calculate the compressive strength of each cube, the maximum load applied is dividing by the cross-sectional area. For this test, cross-sectional area used is 100mm^2. Result of this experiment need to express nearest 0.5 N / mm^2.

Figure 3.52: Satisfactory Failures for Compression Test

3.7.1 Procedure of Laboratory Test

The procedure of testing concrete mixture to get the cube needed is shown below.

1. The materials needed to create concrete mix that is cement, water and aggregates is weight according to quantity needed and the materials is stored in different place.

2. After that, cement, aggregates and plastic waste that been weight is put in clean mixing machine, mix before water added.

3. After that, when the machine started, quantity of water needed is pour into the mixing machine slowly. The mix material is mixing around 3 to 7 minutes until it's obtaining the form needed.

4. To let the concrete easy to take out after its hard condition, wipe the surface of mould with oil grease.

5. After that, concrete mix is pour into the mould and compacted.

6. The method of compacted is by pour the concrete in 3 layers, every layer needed 35 stamps using steel rod size of 25 mm x 25 mm.

7. Then, sample will let to be solid / hard by store it about 24 hours.

8. The samples that been hard, will be take out from its mould and wet curing 28days.

9. After the sample is reach the required age, sample will be taken out and will be put under 2 condition, room temperature and furnace. For furnace, there are 4 different temperature; 50 ^{0}C, 100 ^{0}C, 200 ^{0}C and 500 ^{0}C. Duration of expose in the high temperature is 1 hour, 2 hour and 3 hours.

10. Then, the sample can be test by compacted strength test. When the test begins, load and cube needed to be placed in the middle of platform so that the load can be spread uniformly.

11. Sample will be loading with uniform load 3 kN/s. in this process, the load will be stop automatically when the sample fail (crack) and the maximum load for sample can reach is shown in screen and the reading can be record. Procedure (11) will be repeat with other cube using the same method.

CHAPTER 4

RESULT AND DISCUSSION

4.1 General

This chapter discuss in detail on the result and discussion from the experiments. The results and discussion are divided in two sub-topics according to the materials used as admixture in concrete. The first sub-topic focuses on Effective Microorganism as admixture in mortar and concrete. The second sub-topic focuses on Polymer Based Industrial Waste as admixture in mortar and concrete.

4.2 Effective Microorganism as Admixture

4.2.1 Properties of EM

Physically, EM is in liquid form and brownish in colour. Frankly, it smells foul and similar to leachate. It has very strong sour smell that can be correlated to vinegar. The EM liquid was more workable if being compared with molasses. Molasses comes in blackish colour and very thick texture. During preparing the EM – AS, more caution was taken during handling with molasses. As it was thick, loss might occur during mixing due to leftover of molasses in the bottle. Therefore, it was necessary to rinse the bottle with the prescribed distilled water.

After mixing all the ingredients, the molasses tended to settle downwards by the gravity force as it has higher density. Thus, it was essential that the solution was shaken and mixed hard enough to ensure all the particles were distributed evenly. On the first day after placing the solution into a container, the pH range from 3.8 to 5.0. The next two days, the container lid was opened to check to superficial condition of the solution. Immediately after the lid was lifted, a kind of gas was released out. That was the reason why glass container can’t be used.

A thin white layer was visible on top of the solution surface. Besides that, there were bubbles in the layer. This white layer was formed by yeast and it was harmless. The pH of the solution was 4.8. A week after the mixing day, the solution was tested for pH and the result was 4.7. The fermentation process took a long time to complete. In the end, the solution reached pH 3.85 fortnights after mixing. The cement and mortar mix were in alkali state as their pH range from 12 – 13. Meanwhile, the EM – AS was acidic.

When these two properties react together, saline were produced. The result for EM contribution in the saline will be discussed later on.

Figure 4.1: pH Meter in Environmental Laboratory

4.2.2 Physical Properties of Fresh Cement Paste Added with EM

Theoretically, when water came in contact with cement, hydration process occurred. A simple equation that can represent the process is given below:

$$CaCO_3 + H_2O \quad C - S - H \text{ gel} + Ca\ (OH)\text{-}2 \quad (6)$$

It is seen that silicate gel is one of the product from hydration process. This gel determines the strength for the cubes. The alkaline properties are carried with the negative hydroxide ion. When the quantity of EM – AS was induced in the cement mix, the alkalinity of cement paste was reduced. Besides that, when the quantity of the solution increased, the amount of the water for the hydration process was lessen. The reliability of the principles can be checked with the results from lab works.

During mixing the cement cubes, an obvious difference on the workability was detected. Cement mix that contains EM possessed higher workability. However, the higher the percentage of EM, the higher of the risk of bleeding will be. After the cement pastes were compacted, the water in pastes that contained 30%, 50% and 100% EM–AS tended to move upwards. When the percentage of the EM - AS increased, there was lesser water in the mix. An amount of water was needed to accomplish the hydration process. However in this condition, the water quantity was inadequate. Therefore, the hydration process was incomplete. At certain stage, hydration process cannot occur at all. This happened at cement pastes with 100% EM- AS.

After the cubes hardened, there was not much difference between the control and 5% EM – AS. This was because of the small amount of EM – AS that barely affects the hydration process. The colour for cubes that contains EM – AS were darker than the control cubes. The property was contributed by the EM – AS itself. The higher the percentage of EM – AS, the longer time it took to harden. From the study, cement cube with 50% and 100% EM – AS were not completely hardened even 12 days after casting. The surfaces of the cubes were sticky and moist. Over more, if the cube's surface was pressed with fingertips, dent will occur. This situation can represent how soft the cubes were. No further tests can be done on cubes with 50% and 100% EM – AS, as they crumbled during dismantling.

Figure 4.2: Texture of 100% EM – AS Cement Cube After 3 days

Figure 4.3: Crumbles of 50% EM-AS Cement Cube at day 3

4.2.3 Physical Properties of Fresh Concrete Added with EM

At first glance, there was no much difference between fresh concrete containing 10% EM and the control, in the aspect of physical appearance. The change in the physical appearance of fresh concrete became more obvious when at least 30% of EM was used to replace the mixing water. Under such condition, the fresh concrete containing 30% EM or more looked more viscous and dry. This was due to the reduction of actual mixing water which resulted in lower workability.

Even though the physical appearance of fresh concrete containing 10% EM did not differ much with the normal fresh concrete, the results of slump tests indicated that there was difference in terms of workability. Overall, the slump of fresh concrete containing EM was slightly smaller than the slump of fresh control concrete. When workability is lower, it usually leads to difficulty in the compaction of fresh concrete. However, in this case the slight reduction in workability was expected to be insignificant.

Some more, another property of concrete containing EM seemed to be able to overcome the problem, which was the setting time.

During the making of concrete cubes, it was found out that the concrete containing EM hardened in a rate slower than the control. When normal concrete took one day to harden, the concrete containing EM would require at least three to four days so that it reached a hardened state which dismantling of moulds could be done satisfactorily. Otherwise, problems such as spalling of hardened concrete during dismantling of moulds and dissolution of the cement paste into the curing water during curing would occur. The slower rate of hardening was expected to be due to the effect of molasses, which in fact was a carbohydrate derivative, namely a type of retarder. This retarder delayed the setting and hardening time of cement paste. For that reason, the compacting work could be done longer to compensate for the loss in workability, so that permeability could be minimized.

For testing purpose, the concrete was mixed with 100% EM by the means of fully replacing water. It is observed that the hydration process was not occurred completely due to insufficient of water. The concrete was mixed uniformly and it is considered as homogenous.

Figure 4.4: Physical Appearance of Concrete with EM-5%

Figure 4.5: Physical Appearance of Concrete with EM-30%

Figure 4.6: Physical Appearance of Concrete with EM-100%

4.2.4 pH of Fresh Concrete

As discussed earlier, the pH value for EM is between 3.5 and 4.0; while, the pH value of concrete is between 12 and 13. The differences are significant as EM is in acidic form and concrete is in alkali. Determinations of pH value for all the samples concrete are tested. The sample include 5%, 10%, 15%, 20%, 30%, 50% and 100% of EM-AS compare with the water content. All the samples are tested three times and an average value was recorded. Table 4.1 shows the pH value for all the samples.

Table 4.1: pH Value of the Samples

Percentage of EM in concrete	pH Value
0 %	12.30
5 %	12.06
10 %	12.04
15 %	11.84
20 %	11.32
30 %	11.08
50 %	10.68
100 %	9.86

Refer to Table 4.1, it shows clearly that the pH value decreased with the increasing of EM in concrete. The pH of control sample, without EM, is 12.30 and it is similar with the theoretical value. The pH start to decrease to 12.06 when 5% of EM-AS is added in concrete. pH concrete added with 100% EM-AS, fully replaced water, is recorded as 9.86. This shows that EM will reduce alkalinity of concrete. The chemical composition due to the reaction will be investigate and discussed in latter.

4.2.5 Cement Consistency Test

Cement consistency test was conducted to determine the quantity of EM – AS that was needed in order to achieve a standard mix. For cement that is mixed with water, the range of the water percentage is 26 – 33 % from the dry cement weight. The difference between quantity of water and EM – AS in achieving standard mix was compared. The results from the tests were tabulated in Table 4.6 and Table 4.7.

From the table, a graph consisting water percentage versus distance from base was plotted. The main purpose of the graph was to interpolate the water percentage at 5mm as the standard mix will allow penetration until 5 ± 1 mm from the base of the mould.

Table 4.2: Results of Cement Consistency Test by Using Water

Experiment No	Weight of cement (g)	Percentage of cement (%)	Weight of water (g)	Penetration depth from base (mm)			Average penetration depth from base (mm)
				1	2	3	
1	500	26	130	32	32	33	32
2	500	28	140	23	21	22	22
3	500	30	150	10	11	10	10
4	500	32	160	4	5	4	4
5	500	34	170	3	3	2	3

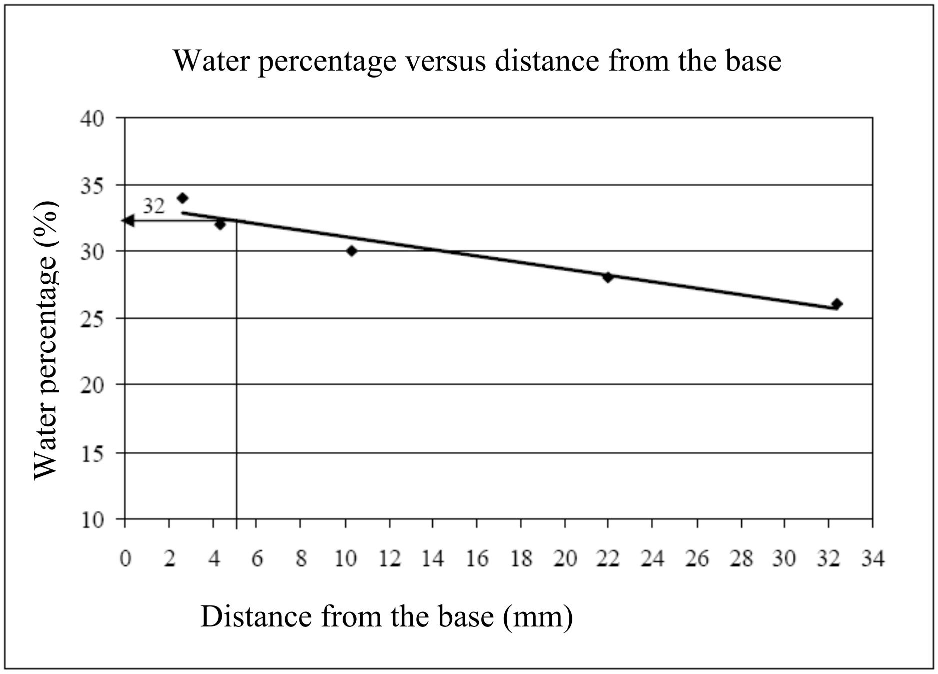

Figure 4.7: Graphs of Water Percentage versus Distance from Base

From the graph, the water percentage at 5 mm was 32%. The result was in the ordinary range which was 26 – 33 %. The water percentage depends on the fineness and quality of the cement itself.

Table 4.3: Results of Cement Consistency Test by Using EM - AS

Experiment No	Weight of cement (g)	Percentage of water (%)	Weight of water (g)	Penetration depth from base (mm)			Average Penetration Depth from base (mm)
				1	2	3	
1	500	32	160	24	24	23	24
2	500	34	170	20	18	19	19
3	500	36	180	10	12	12	11
4	500	38	190	6	5	7	6
5	500	40	200	3	2	2	2

From the table, another graph of was plotted. But this time, the y axis was the EM - AS percentage instead of water percentage. It was vital to check whether the EM – AS percentage is differed from the test using water. From the graph, the EM – AS percentage at 5 mm was 39%. This means that EM mixture needs more water, which is 7% to complete the hydration process.

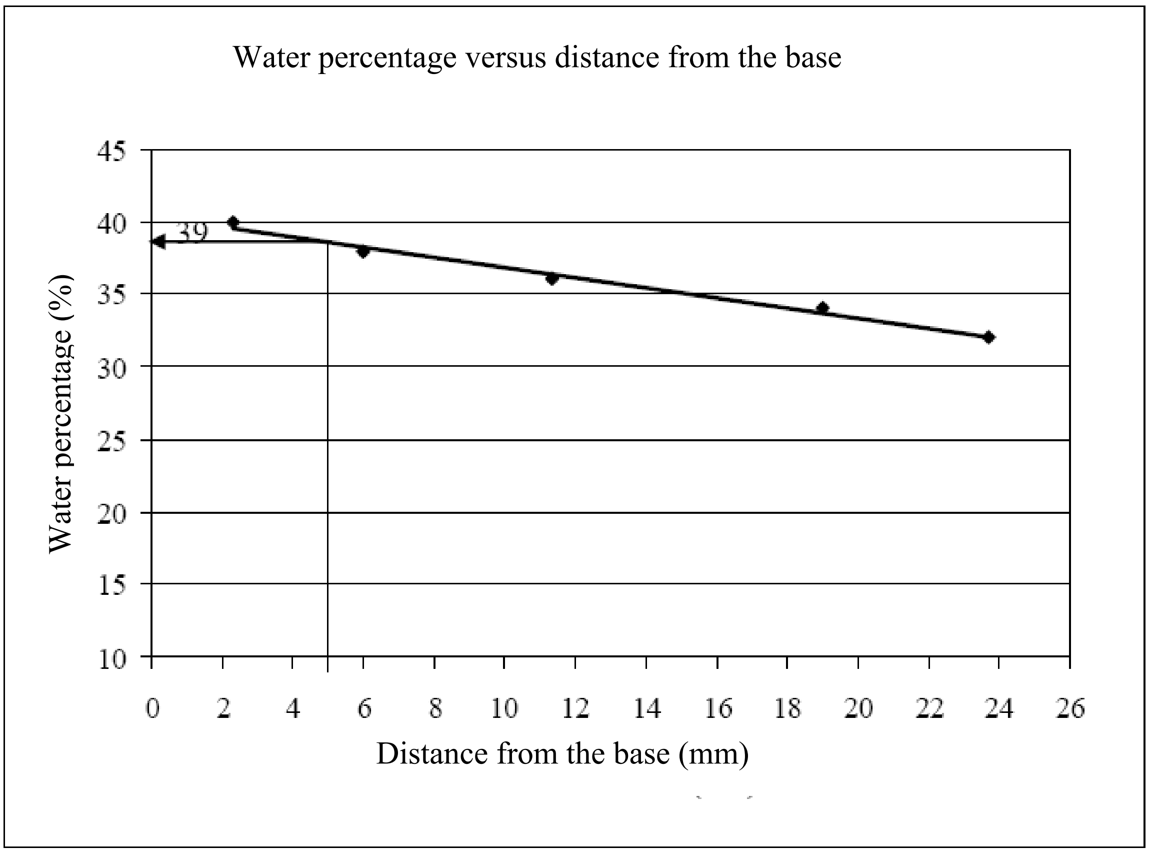

Figure 4.8: Graph of EM – AS Percentage versus Distance from Base

4.2.6 Compressive Strength of Cement Cubes

This test was conducted to compare the strength between the control and EM – AS cubes. In order to achieve that objective, the water – cement ratio (0.5) was remaining constant in any batch. As been explained in previous chapter, the percentage of EM – AS that were brought into design were 5%, 10%, 20%, 30%, 50% and 100% from the water content. However for cubes 50% EM – AS and 100% EM – AS, no compression test can be conducted as they crumbled and didn't hardened even after 7 days. It can be concluded that the compressive strength of that particular cubes was negligible. They might possessed a value of compressive strength but it might be too small or almost zero.

The cubes were cured by dry curing method. On the day 3rd and 7th after curing, the cubes were tested for compression test. The results for tests are shown in Table 4.1 and Table 4.2. The best way to get the compressive strength of the cubes is by using compression machine. However, during the study was conducted, the machine was broke down and not functioning. As an alternative, load cell has been used. The maximum capacity of the load cell is 50 ton (500 kN). The sensitivity of the compression machine is better than load cell. However, after analyzing the results, the reliability of the results was convincing.

Based on the results, graphs were plotted as shown in Figure 4.10. From the results, it was proven that cubes with EM – AS (except 30% EM – AS) had higher strength than control cubes.

Table 4.4: Compressive Strength of Cement Cubes after 3 days

EM - AS percentage (%)	Average compressive load (kN)				Average compressive strength (N/mm^2)
	Sample 1	Sample 2	Sample 3	Average	
0	35	33.2	31.3	**33.17**	**13.27**
5	34.3	38.6	41.4	**38.10**	**15.24**
10	56.9	57.8	50	**54.90**	**21.96**
20	45.6	42.5	39.9	**42.67**	**17.07**
30	13.3	12.9	14.1	**13.43**	**5.37**

Table 4.5: Compressive Strength of Cement Cubes after 7 days

EM -AS percentage (%)	Average compressive load (kN)				Average compressive strength (N/mm^2)
	Sample 1	Sample 2	Sample 3	Average	
0	42.4	43.3	53.8	**46.50**	**18.60**
5	45.1	54.9	50.7	**49.57**	**19.83**
10	55.6	61.9	58.3	**58.60**	**23.44**
20	46.7	54.5	47.5	**50.23**	**20.09**
30	46.8	38.7	44.9	**43.47**	**17.39**

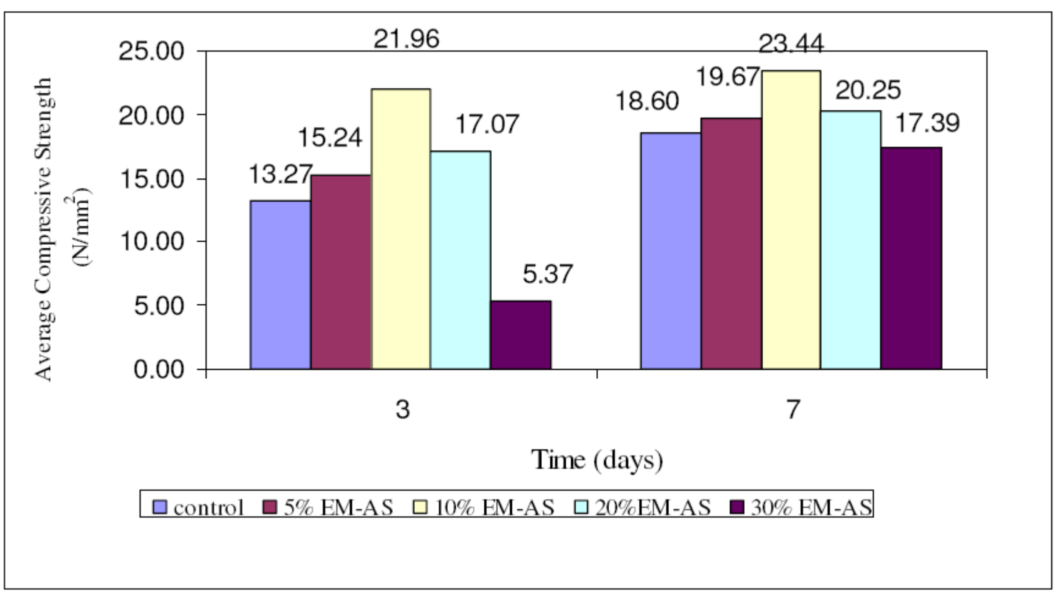

Figure 4.9: Histogram of Average Compressive Strength versus Time

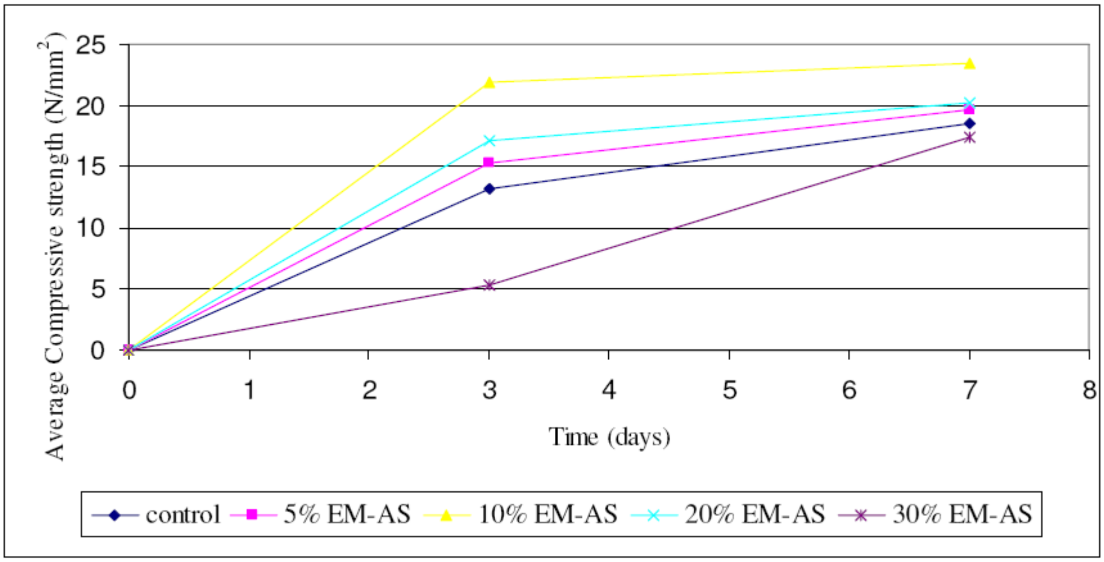

Figure 4.10: Graph of Average Compressive Strength versus Time

4.2.6.1 Compressive strength after 3 days

The average compressive strength after 3 days can be summarized in Figure 4.11:

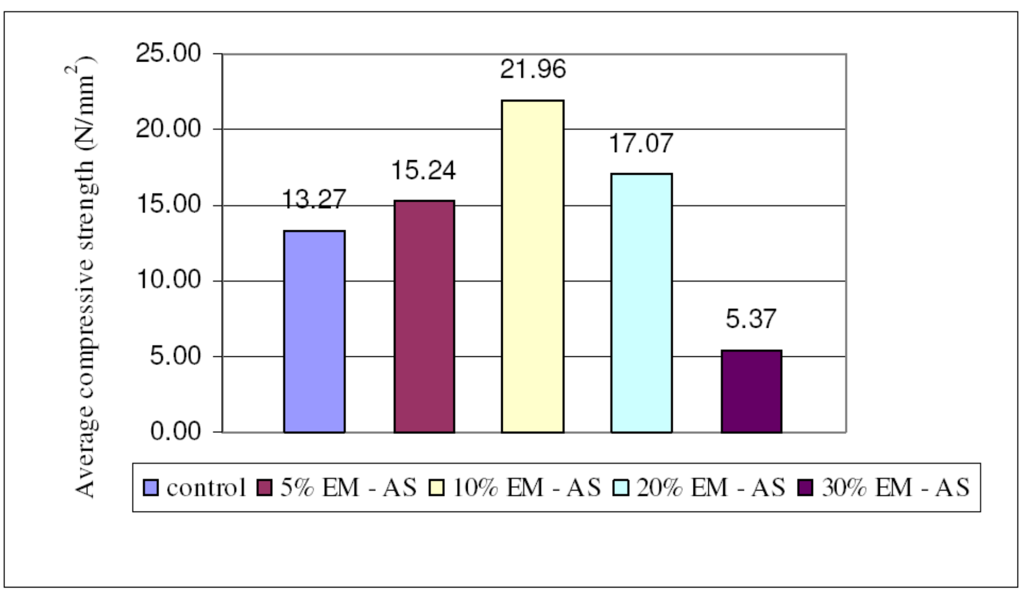

Figure 4.11: Histogram of Average Compressive Strength after 3 days

Generally, it can be seen that all cement cubes with EM – AS (except 30% EM – AS) possessed higher strength than control cubes. The average compressive strength for control cubes was 13.27 N/mm2. This value was the benchmark for any comparison between the cubes later on. Meanwhile, for cubes with 5% EM – AS the value was 15.24 N/mm2. The strength had increased to 14.84%.

From the histogram, it was crystal clear that the maximum strength was obtained from 10% EM – AS. The increment was 65.49%. The batch that possessed second higher value was 20% EM – AS with 28.64% increment. The average compressive strength of 30% EM – AS drop drastically compared to control. In those cubes, less hydration process were taking place because of the inadequate water supply. Less hydration process means less C – S- H gel. Consequently, the cubes were weak in compressive strength. The most optimum dosage of EM – AS for cement cubes was 10% from the water content as it produce the highest compressive strength among the others. The 30% EM – AS exhibited low strength value, logically, the 50% and 100% EM – AS cubes will exhibit smaller values. That was the reason why the cubes tended to crumble. They do not have strength to withstand any load.

4.2.6.2 Compressive strength after 7 days

The average compressive strength after 7 days can be summarized into Figure 4.12 below:

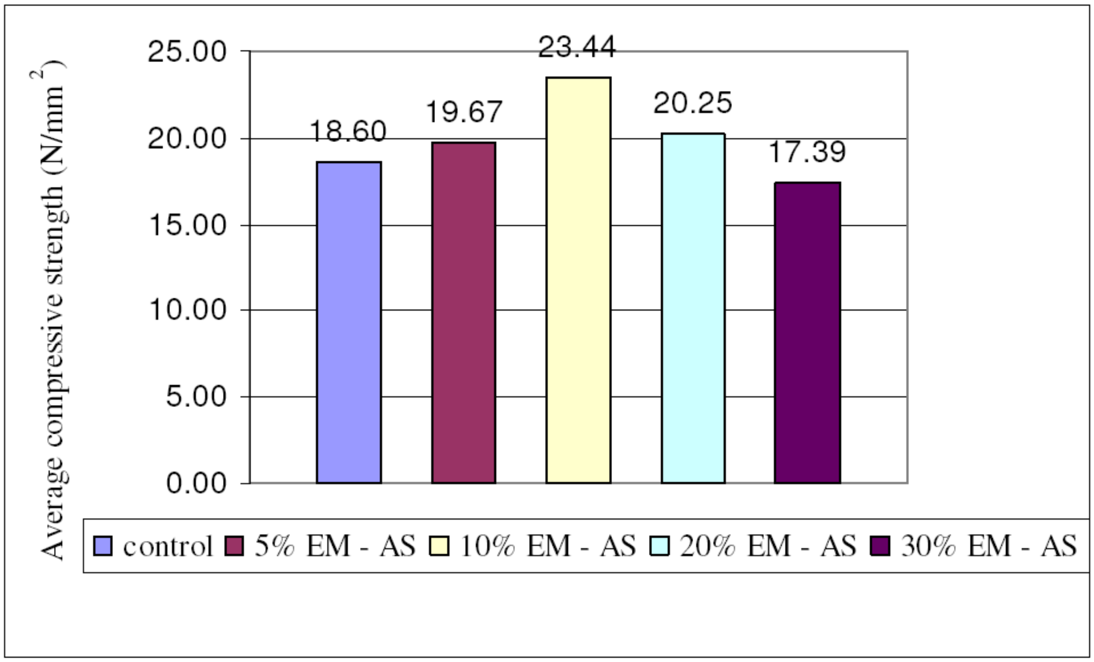

Figure 4.12: Histogram of Average Compressive Strength after 7 days

From the histogram it can be concluded that there was continuity between the strength after 3 days and 7. The pattern of the histogram was similar. The highest peak was at 23.44 N/mm2, obtained from 10% EM – AS cubes. The increment for 5%, 10% and 20% EM – AS cubes were 5.75%, 26.02% and 8.87% respectively. For cubes with 30% EM – AS, the strength after 7 days was increased significantly compared to day 3. After 3 days, the strength was only 5.37 N/mm2 whereas after 7 days it increased to 17.39 N/mm2.

4.2.6.3 The failure pattern

When the cubes had reached maximum load, they failed at certain angle and plane. The plane will be more visible if the compression machine is used as the load increment is constant. For load cell, the increment of load did not worked automatically.

The load must be induced by pushing a certain button. Therefore, the range for every load increment is not uniform. There are explanations from the failure behavior of each cube. Cement cubes that were high in EM – AS (30%, 50% and 100%) had poor bonding. Therefore, they can easily get crushed without showing any clear failure plane. In other hand, if the cement cubes possessed higher strength, they reached their ultimate load by a small explosion. However, for control, 5% and 20% EM – AS, their failure plane was visible.

Figure 4.13: Obvious Failure Plane of Control Cube

Figure 4.14: 10% EM – AS after Failure

4.2.7 Compressive Strength of Concrete Cubes

The tests were conducted to compare the strength between the control and EM – AS in concrete cubes. In order to achieve the objective, the water – cement ratio (0.5) was remaining constant in any batch. The percentage of EM – AS that were brought into design were 5%, 10%, 15%, 20%, 30%, 50% and 100% from the water content.

The cubes were cured by dry curing method. On the day 7^{th}, 14^{th} and 28^{th} after curing, the cubes were tested for compression test. The results for tests were shown in Table 4.6 and Table 4.7. The compressive strengths of the cubes were determined by using compression machine. Based on the results, graphs were plotted as shown in Figure 4.15, Figure 4.16, Figure 4.17 and Figure 4.18. From the results, the cubes with EM – AS (except more than 30% of EM – AS) were proved to achieve higher strength than the control cubes. The table and graph obviously indicated the concrete with admixture achieved higher compressive strength than the control cube for both wet and dry curing. This showed that the right amount of admixture EM is able to improve the compressive strength of concrete.

Table 4.6: Results of Compressive Strength of Concrete Cube through Wet Curing Method.

No.	Percentage of EM (%)	Average compressive strength of concrete cubes (N/mm^2)		
		7 Days	14 Days	28 Days
1	Control	30.50	32.56	42.73
2	5%	31.25	33.47	42.87
3	10%	36.27	39.33	45.30
4	15%	34.63	35.30	42.83
5	20 %	34.13	34.33	43.03
6	30%	35.27	33.76	35.70
7	50%	26.39	29.21	32.13
8	100%	1.02	0.80	0.74

Table 4.7: Results of Compressive Strength of Concrete Cube through Dry Curing Method.

No.	Percentage of EM (%)	Average compressive strength of concrete cubes (N/mm^2)		
		7 Days	14 Days	28 Days
1	Control	30.19	31.07	42.63
2	5%	31.88	32.73	42.67
3	10%	33.47	34.83	45.00
4	15%	33.23	34.63	42.43
5	20%	33.18	34.10	42.87
6	30%	32.83	33.07	34.90
7	50%	25.25	28.86	31.87
8	100%	1.40	1.00	0.87

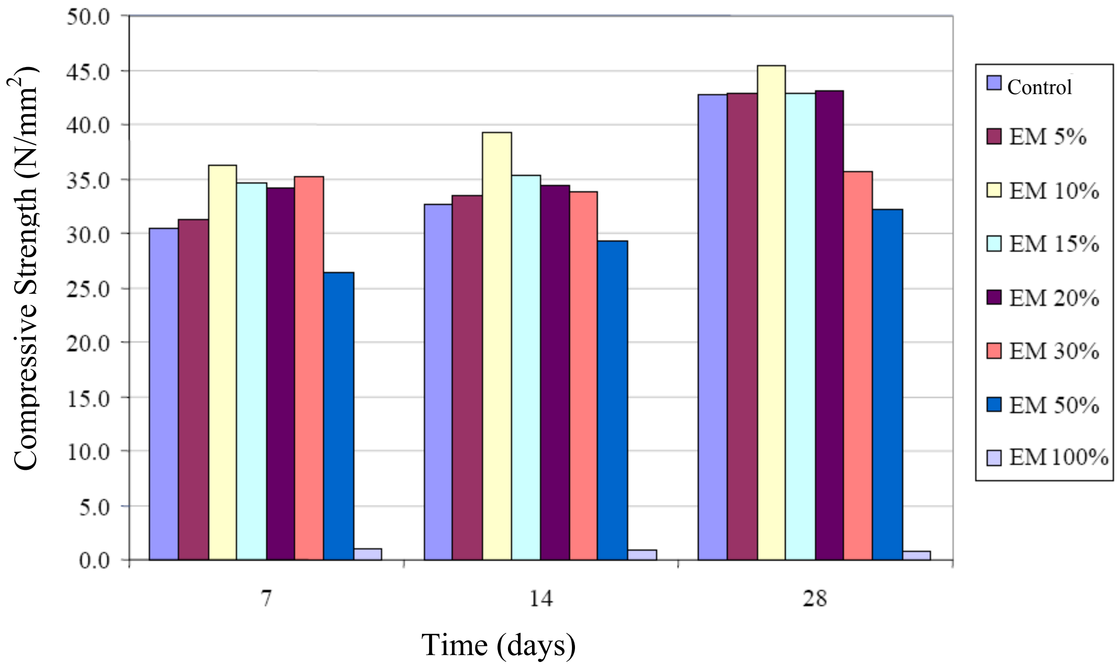

Figure 4.15: Histogram Shows Average Compressive Strength versus Time (Wet Curing).

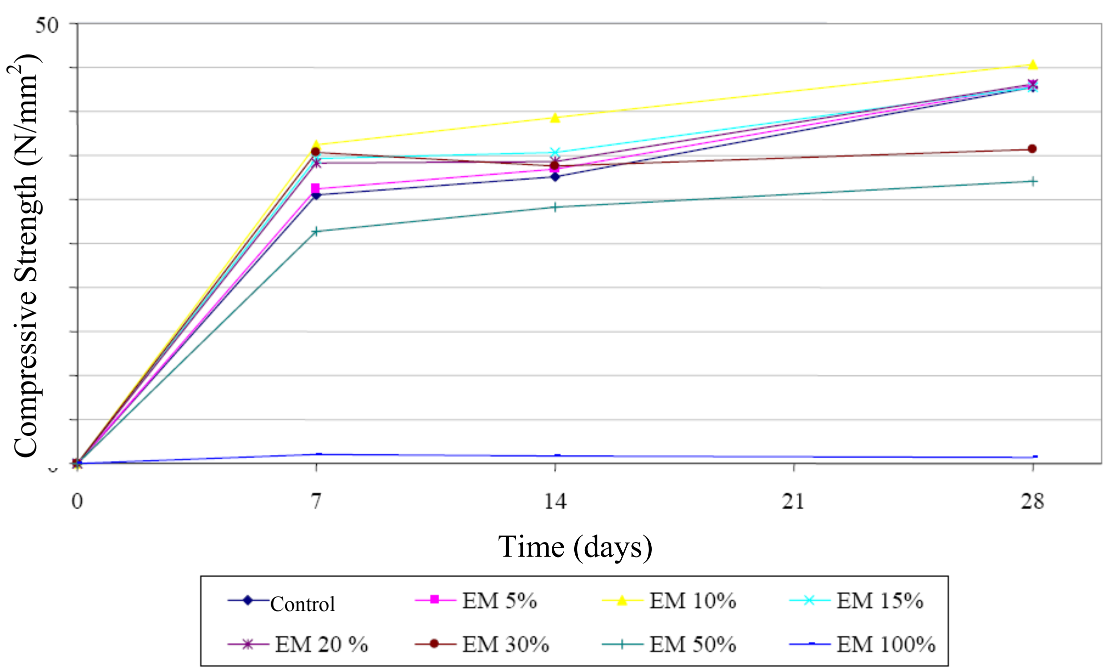

Figure 4.16: Graph Shows Compressive Strength versus Time (Wet Curing).

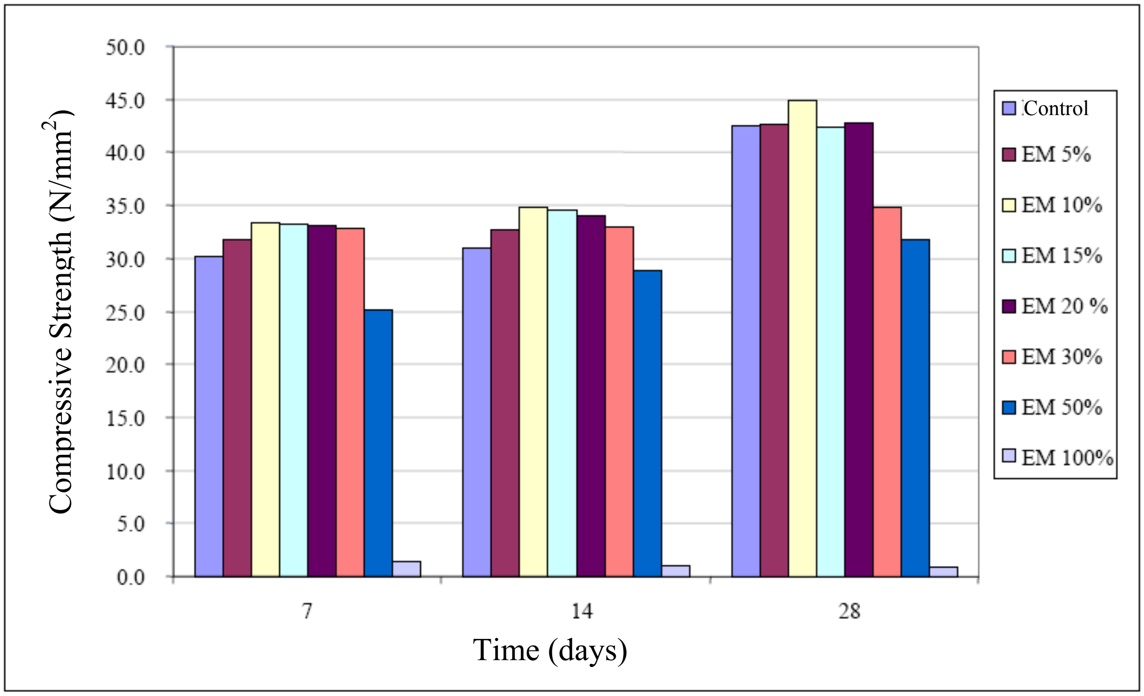

Figure 4.17: Histogram Shows Average Compressive Strength versus Time (Dry Curing).

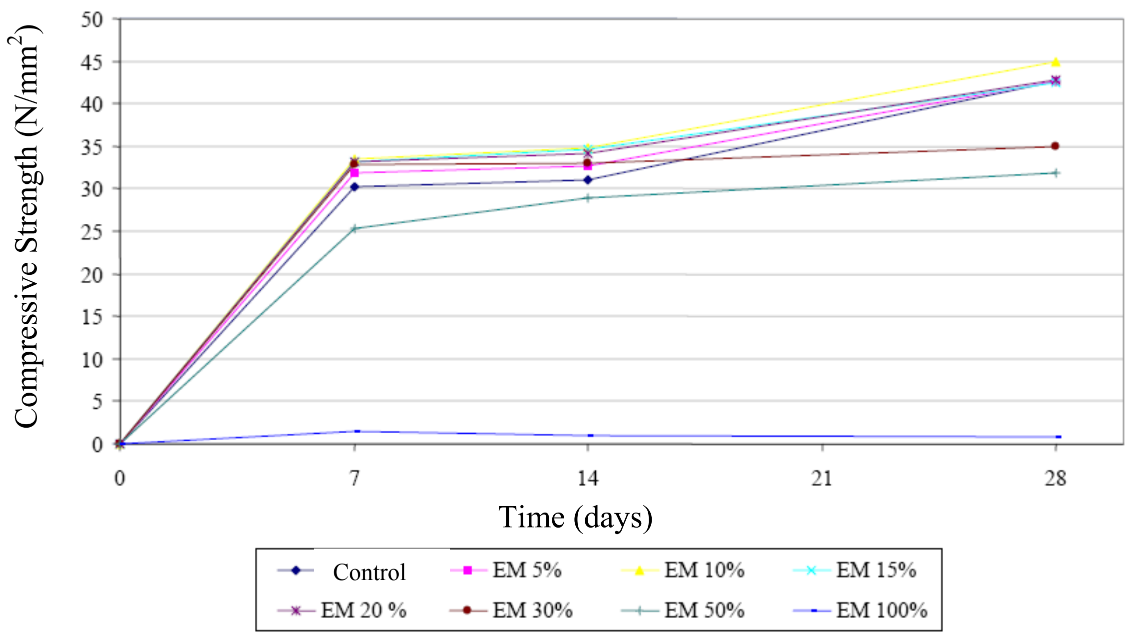

Figure 4.18: Graph Shows Compressive Strength versus Time (Dry Curing).

Referring to the graphs, the overall compressive strength of the concrete cube using wet curing method was higher than using dry curing method. The results can be explained under hydration of cement theory. The purpose of curing was to encourage the process of hydration in cement by controlling the temperature and the moisture movement from and into the concrete. More specifically, curing was to keep the concrete in a saturated state or nearly saturated state in order to let the void contained with water filled with by product of hydration of cement.

For wet curing method, the cubes were immersed in the water all the time. The cubes were able to maintain the moisture for hydration of cement. This has resulted in more C-S-H gel created from hydration process and hence, the compressive strength using wet curing method was slightly higher than concrete cube using dry curing method. The next chapter explained in detail the influence of EM in compressive strength of concrete.

4.2.7.1 Compressive Strength after 7 Days

Referring to Figure 4.19, the control specimen was recorded as 30.50 N/mm^2 by using wet curing method. Specimens added with 5%, 18.9%, 13.5%, 11.9% and 15.6% EM-AS resulted in an increment of compressive strength of 2.5%, 10%, 15% and 30% respectively compared to control specimen. For specimen of 50% EM-AS, the compressive strength slightly decreased to 26.39 N/mm^2. The compressive strength of 100% EM-AS specimen can be neglected as it is 1.02 N/mm^2. The compressive strengths of specimens range from 15% to 30% EM-AS were not in a uniform pattern. The highest compressive strength of specimen was 10% EM-AS concrete cube.

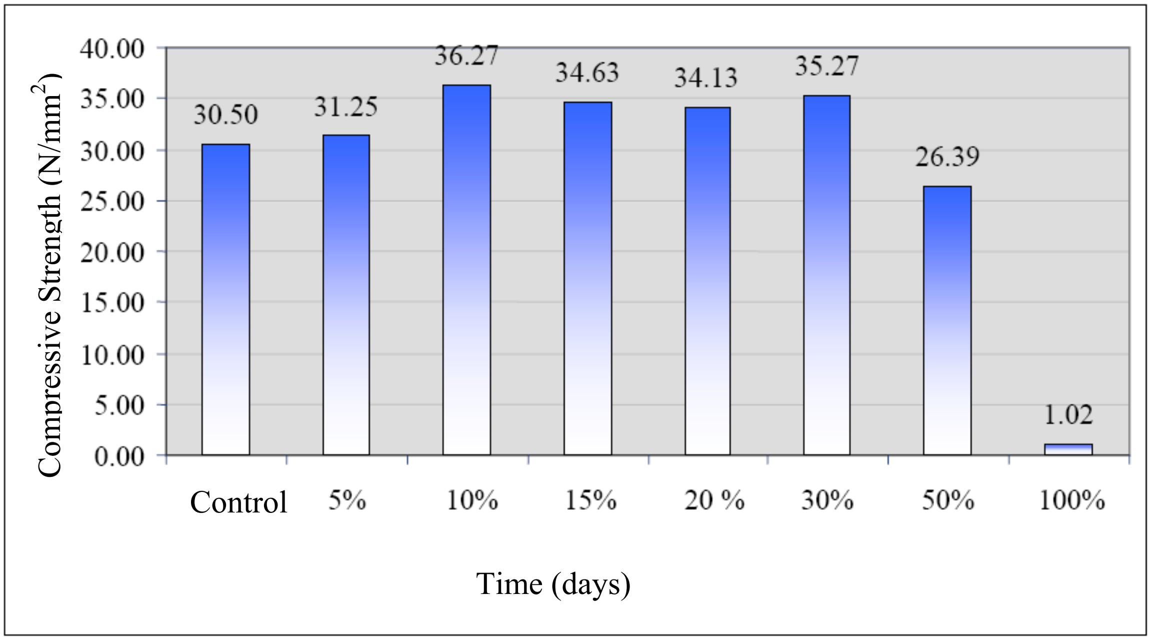

Figure 4.19: Compressive Strength of 7 days Concrete Using Wet Curing Method

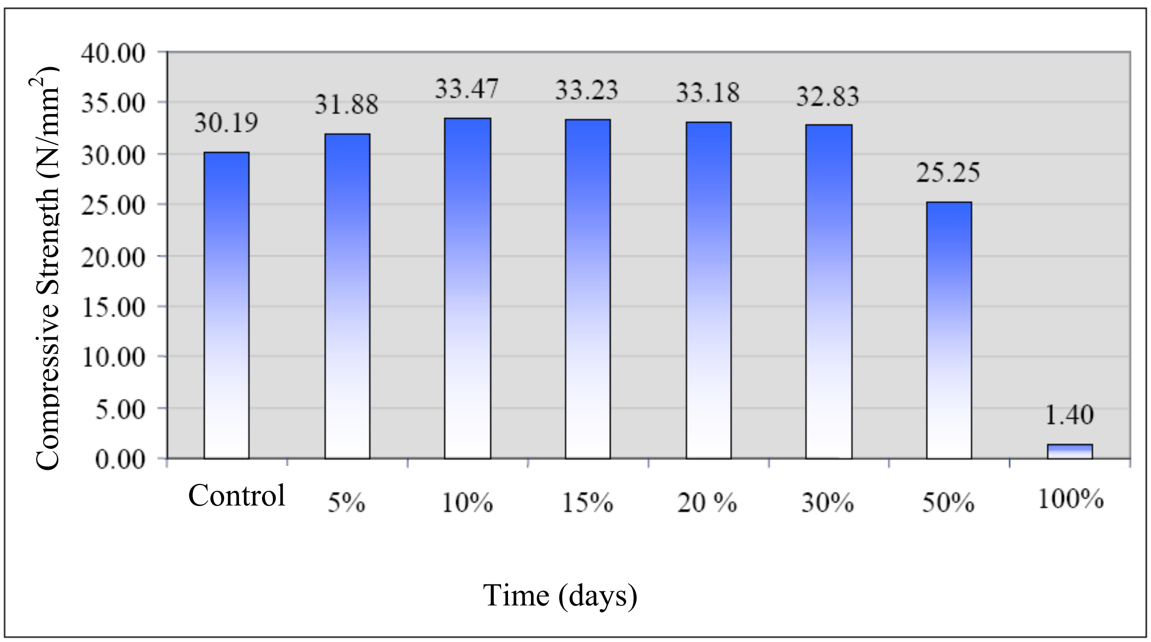

Figure 4.20: Compressive Strength of 7 days Concrete Using Dry Curing Method.

For concrete using dry curing method, the compressive strengths of the cubes were slightly lower than concrete immersed in water. Referring to Figure 4.20, the compressive strength of control cube was 30.19 N/mm^2, a lower value of 0.31 N/mm^2 than the concrete cube using wet curing method. The overall compressive strength of concrete increased when the concrete was mixed with EM except for EM-AS 50% and 100%. The strengths of specimens ranged from 10% to 30% EM-AS resulted in a slightly difference. The 10% EM-AS again achieved to be the highest of compressive strength.

4.2.7.2 Compressive Strength after 14 Days

For control concrete cube at 14 days, 32.56 N/mm^2 of compressive strength was recorded for wet curing method and it was 6.8% higher than the control concrete cubes at 7 days. The 10% EM-AS specimen is 39.33N/mm^2 which was also the highest compressive strength among the cubes. The increment of compressive strength was 8.4% and it was much higher than the 10% EM-AS specimen at 7 days. For 15% and 20% EM-AS specimens, the compressive strengths slightly increased. However for 30% EM-AS specimen, the compressive strength decreased if compared to specimens at 7 days. The decrease was 1.51N/mm^2. However, for 50% EM-AS specimen, the compressive strength indicates an increment from 26.39 N/mm^2 at 7 days to 29.21 N/mm^2 at 14 days.

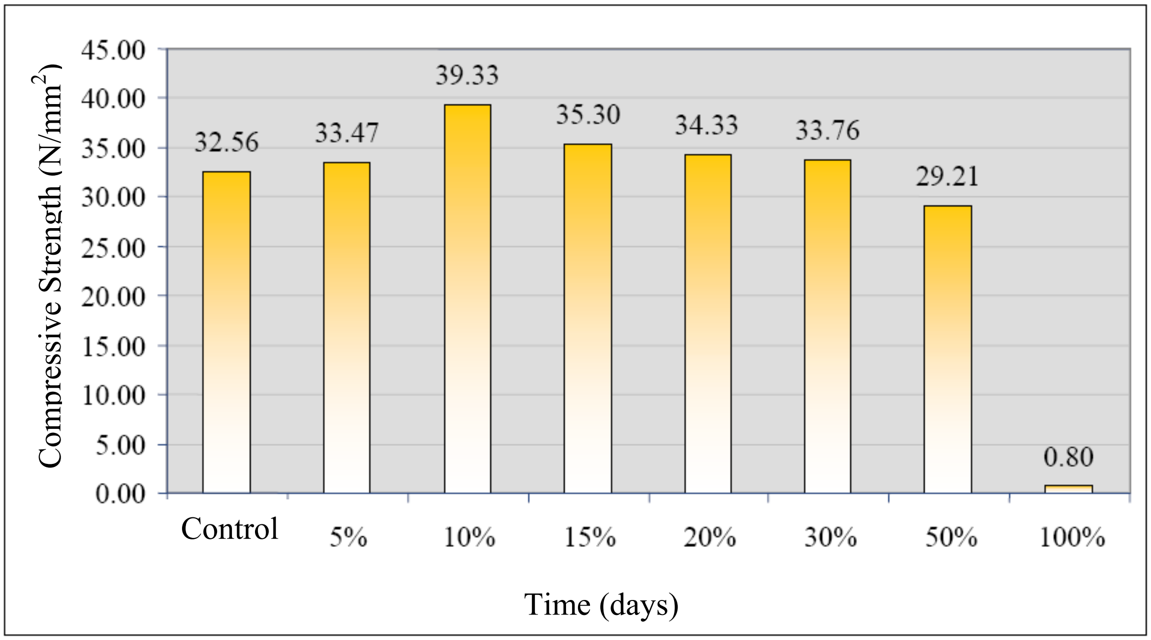

Figure 4.21: Compressive Strength of 14 days Concrete Using Wet Curing Method.

For dry curing method, the compressive strengths of all specimens have a uniform pattern and it was shown in Figure 4.22. The 10% EM-AS again was recorded as the highest compressive strength with 34.83 N/mm^2. The value was slightly lower than the wet method at the same age. For 100% EM-AS, the compressive strength of the cube not achieved any strength although the age of the concrete cube is older. Further explanation will be discussed in the latter chapter.

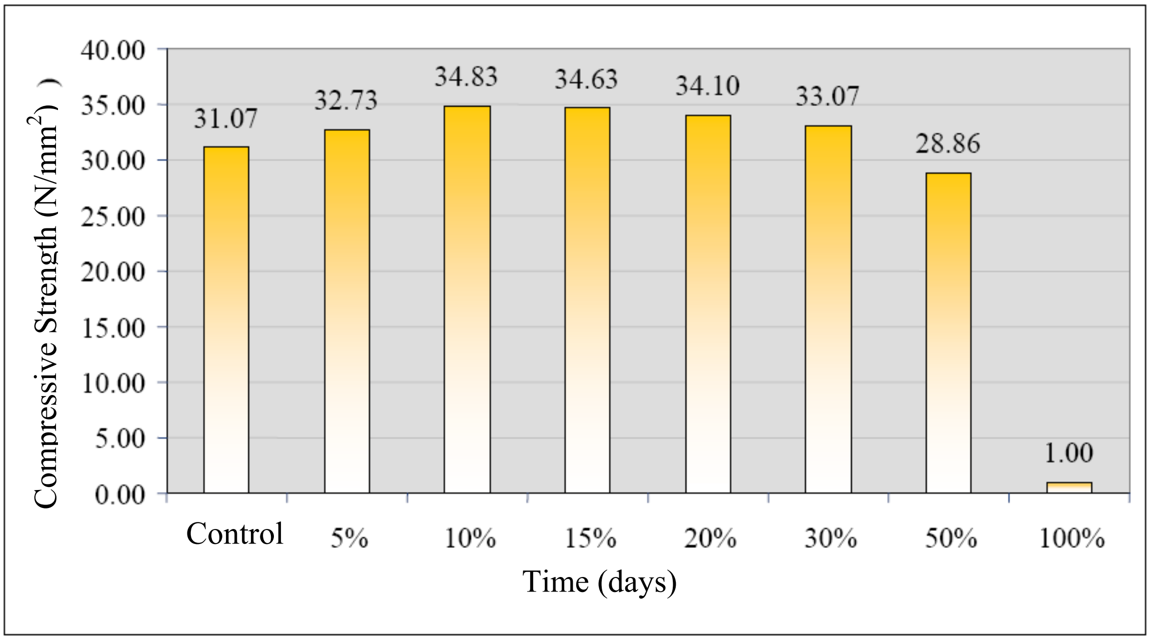

Figure 4.22: Compressive Strength of 14 days Concrete Using Dry Curing Method.

4.2.7.3 Compressive Strength after 28 Days

Referring to Figure 4.23, the compressive strength of concrete at 28 days was recorded as the highest value. For control specimen using wet curing method, the compressive strength of the concrete was 42.73 N/mm^2 and it was higher than the characteristic strength of the concrete which was 30 N/mm^2. It was obvious that the specimens with EM content at 28 days achieved a higher of compressive strength than at 14 days. The 10% EM-AS achieved compressive strength of 45.30 N/mm^2 and it was higher than the target mean strength, which was 43 N/mm^2.

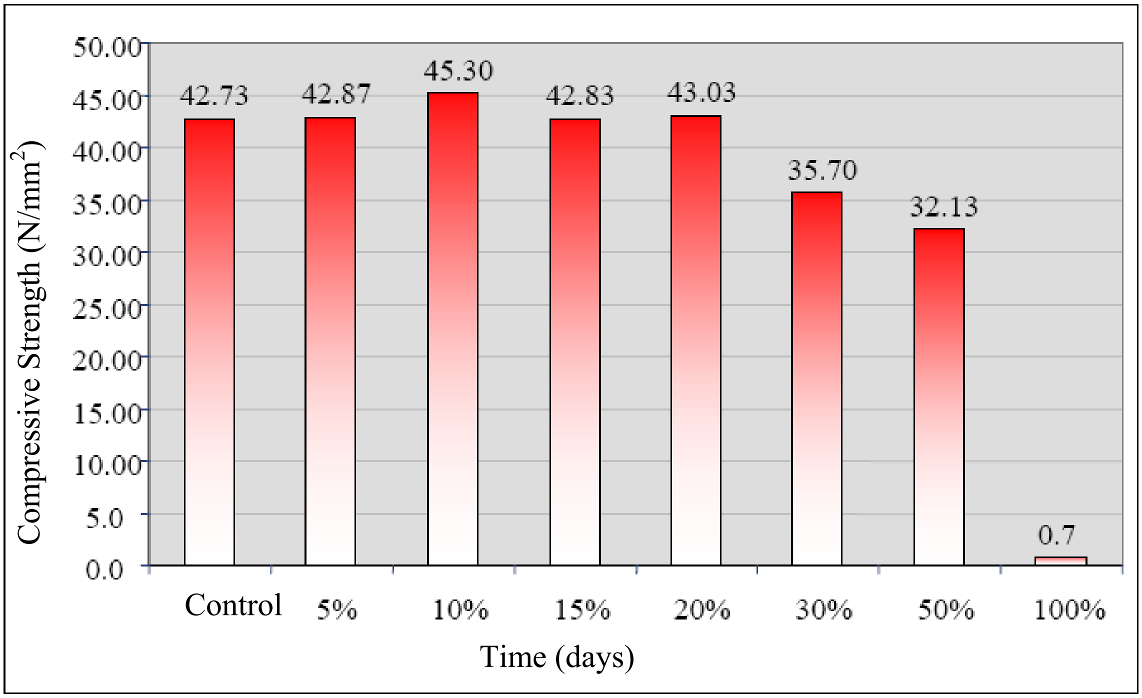

Figure 4.23: Compressive Strength of 28 days Concrete Using Wet Curing Method.

The histogram of compressive strength of specimens using dry curing method tallied with the specimens using wet curing method. However, the pattern of the graph was not in a consistent trend as at 7 days and at 14 days. The compressive strengths of the concrete started to decrease at 20% to 100% EM-AS. The 10% EM-AS concrete cube again achieved the highest compressive strength. It can be concluded that the admixture of EM can improve the compressive strength with content not more than 20% of water.

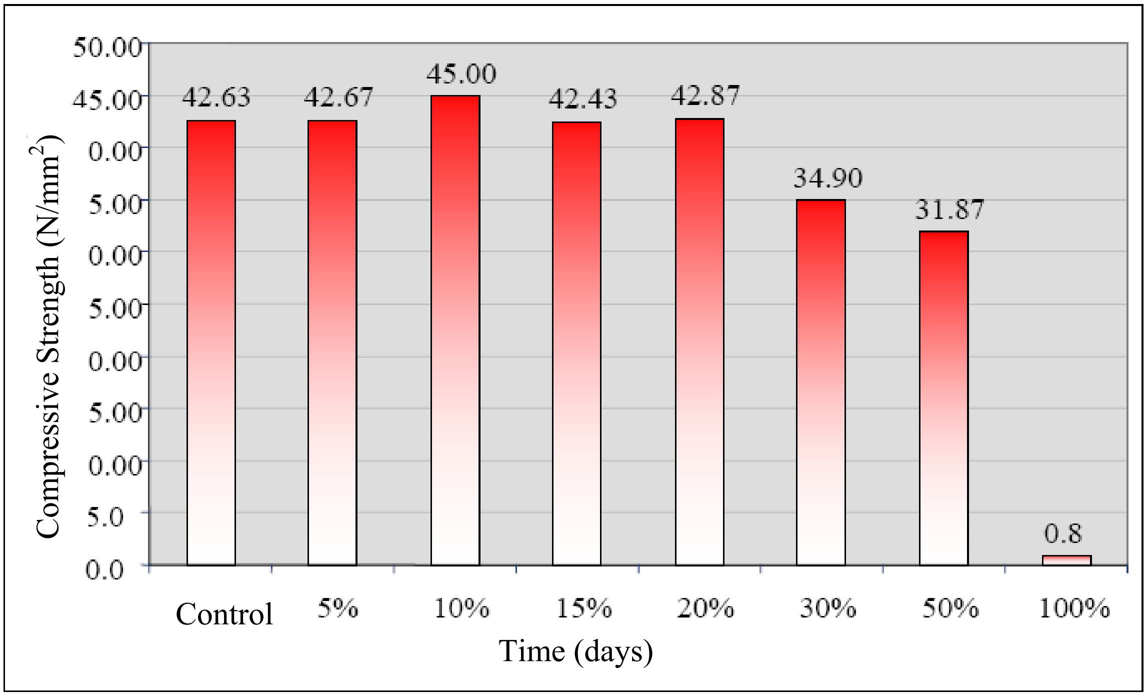

Figure 4.24: Compressive Strength of 28 days Concrete Using Wet Curing Method.

4.2.7.4 Early strength of the concrete

All specimens added with EM content showed a higher early compressive strength than control specimen. This can be explained EM in concrete may increase the rate of hydration and produce more by product of cement in early age. When more cementing material is produced to fill the void in the concrete at the early age, the early compressive strength is increased. This characteristic is suitable for precast construction and prestressed concrete.

The results showed 10% EM-AS achieved highest strength than the control concrete and others mixture. This may result to the water ratio of the mixture was the most optimum ratio. The low water cement ratio of relatively increase the strength of the concrete. The reason is no excessive moisture present in the concrete which may cause void. Excessive moisture may evaporate and cause void in the concrete, and thus may result high porosity in the concrete. Strictly speaking strength of the concrete is influenced by the volume of all voids in concrete: entrapped air, capillary pores, gel pores and entrained air, if present. Therefore, dense concrete produced higher compressive strength.

Beside the influence of EM in concrete, other factors like the method of compaction fresh concrete may contribute also the early strength of the concrete. The procedures of compaction were in accordance to the standard. The compaction was perfectly done and the concrete were really compacted uniformly. This can be proved that the there was no honey comb or void at the surface of the concrete.

In addition, the condition of the material has been used may also influence the early strength of the concrete. The aggregate is dried by air dry method. It is important to maintain surface saturated dry of the aggregate to avoid the absorption of excessive moisture which will affect the strength as discussed earlier.

In this testing, not all the aggregate in surface saturated dry because no further study on the quality of material.

4.2.7.5 Incremental Rate of the Concrete Strength

The ratio of the compressive strengths at the age of 7 days and 14 days over compressive strength at the age of 28 days are shown in Table 4.8. The table considers the factors of wet curing and dry curing method. For control cube, that the average ratio of compressive strength at 7 days over compressive strength at 28 days is 0.714 for wet curing and 0.762 for dry curing.

For concrete contain EM, the increment of 5% EM-AS for both curing method is the most obvious. This shows the present of small amount EM in water give positive effect to the concrete strength. The incremental rate started to decrease at 30% EM-AS as the ratio approaching value 1.0 for both curing method.

Obviously, all concrete added with EM showed lower incremental rate compare to the control concrete. The reason is the control cube achieved having a higher strength at the early age but lower strength at 28 days. The fineness of the cement may increase the hydration rate as more total surface area of cement is available for hydration. Thus, the early strength of the concrete is developed.

Table 4.8: Average Ration of Compressive Strength over Age 28 days

Percentage of EM (%)	Compressive Strength Ratio			
	7/28		14/28	
	Wet curing	Dry curing	Wet curing	Dry curing
Control	0.714	0.708	0.762	0.729
5%	0.729	0.747	0.781	0.767
10%	0.801	0.744	0.868	0.774

15%	0.809	0.783	0.824	0.816
20%	0.793	0.774	0.798	0.795
30%	0.988	0.941	0.946	0.948
50%	0.821	0.792	0.910	0.906
100%	1.378	1.609	1.081	1.149

The concretes with highly EM content have no compressive strength. This may result to insufficient of moisture, namely H_2O for hydration process. The chemical composition in EM does not studied in detail. According to the understanding of the literature review, the EM is in acidic condition and may neutralize the alkali of cement which may cause the no bonding in cement. Another reason which may cause no compressive strength is the present of EM may reduce the moisture and thus affect the hydration of cement and cause low strength of the concrete.

4.2.7.6 The physical appearance of the concrete cube

The appearance of concrete mixed with low amount of EM does not differ much to the control cube. Referring to Figure 4.25 and 4.26, the appearance is similar to the control cube. The surface of concrete cubes mixed with EM is smooth and dense with no honey comb.

Figure 4.25: The Appearance of 20% EM-AS Concrete Cube

Figure 4.26: The Appearance of 30% EM-AS Concrete Cube

For concrete cube mixed with 50% EM-AS and 100% EM-AS, the appearance of the concrete were very difference than the others. Referring to Figure 4.27, the concrete cube at 7 days was in wet condition and was not set like other concrete. The edge of the concrete is fragile and seems like no bonding. In a normal condition, the by product of cement hold the mixture together. Obviously, there is no strength and no boding effects in the concrete.

The reason concrete looks like wet and unset because the rate of hydration is slow. The hydration may not happen in the 7^{th} day. The second reason may cause by the new product from the chemical reaction of EM and cement. Referring to Figure 4.28, the surface of the concrete has a brownish color material and it seemed like fungus. The appearance has caused low aesthetic value and the by product of the chemical reaction did not provide any contribution to strength.

Figure 4.27: The Appearance of 50% EM-AS Concrete Cube

Figure 4.28: The Appearance of 100% EM-AS Concrete Cube

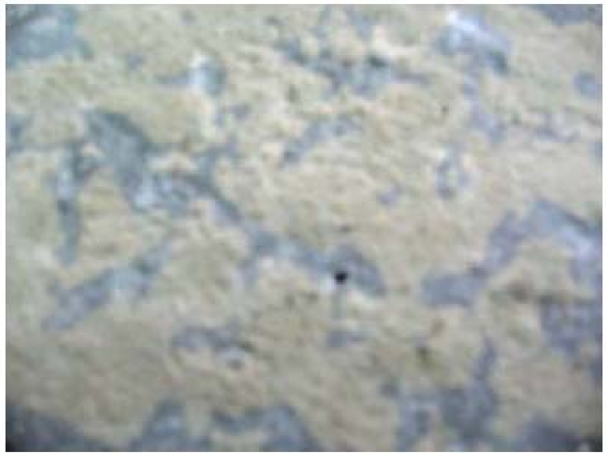

Figure 4.29: The Closer Look at the Surface of 100% EM-AS Concrete Cube

4.2.7.7 The failure pattern

When the load reached maximum, the concrete cube failed at certain angle. Referring to Figure 4.30, Figure 4.31 and Figure 4.32, the concrete with 50% EM-AS have spalling problem at the edge of the concrete. This showed that there was no bonding in the matrix and it was fragile. For concrete with low content EM-AS, the microstructure of the concrete cubes was dense and the failure has an obvious plane.

Figure 4.30: The Physical Appearance after Failure.

Figure 4.31: The Physical Appearance before the Compression Test.

Figure 4.32: Spalling Happened at the Edge of the Concrete Cube before Testing.

4.2.8 Compressive Strength of Mortar Cubes

The third phase of study was done on mortar cubes. In this phase, the scope will be smaller by choosing five types of cubes only. It covered the study on 0%, 5%, 10%, 20% and 30% EM –AS mortar cubes. There were no cubes containing 50% and 100% EM –AS as they did not produce good results in the first phase. The work flow in this phase was similar to the first one. In this study, there were 30 mortar cubes with different EM – AS percentages. All cubes were cured by dry curing as continuity from the first phase of study. The standard testing days for mortar cubes were after 3 and 7 days. The load cell was used to determine the compressive strength of the cubes.

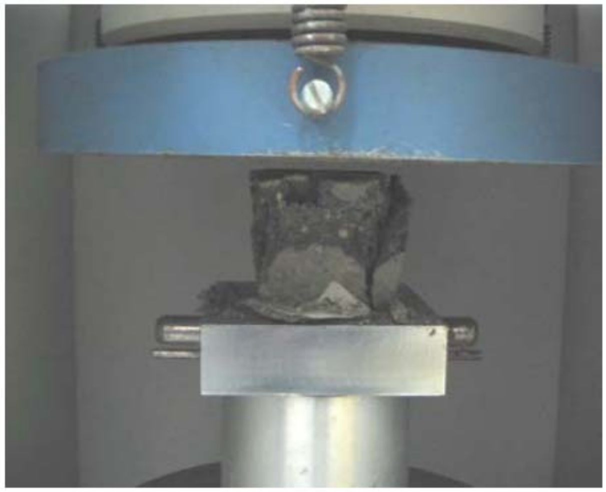

Figure 4.33: Compression Test

Figure 4.34: Failure Pattern for Mortar Cube

Figure 4.35: Physical Appearance of Mortar Cube Added with Different Proportion of EM-AS.

4.2.8.1 Average compressive strength

The results from the compression test were summarized in Table 4.9. The load value was appeared at the monitor screen. The time when the cube failed, the reading at the monitor screen was taken as the maximum load that it can withstand. In order to obtain the compression load, the maximum load was divided with the surface are

Table 4.9: Average Compressive Strength of Mortar Cubes

EM - AS percentage (%)	Average compressive strength (N/mm^2)	
	After 3 days	After 7 days
control	18.48	26.61
5	23.00	31.12
10	20.16	27.36
20	13.65	20.67
30	13.43	18.60

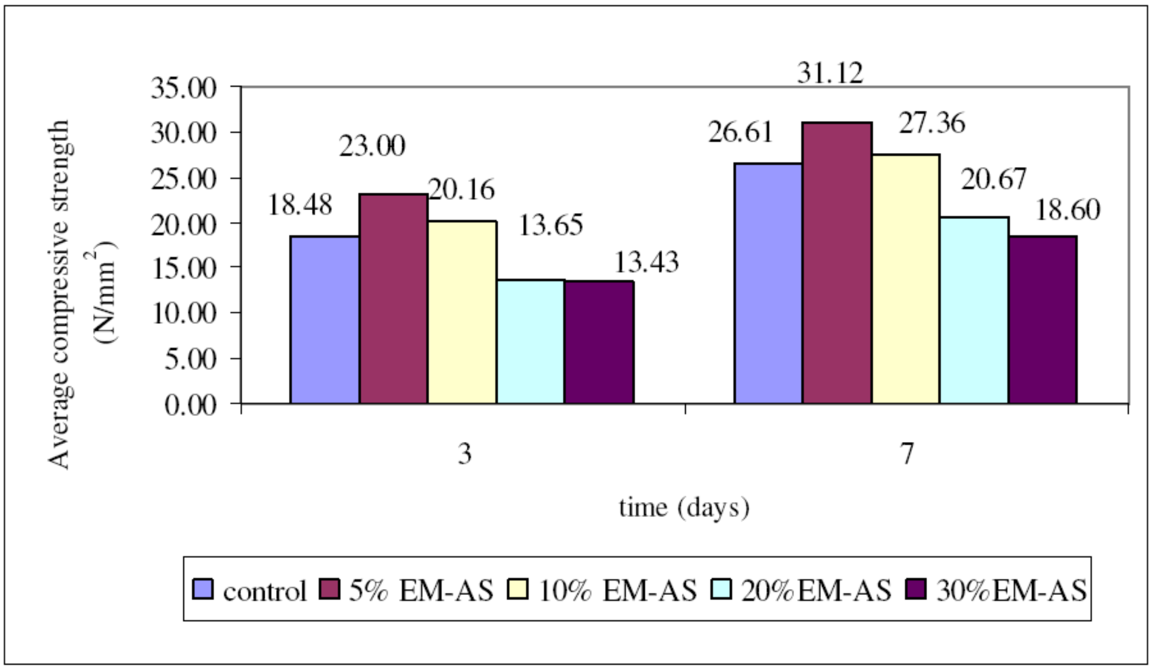

Figure 4.36: Histogram of Average Compressive Strength versus Time

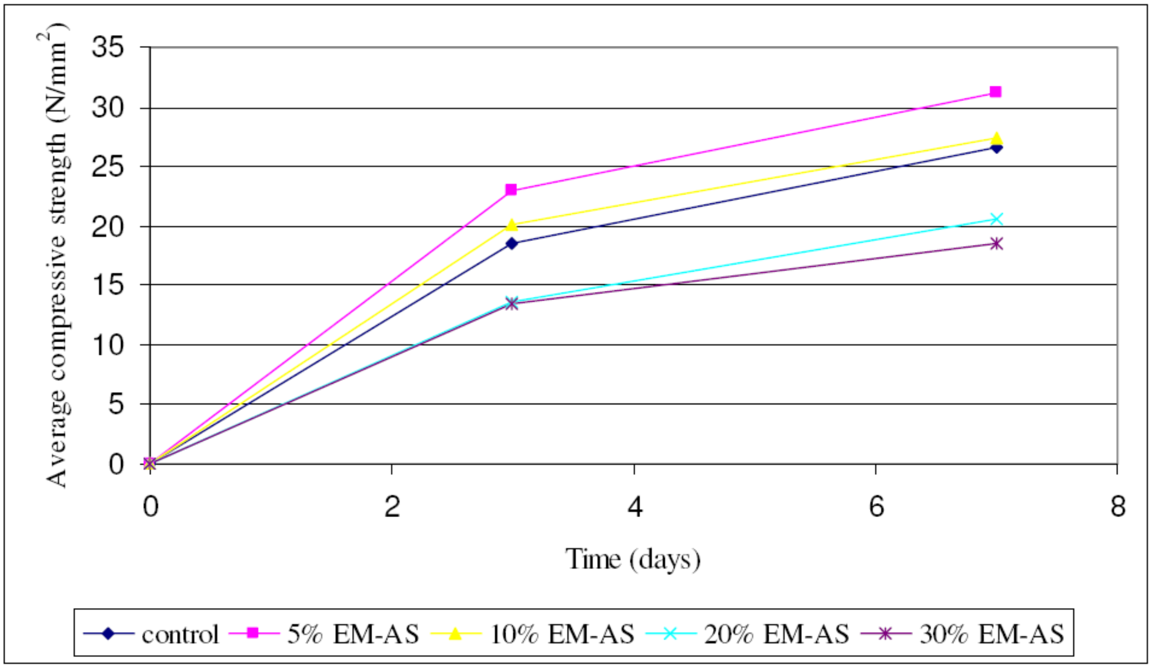

Figure 4.37: Graph of Average Compressive Strength versus Time

4.2.8.2 Compressive Strength after 3 days

The results for compressive strength of the cubes after 3 days are shown in Table 4.10 and Figure 4.38 below:

Table 4.10: Average Compressive Strength of Mortar Cubes after 3 days

EM-AS percentage (%)	Compressive Load (kN)				Average compressive strength (N/mm^2)
	Sample 1	Sample 2	Sample 3	Average	
0	51.3	40.5	46.8	**46.20**	**18.48**
5	53.9	59.7	58.9	**57.50**	**23.00**
10	51.8	50.1	49.3	**50.40**	**20.16**
20	31.4	36.3	34.7	**34.13**	**13.65**
30	34.8	33.6	32.3	**33.57**	**13.43**

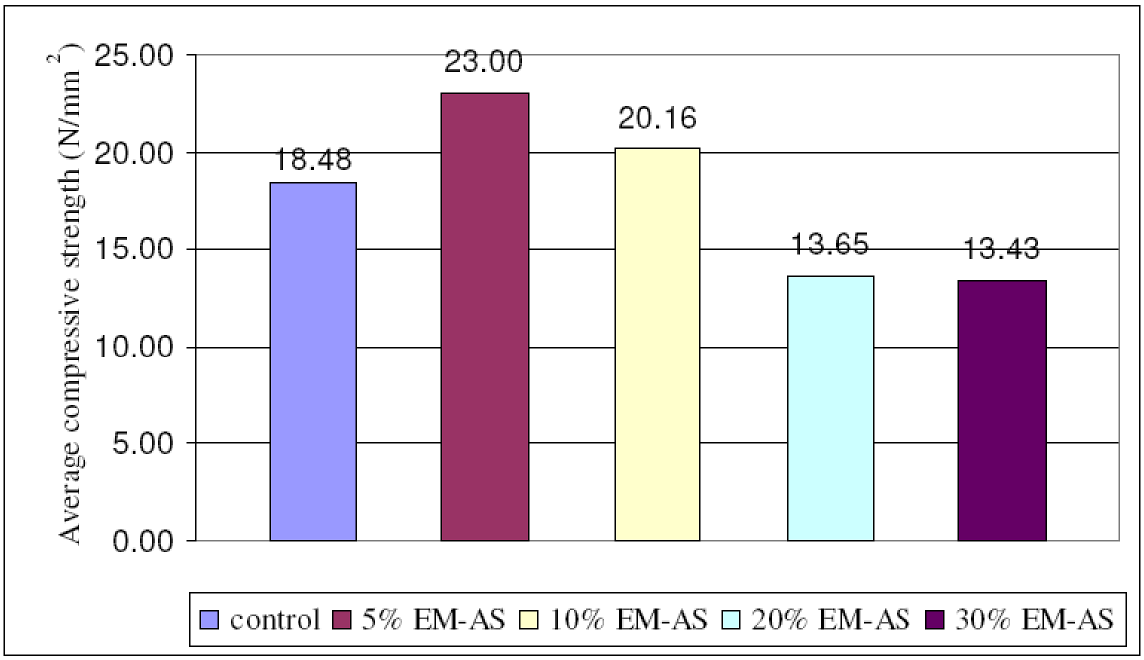

Figure 4.38: Histogram of Average Compressive Strength after 3 days

From the histogram, it was known that the highest peak was obtained from mortar cubes with 5% EM – AS. The result was different from cement cubes. In cement cubes, the highest peak was from 10% EM – AS. Therefore, the optimum percentage of 71 EM – AS in cement and mortar was different. In mortar, there were sands that can increase the bonding. Therefore, the maximum compressive strength was greater than cement cubes. In mortar cubes, only cubes with 5% and 10% EM – AS recorded higher values than control.

The increment for cubes with 5% and 10% EM – AS is 24.46% and 9.09% respectively. The increment was calculated based on the control value. The strength started to decrease at 20% EM – AS. The minimum compressive strength for mortar after 3 days is 15.2 N/mm2 (Mat Lazim, 1997) [10]. Eventually, the only cubes that exceeded the minimum limit were; control, 5% EM – AS and 10% EM – AS.

4.2.8.3 Compressive Strength after 7 days

The results for compressive strength of the mortar cubes are tabularized in the following Table 4.11 and Figure 4.39:

Table 4.11: Average Compressive Strength of Mortar Cubes after 7 days

EM-AS percentage (%)	Compressive load (kN)				Average compressive strength (N/mm^2)
	Sample 1	Sample 2	Sample 3	Average	
0	63.4	62.5	73.7	**66.53**	**26.61**
5	82.5	79.2	71.7	**77.80**	**31.12**
10	68.7	66.4	70.1	**68.40**	**27.36**
20	52.6	51.6	50.8	**51.67**	**20.67**
30	41.8	46.8	50.9	**46.50**	**18.60**

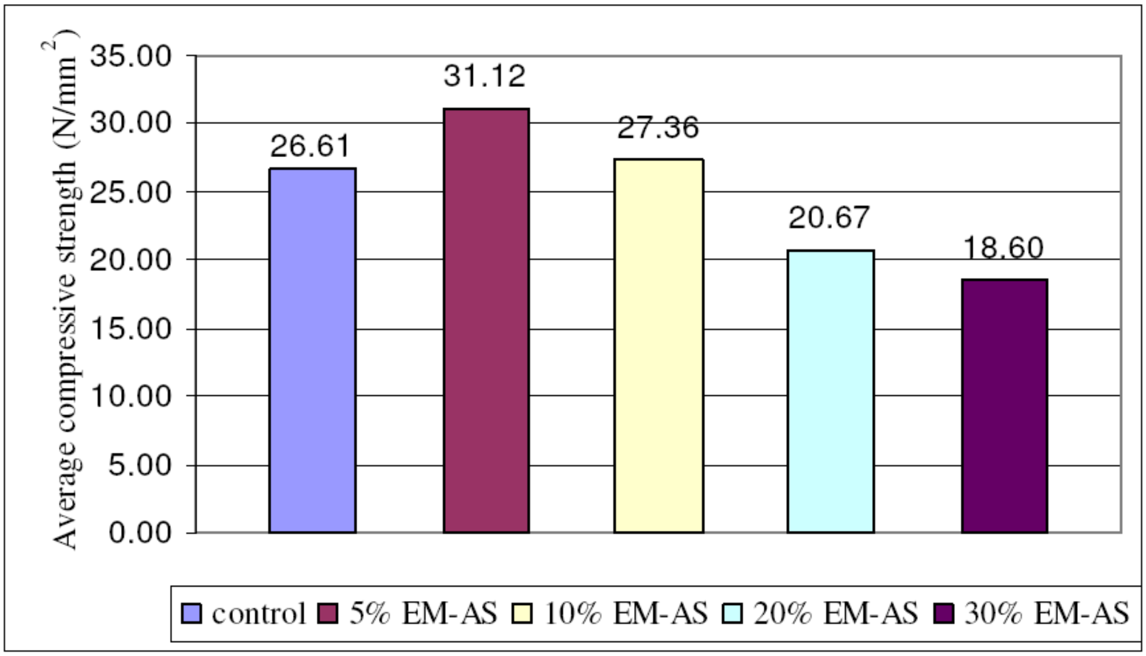

Figure 4.39: Histogram of Average Compressive Strength after 7 days

According to Mat Lazim, the minimum compressive strength for mortar cubes after 7 days is 23.4 N/mm^2. The pattern of the strength value was similar to value after 3 days. The optimum EM - AS percentage for mortar mix was 5% from the water content.

The strength for cubes with 5% EM – AS increased 4.51% while the 10% EM – AS only increased 2.82%. After 7 days, the strength increment is small compared after 3 days. It shows that cubes with 5% and 10% EM – AS gained most of the strength at early age. The usage of EM in mortar is proven efficient in increasing the compressive strength. However, the percentage of EM does influence the strength. It is encouraged to use EM in architectural works such as brickworks and plastering.

4.2.9 Environmental Effects

In this chapter, the environmental effects on the concrete added with optimum amount of EM, namely 10% (from the previous test) are tested. The materials used in the test are considered to have the same properties as in previous test. The result of the testing environments and the compressive strength of concrete cube test is recorded. Statistical analysis will be performed on the results to produce outputs which are more organized, summarized and systematic. After that, analysis on the results will be carried out to find out the answers of this research.

The pH of each prescribed environment is measured to be a reference to check how the pH of the environments affects the performance of concrete. Then, the results of the compressive strength of concrete cube tests after 7, 28 and 91 days are recorded. Analysis on the results is made to provide answers to the research.

4.2.9.1 pH Of The Prescribed Environments

A normal concrete usually has a pH around 12 when the EMAS must have pH less than 4 before it can be used to mix with concrete. When these two different materials; one is alkaline and another acidic, are mixed together, as according to the theory, reaction called neutralization occurs and produces salt. It is expected that it was the salt that had contributed to the increment of compressive strength of concrete containing EM.

In this research, the concrete cubes were exposed to seven prescribed environments, each with its unique complex composed of various physical, chemical and biotic factors. Any factor from the environment could possibly give different influence on the performance of concrete containing EM in its own way. To reduce the scope, the pH of each environment was measured to be the reference to check whether there was a relationship between the pH of the environments and the compressive strength of concrete or not. Table 4.12 below shows the pH value of each environment except for outdoor and indoor environments.

Table 4.12: pH of the Seven Prescribed Environments

Environment	**HCL**	**SOIL**	**WWTR**	**SWTR**	**NaOH**	**OUTDR**	**INDR**
pH	2.0	6.3	7.3	8.8	12.0	-	-

4.2.9.2 Compressive Strength after 7 Days

The compressive strengths of the concrete cubes containing EM and the controls (concrete cubes without EM) after 7 days are shown in Table 4.13 and Figure 4.40.

The difference in strength was only considered to be distinct when it had at least 10 % difference when compared to the strength of cubes under the indoor environment. Otherwise, the difference was considered insignificant and negligible. Among the concrete cubes containing EM, when they were compared to the strength of the cubes exposed to the indoor environment; 40.3 N/mm^2 (which at the same time functioning as the control of environments), their strengths did not differ much and ranged from 39.0 N/mm^2 to 41.3 N/mm^2 except for the cubes exposed to outdoor environment; had a relatively lower strength at 38.0 N/mm^2.

Table 4.13: **C**ompressive Strength of Concrete Containing EM and the Control after 7 days

Environment	7-day Compressive Strength (N/mm^2)		Percentage Of Difference As Compared To Control (%)
	EM	Control	
HCL	41.2	36.0	14.35
SOIL	40.8	35.0	16.67
WWTR	41.3	37.2	11.21
SWTR	39.0	30.8	26.49
NaOH	39.2	28.7	36.63
OUTDR	38.0	37.5	1.33
INDR	40.3	37.7	7.08

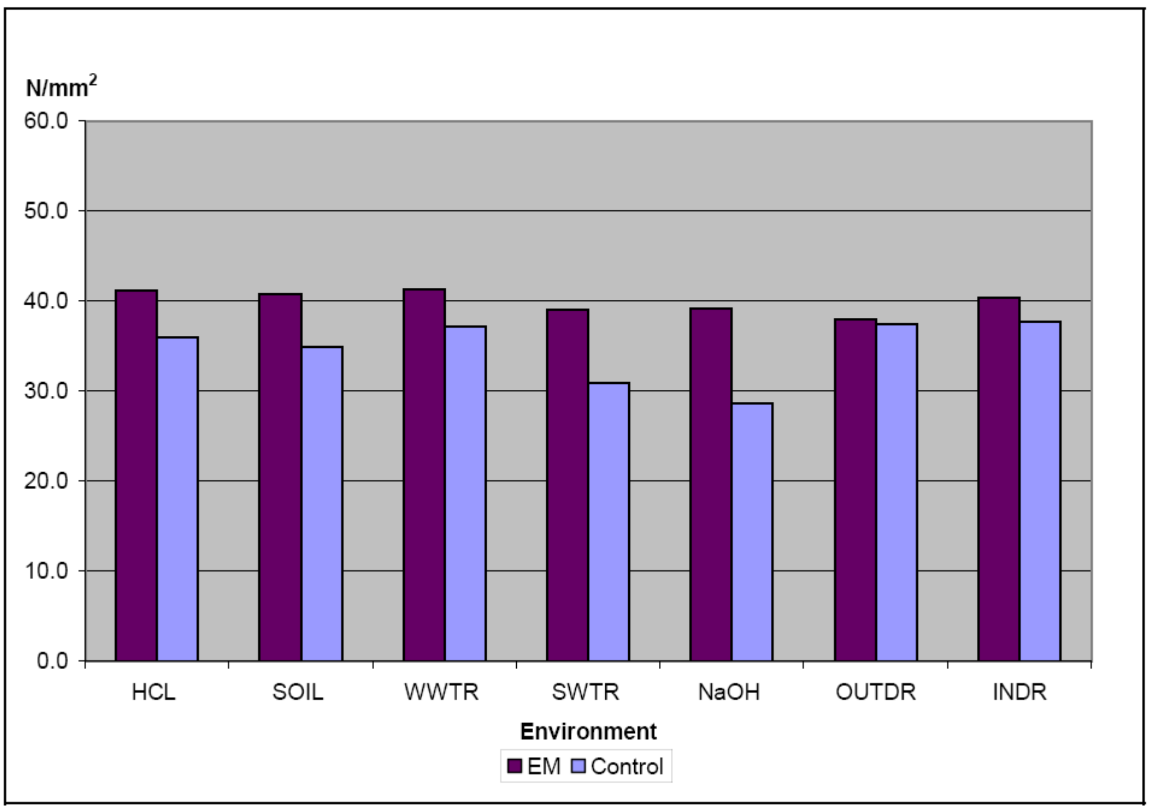

Figure 4.40: **C**ompressive Strength of Concrete Containing EM and the Control after 7 days

Among the normal concrete cubes (the controls which is without EM), when they were compared to the strength of the cubes exposed to the indoor environment; 37.7 N/mm^2 (which also at the same time functioning as the control of environments), the difference of strengths was slightly obvious, ranging from 35.0 N/mm^2 to 37.7 N/mm^2 except for the cubes exposed to marine and alkaline liquids; each had a distinctly lower strength at 30.8 N/mm^2 and 28.7 N/mm^2, respectively.

By comparing the concrete cubes containing EM to the controls, the strengths of the concrete cubes containing EM were evidently higher than the controls, under all seven types of environments. The best improvement occurred at the concrete cubes containing EM under the alkaline liquid which was 36.63% higher in strength than the controls. The lowest improvement was 1.33% which belonged to the cubes of outdoor environment.

4.2.9.3 Compressive Strength After 28 Days

The compressive strengths of the concrete cubes containing EM and the controls (concrete cubes without EM) after 28 days are shown in Table 4.14 and Figure 4.41. Among the concrete cubes containing EM, when they were compared to the strength of the cubes exposed to the indoor environment; 43.0 N/mm^2 (which at the same time functioning as the control of environments), again, their strengths did not differ much and ranged from 42.2 N/mm^2 to 44.0 N/mm^2 except for the cubes exposed to outdoor environment; which had a relatively lower strength after 7 days but was now 45.3 N/mm^2; relatively the highest strength after 28 days.

Among the normal concrete cubes (the controls which is without EM), when they were compared to the strength of cubes exposed to indoor environment; 37.8 N/mm^2 (which also at the same time functioning as the control of environments), the difference of strengths was slightly obvious, ranging from 37.0 N/mm^2 to 40.7 N/mm2 except for the cubes exposed to soil and alkaline liquids; each had a distinctly higher strength at 42.3 N/mm^2 and 42.2 N/mm^2, respectively.

As a whole, by comparing the concrete cubes containing EM to the controls, the strengths of the concrete cubes containing EM were evidently higher than the controls, under all types of environments except for the alkaline liquid; which both the concrete containing EM and the normal concrete had an equal strength. The best improvement occurred at the concrete cubes containing EM under the outdoor environment which was 16.24% higher in strength than the controls. The lowest improvement was 0% which belonged to the cubes of alkaline liquid.

Table 4.14: Compressive Strength of Concrete Containing EM and the Control after 28 days.

Environment	**28-day Compressive Strength (N/mm^2)**		**Percentage Of Difference As Compared To Control (%)**
	EM	**Control**	
HCL	42.5	40.7	4.51
SOIL	44.0	42.3	3.94
WWTR	42.5	39.0	8.97
SWTR	42.7	37.0	15.32
NaOH	42.2	42.2	0.00
OUTDR	45.3	39.0	16.24
INDR	43.0	37.8	13.66

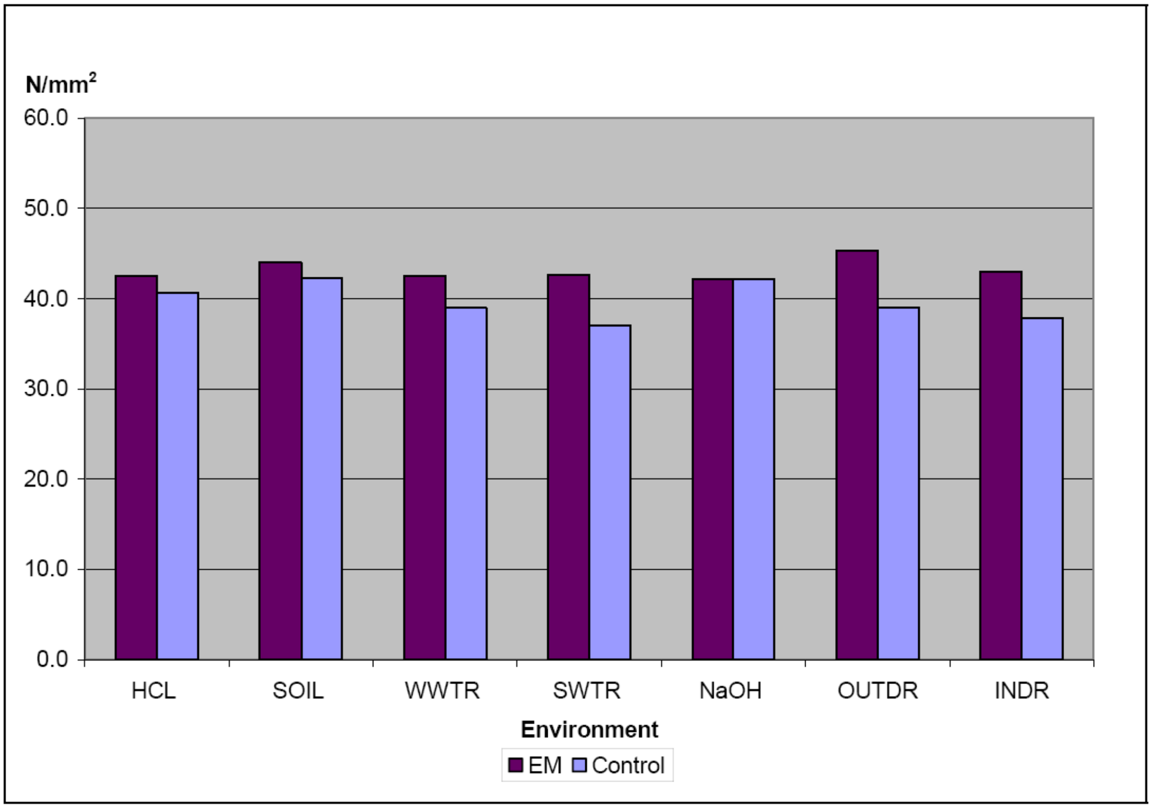

Figure 4.41: **C**ompressive Strength of Concrete Containing EM and the Control after 28 days.

4.2.9.4 Compressive Strength After 91 Days

The compressive strengths of the concrete cubes containing EM and the controls (concrete cubes without EM) after 91 days are shown in Table 4.15 and Figure 4.42. Among the concrete cubes containing EM, when they were compared to the strength of the cubes exposed to the indoor environment; 46.8 N/mm^2 (which at the same time functioning as the control of environments), this time, their strengths showed a higher degree of distinction. The highest strength was recorded at the alkaline liquid which was 54.3 N/mm^2 while the lowest strength fell to the sea water; 41.7 N/mm^2.

Among the control specimens (the controls which is without EM), when they were compared to the strength of the cubes exposed to the indoor environment; 45.2 N/mm^2 (which also at the same time functioning as the control of environments), the difference of strengths also showed a higher degree of distinction. The highest strength was recorded at the alkaline which was 48.0 N/mm^2 while the lowest strength fell to the acidic; 34.2 N/mm^2.

After 91 days, not all the concrete cubes containing EM had higher strength than the controls anymore. Under the effect of sea water, the controls gave a higher strength than the concrete containing EM. As a result, the best improvement occurred at the concrete cubes containing EM under the acidic liquid which was 31.22% higher in strength than the controls. Instead of having a lowest improvement, the concrete cubes containing EM under the marine environment showed deterioration in strength as much as 11.03% by comparison to the controls.

Table 4.15: Compressive Strength of Concrete Containing EM and the Control after 91 days

Environment	**91-day Compressive Strength (N/mm^2)**		**Percentage Of Difference As Compared To Control (%)**
	EM	**Control**	
HCL	44.8	34.2	31.22
SOIL	48.5	41.2	17.81
WWTR	-	-	-
SWTR	41.7	46.0	-9.42
NaOH	54.3	48.0	13.19
OUTDR	50.8	47.8	6.27
INDR	46.8	45.2	3.69

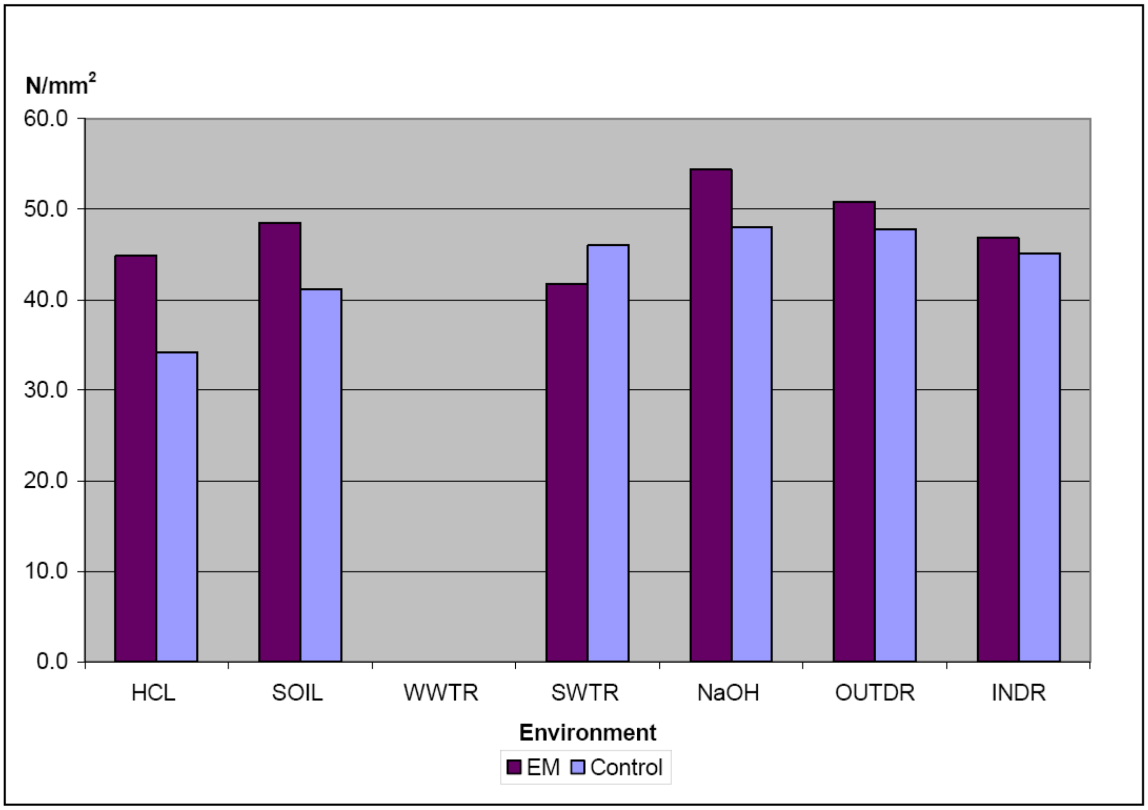

Figure 4.42: Compressive Strength of Concrete Containing EM and the Control after 91 days

4.2.9.5 Effects Of EM On The Performance Of Concrete

To find out how EM affected the performance of concrete, bar charts in Figure 4.40, Figure 4.41 and Figure 4.42 at the previous sections and another new bar chart in Figure 4.43 were graphically analyzed. Apparently, the use of EM in the concrete had increased its compressive strength in almost all ages and environments except for one and only case which the concrete containing EM showed lower strength as compared to the control after 91 days under the marine environment. Anyway, changes of the performance of concrete containing EM were observed age by age in the following.

After 7 days and also 28 days, as seen in Figure 4.36 and Figure 37, all concrete cubes containing EM under all environments developed their strengths at a considerably consistent trend and the range of the highest and the lowest strengths was slight. At this point, the effect of using EM in concrete seemed to enable the concrete containing EM to develop its strength steadily, no matter what kind of environment the concrete was in. However, for the normal concrete cubes, the trend of strength development was less consistent and there was an obvious gap between the highest and lowest strengths. Therefore, it was a sign showing that without the use of EM in concrete, the environments had started to exhibit their effects and disturbed the strength development of normal concrete.

Somehow after a considerably long term, after 91 days, the effects of the environments had been prolonged and became magnified. For concrete cubes containing EM under all environments now had a very clear difference. The same also went to the normal concrete. Yet, the use of EM in concrete still showed an overall better performance; the concrete cubes containing EM had higher strength than the controls except for the marine environment.

Conclusively, one of the effects of EM on the performance of concrete is to increase the compressive strength of concrete. One of the expected factors of the improvement of strength is expected to be the biochemical reaction that occurs between the alkaline cement paste with the acidic EM-AS to produce a new and yet-unidentified substance. It is expected that the new substance having property and behavior similar to pozzolanic materials, will later fill up the voids in the concrete and strengthen the internal bonding.

Another speculation is that instead of the EM inside the concrete reacts with the cement paste, the EM actually does not have any reaction but use up the air inside the concrete for its aerobic activities. When the internal air is used by the EM living inside the concrete, the total volume of air voids will become lesser and finally the concrete becomes denser and then exhibits higher compressive strength. However, when the air is all used up and the EM begins to turn into anaerobic condition, this will raise up questions like: “When the EM in the concrete is in anaerobic condition, is there any effects on the concrete and is it different than the effects when the EM is in aerobic condition?”. Again, more researches are needed to confirm the actual answers.

One thing is for sure for the time being, which is the use of EM can really improve the compressive strength of concrete.

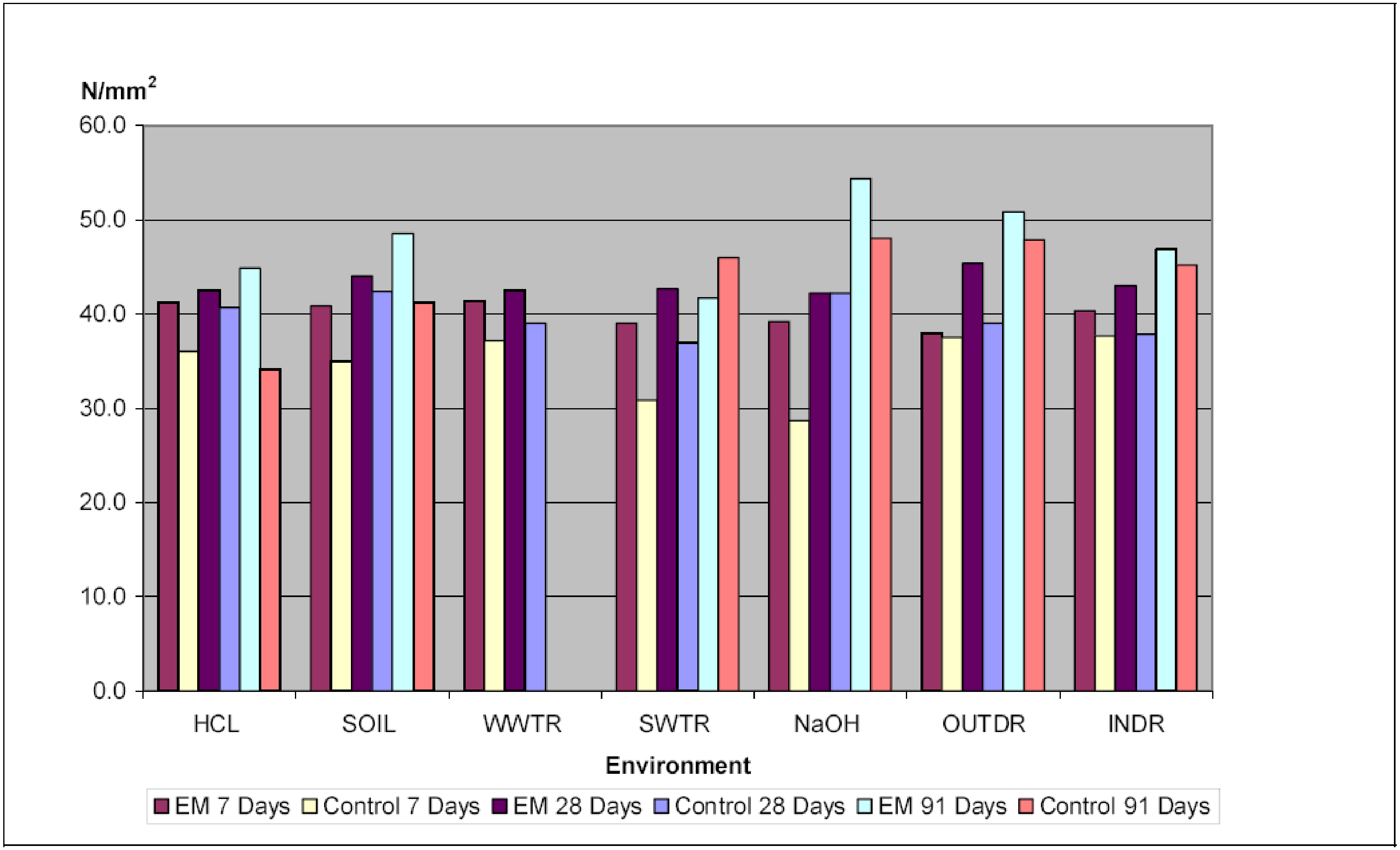

Figure 4.43: Compressive Strength of Concrete Containing EM and the Control after 7, 28, 91 days

4.2.9.6 Effects of Environments on the Compressive Strength of Concrete Containing EM

When it has been results showing that using EM in concrete can improve the compressive strength, now it is time to find out how do the different environments affect the performance of concrete containing EM, which in this study, the effects on the compressive strength. In the previous section, short-term (7 to 28 days) exposure to the environments seemed to bring insignificant effects to the concrete containing EM. The effects of the environments became very obvious on the compressive strength of concrete containing EM when they had a long-term (91 days) exposure to those environments. The graphs at below; from Figure 4.44 to Figure 4.50 can be referred to, to get a picture of how the strength development of concrete is affected under different kind of environments.

For the concrete containing EM exposed to HCL, SOIL, WWTR, OUTDR and INDR, the trend of their strength developments are quite similar in a way that their strengths increase at an almost constant rate; the slope is almost constant. In the case of SWTR, the strength becomes lower after 91 days but a very outstanding improvement is found in the NaOH condition, in which after 91 days, the strength goes up enormously.

For the normal concrete, a similar trend of strength development is found at those normal concrete exposed to WWTR, SWTR, NaOH, OUTDR and INDR. Under these environments, their strengths also increase at an almost constant rate similar to the concrete containing EM exposed to HCL, SOIL, WWTR, OUTDR and INDR but at all conditions, the strengths of concrete containing EM still top the normal concrete except in the SWTR condition. The other two conditions, namely HCL and SOIL, both are acidic liquid with pH less than 7, their strengths reduced after 91 days. Relatively, the

HCL liquid was worse because the strength after 91 days has dropped to a value lower than the strength after 7 days.

Conclusively, the concrete containing EM seems to be performing better in all conditions especially in the alkaline liquid, the performance is the greatest. But the concrete containing EM is expected to be not suitable to be used in marine environment. For the normal concrete, some perform well but not better than the concrete containing EM except for the marine environment. Again, the normal concrete seems to perform better in the alkaline liquid. However, worse cases occur in the acidic and soil Environments, the strengths drop so much after a long while.

As a whole, concrete containing EM can be considered as a more sustainable material because it performs better in most kind of environment. Without considering the outdoor and indoor environment, the alkaline liquid seems to be the most friendly environment for both kinds of concrete. To determine the environment where concrete containing EM will be the best construction material to be used in, it must be the one where the normal concrete performs at the worst but the concrete containing EM performs at its best, so that there is a significance to use the EM in concrete. As a result, the acidic liquid is the environment which concrete containing EM performs outstandingly.

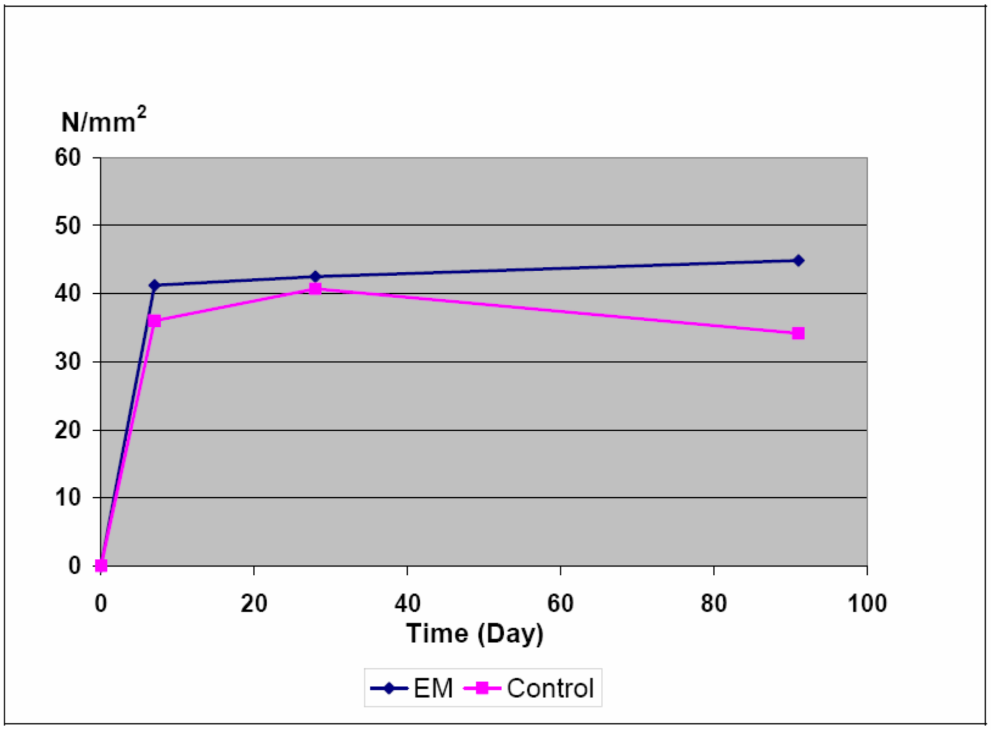

Figure 4.44: Strength Development of Concrete Containing EM and the Control in the Acidic Liquid (pH 2).

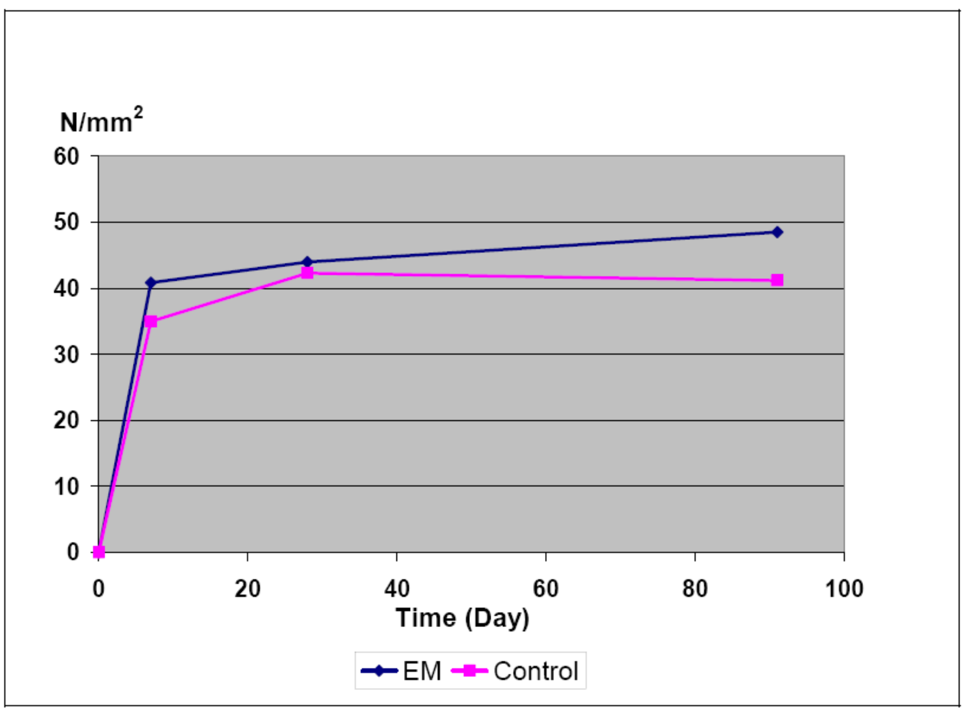

Figure 4.45: Strength Development of Concrete Containing EM and the Control in the Clayey Soil Environment (pH 6.3).

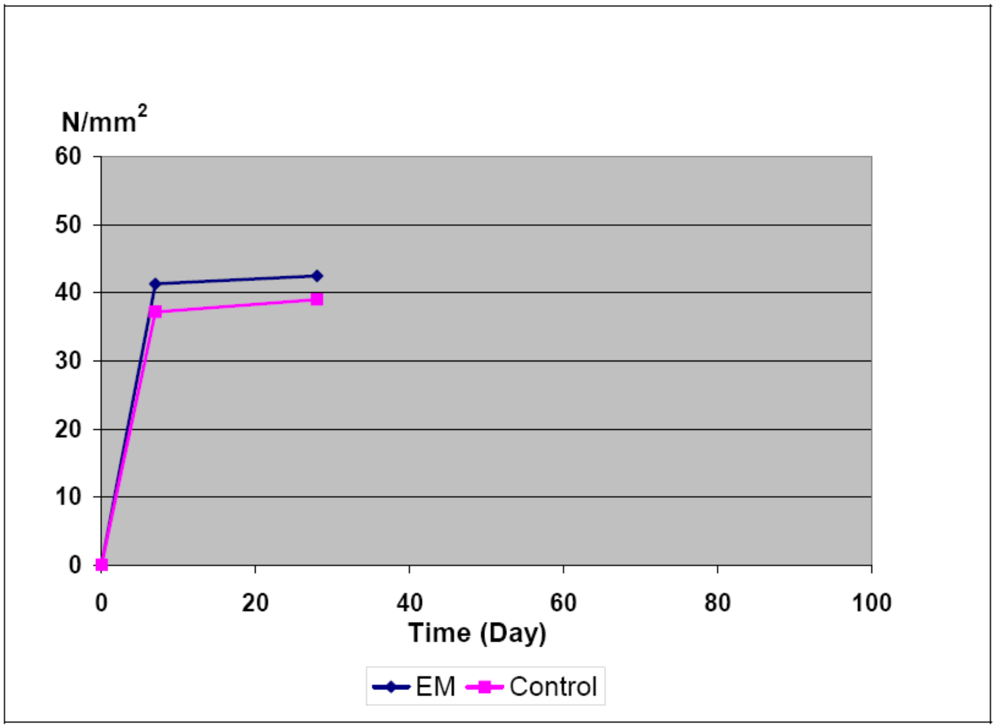

Figure 4.46: Strength Development of Concrete Containing EM and the Control in the Wastewater Environment (pH 7.3).

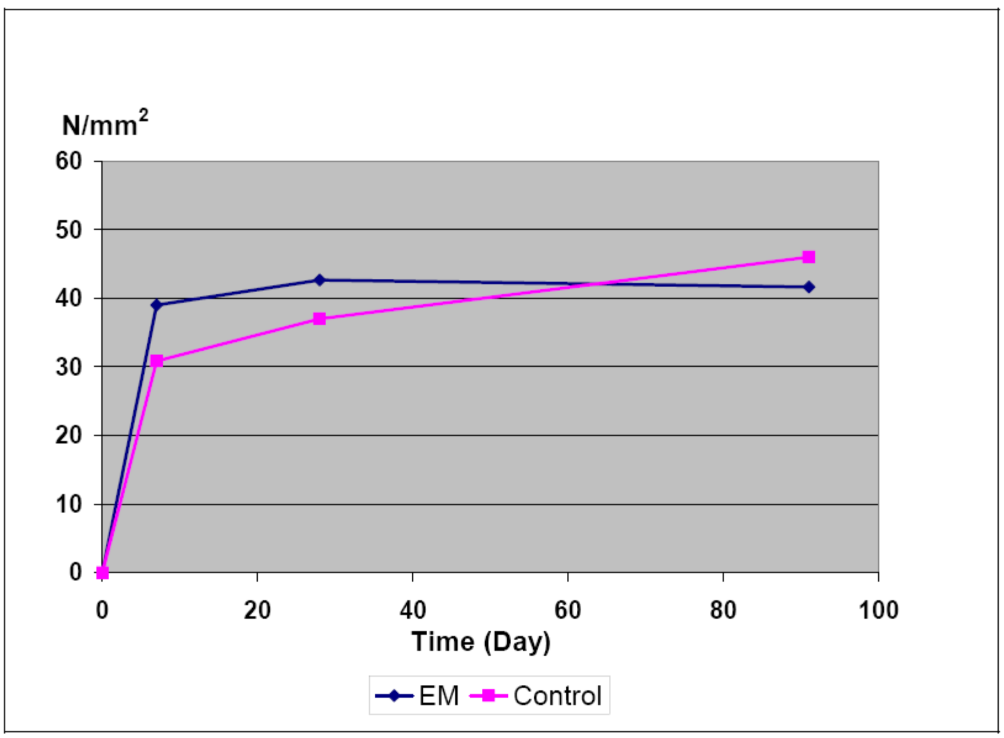

Figure 4.47: Strength Development of Concrete Containing EM and the Control in the Sea Water (pH 8.8).

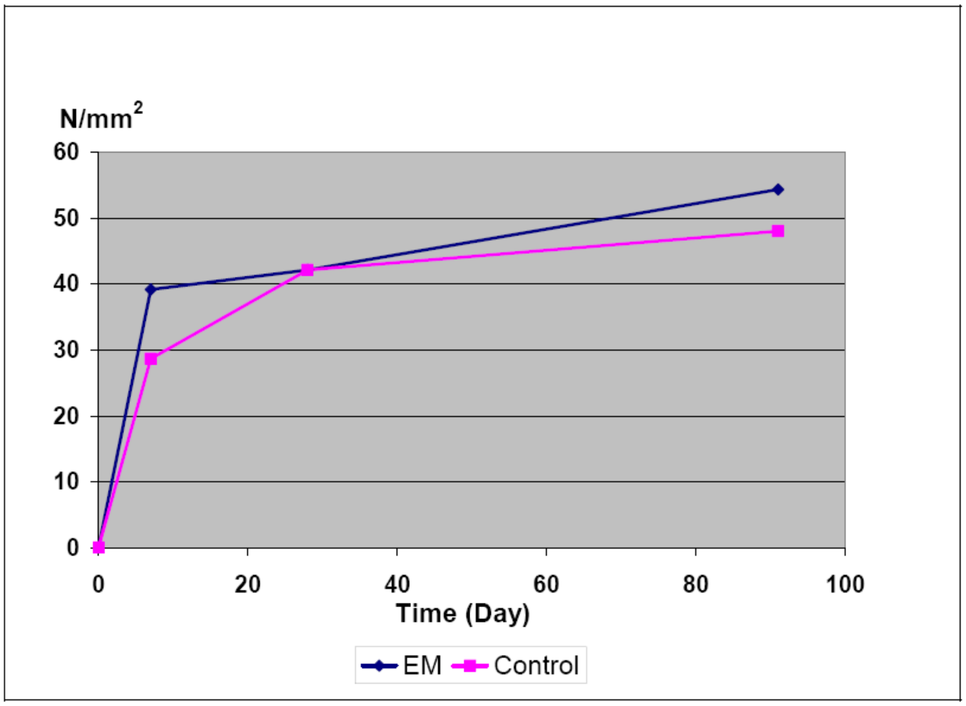

Figure 4.48: Strength Development of Concrete Containing EM and the Control in the Alkaline Liquid (pH 12).

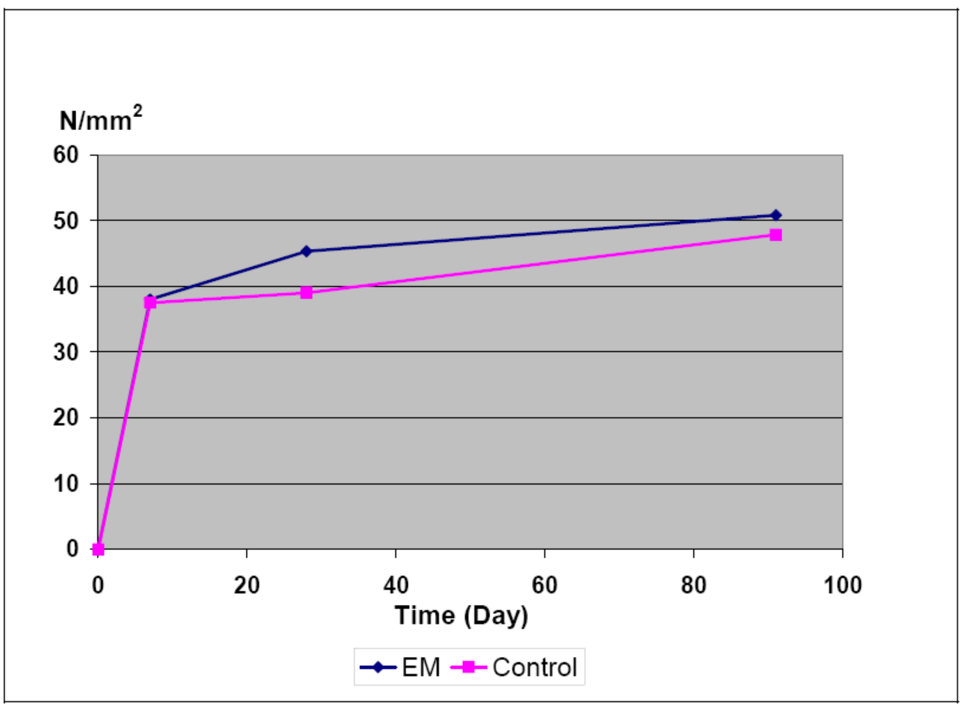

Figure 4.49: Strength Development of Concrete Containing EM and the Control in the Outdoor Environment.

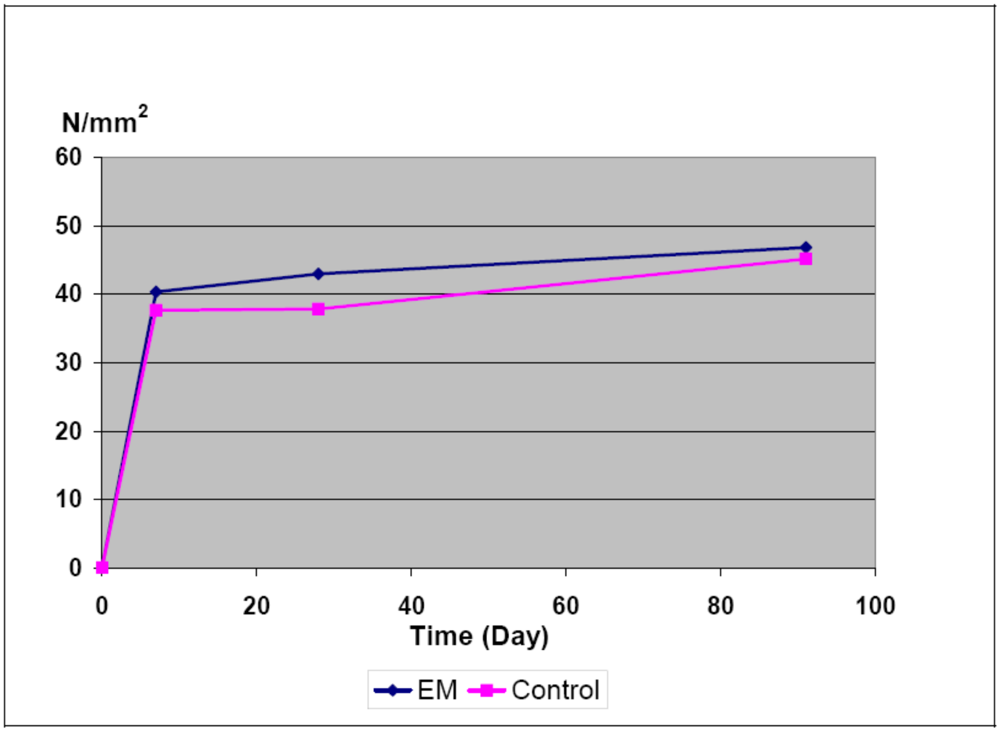

Figure 4.50: Strength Development of Concrete Containing EM and the Control in the Indoor Environment.

4.2.10 Chemical Analysis on Cement Cube

Fourier Transform Infrared Spectroscopy (FTIR) was the medium that was used to analyze the chemical content of cement cubes. The main function of FTIR was to detect the functional groups in the cement cubes. One of the objectives of this study was to identify the contribution of EM during hydration process. It was suspected that EM produced certain gel or particles during hydration process. Thus, it will affect the properties of the cement cubes.

To investigate the contribution of EM, samples were prepared and tested. From the spectroscopy, the results were represented in graph form. It was a graph of transmittance (%) versus wavelengths (cms-1). There were handbooks that listed down all the functional groups according to their wavelengths. However, not all people can extract the information easily. One needs to have deep knowledge on organic and inorganic compounds. For civil engineering students who own no knowledge in the field, other alternative was used. Besides referring to handbook, the functional groups of certain material can be obtained from journal or previous research.

The contribution of EM can be detected by comparing the graphs between control cubes and cubes that contained EM – AS. Any discrepancies or differences might be the contribution from EM. The functional groups for cement paste were obtained from a journal. According to the research, the FTIR spectrum for ordinary Portland cement are as follows: calcium hydroxide bands (3642 cm-1), combined and absorbed water of C-S-H phases (3440-3446 cm-1), molecular water (3440-3446 and 1640-1645 cm-1), carbonate phases (1424-1436, 874-880 and 704-712 cm-1), sulphates phases (1116-1118 cm-1), anhydrous calcium silicates (920, 526-536 and 458-464 cm-1) and calcium silicates (970-986 cm-1) (Sao Carlos, 2005). The results from FTIR were reliable if the specimen was homogenous. They are two ways to ensure that the specimen was homogenous. The first is just made an assumption that the sample was homogenous. Or else, few samples from different surface should be tested for each cube. In this study, the latter was adopted. If the cubes were homogenous, the graphs for each trial should be similar. From the tests, it can be concluded that the cubes were homogenous as the graphs were similar to each other. After the tests were done, the graphs were compiled according to the cube type. Cubes that were tested by FTIR were control, 5%, 10% and 20% EM – AS. Cubes that contained 30% EM –AS were excluded as their strength were lower than control.

The first step in analyzing the results was by comparing the graphs between control and EM – AS cubes. Advices and consultation from lecturers that are specialized in the field were referred. The personnel are Assoc. Prof Dr. Wan Aizan and Prof. Dr. Mazlan Aziz. All the graphs were laid side by side to detect any discrepancies. From the observation, there were no major differences between the control and the EM – AS cubes. The peaks' values and locations might differ slightly from each other but it didn't affect the functional groups in the cubes. The next step is to identify the functional groups. The FTIR spectrum for control cubes should be same with previous research (Sao Carlos, 2005). In this study, certain of the wavelengths value were not exactly the same with the previous study. However, it can be concluded that the functional groups for control cubes in this study were the same group as stated in the previous research. The differences between the latter and the older was small hence negligible. From the analysis, all the cubes have the same functional groups. The only differences were the values of the peaks. Although the values were varied, they were still in the group's wavelengths range.

This means that EM has no contribution in the chemical properties of the cubes. In other words, EM is inert. This new finding was spectacular as it will be troublesome if the chemical properties of the EM - AS cubes differed from the control. If this happen, the chemical resistance of the cubes might changed or weakened. The cubes might good at certain criteria and vice versa. If the chemical properties of the EM – AS cubes have changed, it is risky to adopt the usage of EM in the construction world. Unless, a further study on the chemical behaviour of the cubes were conducted before it can be applied widely in construction.

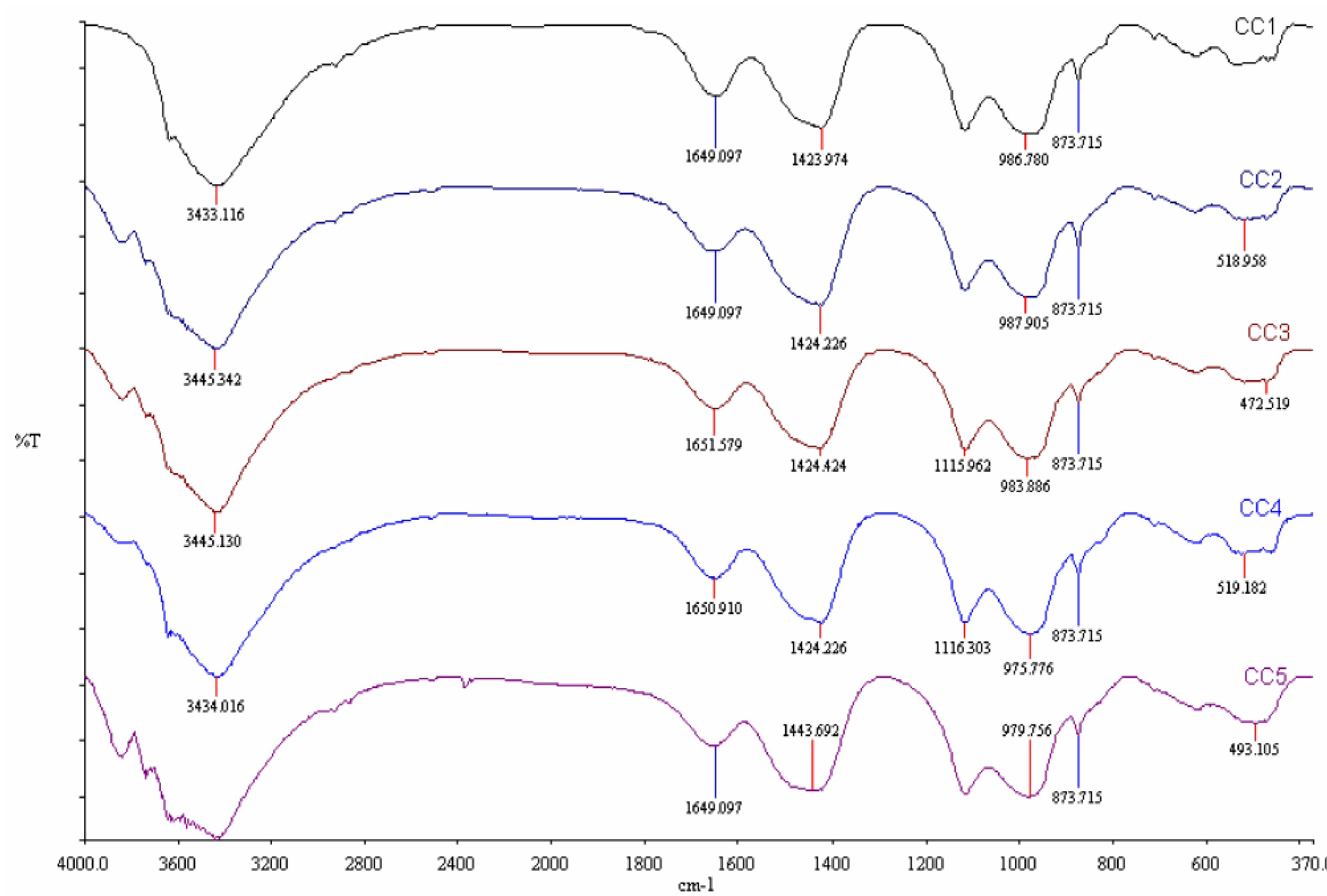

Figure 4.51: FTIR Spectrum for Cement Control Cubes

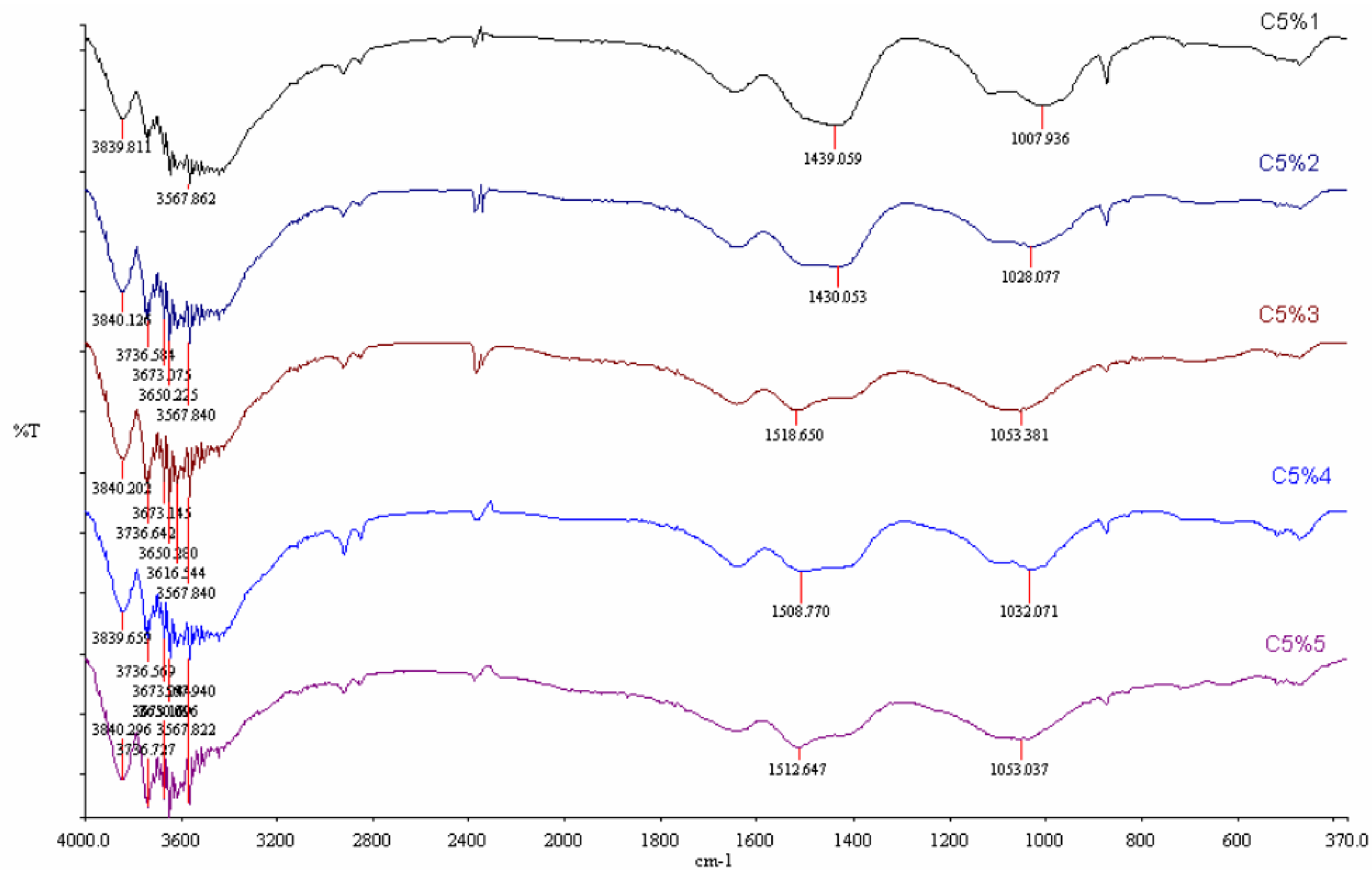

Figure 4.52 FTIR Spectrum for 10% EM – AS Cement Cubes

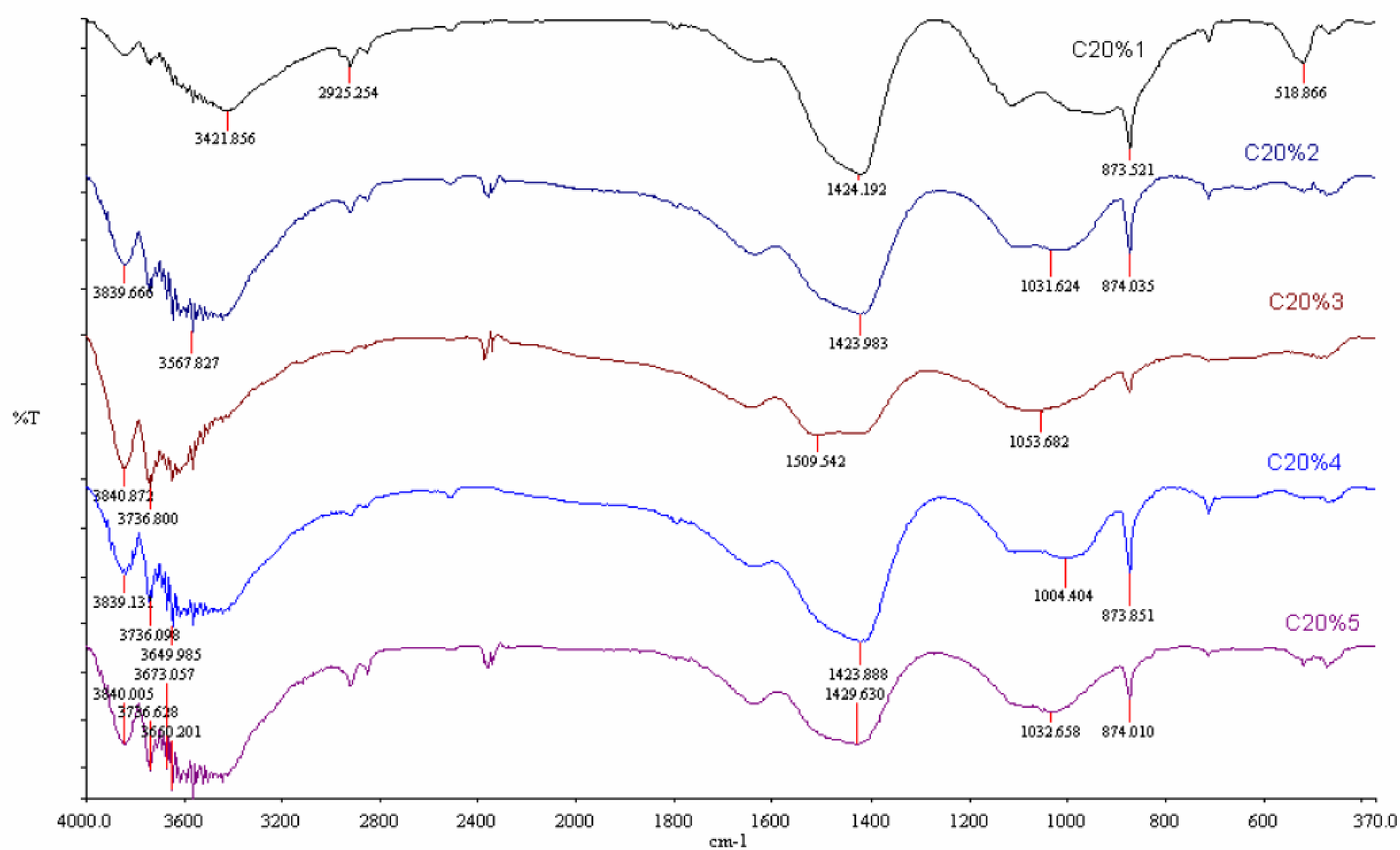

Figure 4.53: FTIR Spectrum for 20% EM – AS Cement Cubes

4.2.11 Chemical Analysis on Mortar Cube

The next chemical analysis test was conducted to analyze the mortar cubes. Specimens from cubes control, 5% EM – AS, 10% EM - AS and 20% EM - AS were taken to be tested under infrared wave. In order to identify the functional groups of mortar, a journal had been referred. However, it is almost impossible to get the peak value exactly the same like the previous study. The peak value was influenced by many factors such as the quality of the cement, the mixing proportion, and the sand properties.

In order to identify the functional groups of mortar, a journal had been referred. Researchers that conducted study on mortar; collected from Roman Collosseum and cistern, had published the FTIR spectrum for the materials. According to the study, the wavelengths spectrum for mortar are as follows; carbonate phases (1424-1436, 874-880 and 704-712 cm^{-1}), presence of bound water (around 3400 and 1630–1640 cm^{-1}). The water might be bound to hydraulic compounds, like silicate and aluminate hydrates. Silicate phases are also responsible for the bands at 463 and 451 cm^{-1}. The Al-O vibrations from silicoaluminate hydrates may also be responsible for the strong band at around 1000 cm-1. For peaks with 2920 and 2860 cm^{-1} that could be related to some organic material (stretching vibrations of the bond C-H in CH2) (DA Silva et al, 2005). The FTIR graph from the study is as follow:

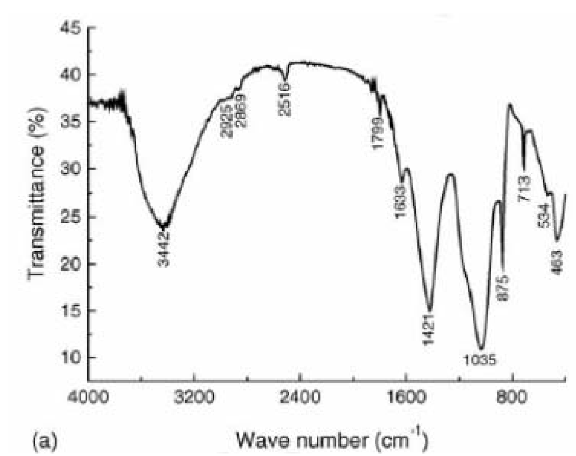

Figure 4.54: Infrared Spectra of Colosseum Mortar

The results of the infrared spectra of the mortar cubes were given below in Figure 4.55, 4.56, 4.57 and 4.58. From the graphs obtained from the study, it can be concluded that they were similar to previous study. Although they were not exactly same due to certain circumstances, the results from the FTIR can be considered reliable. The graphs between cubes were alike in many ways. It showed that the cubes possessed the same functional groups. There were no changes in the functional groups. Therefore, it is proven again that EM has no contribution on the chemical content of any mixture; neither cements nor mortar.

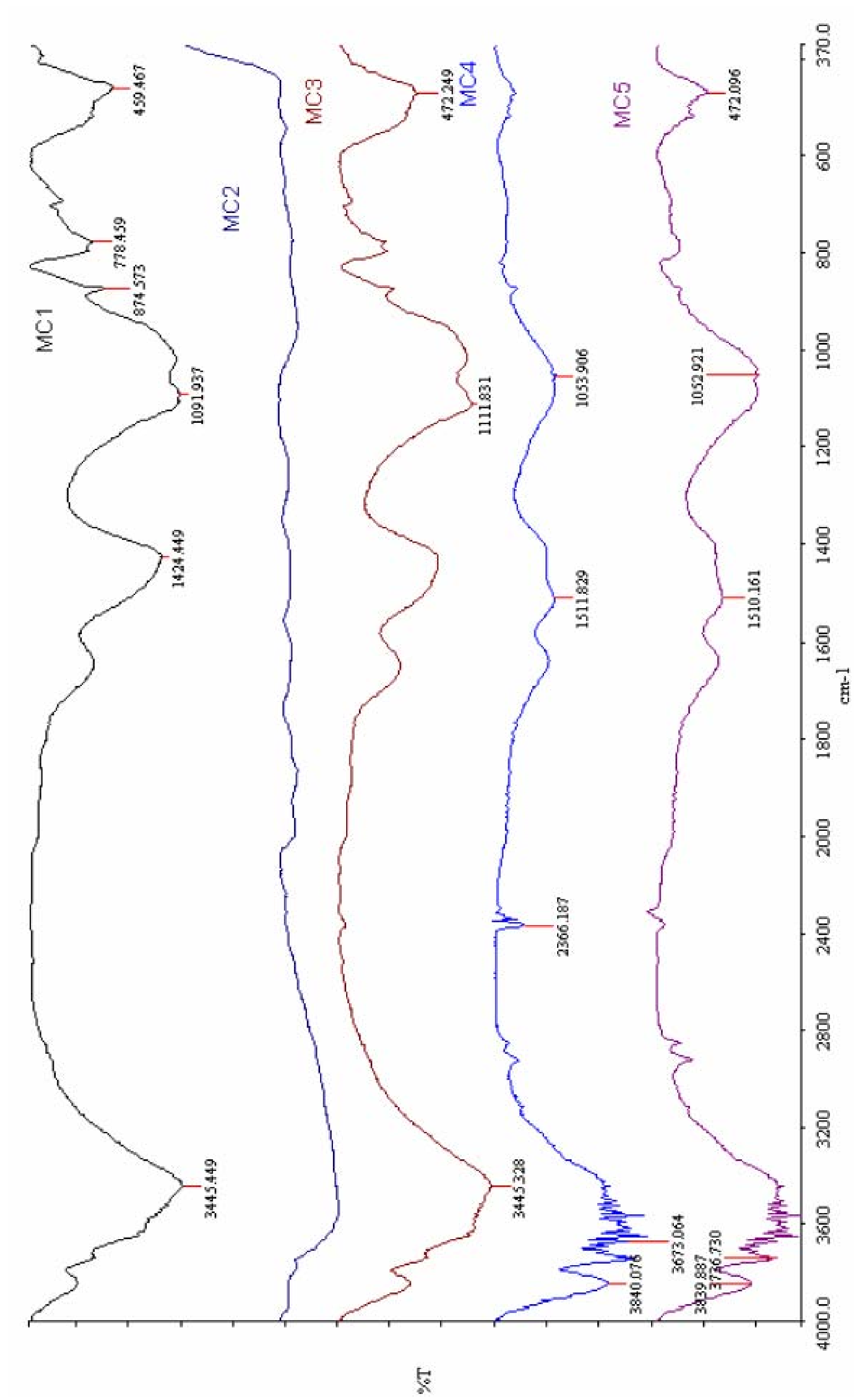

Figure 4.55: Infrared Spectra of Control Mortar Cubes

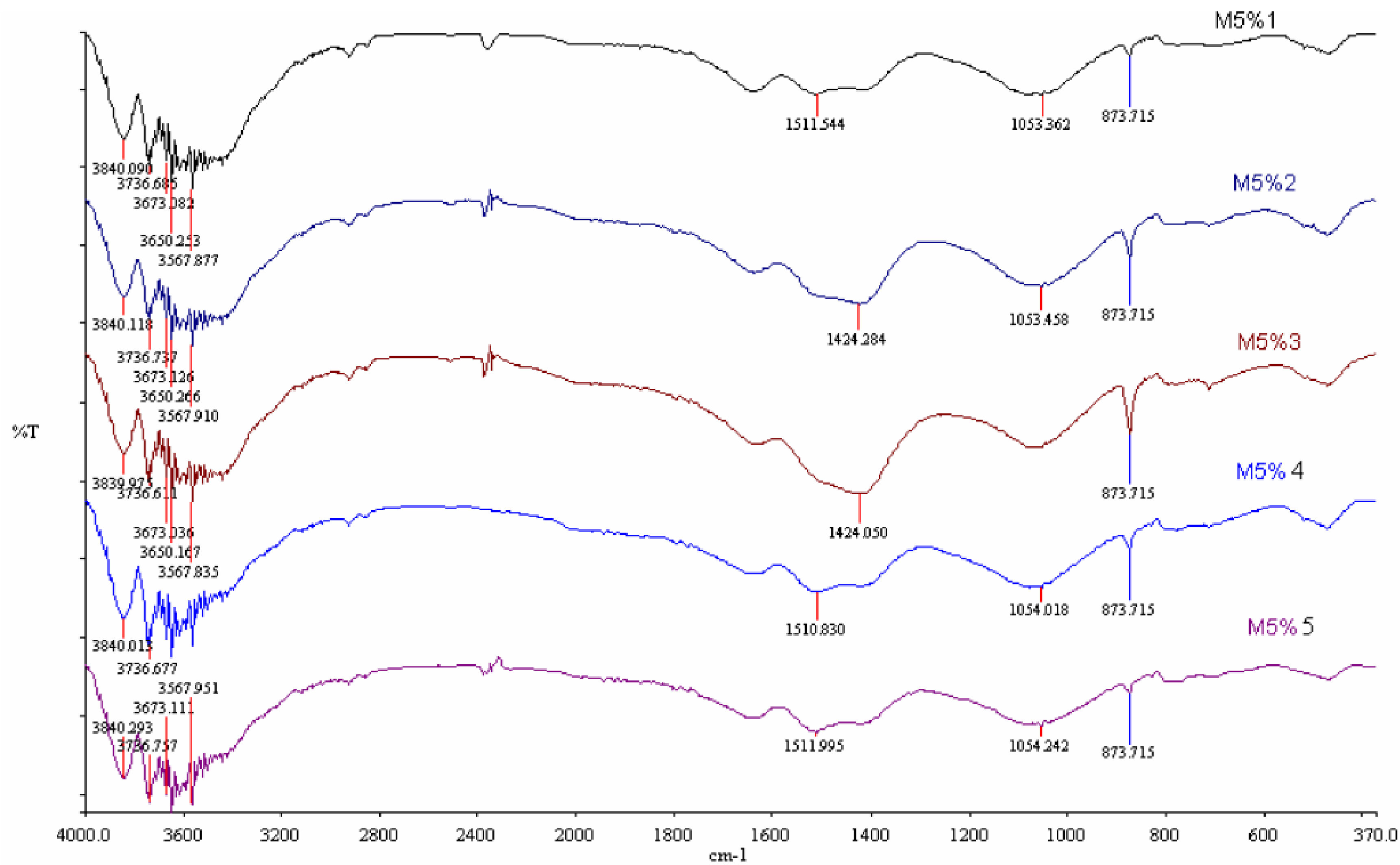

Figure 4.56: Infrared Spectrum of 5% EM – AS Mortar Cubes

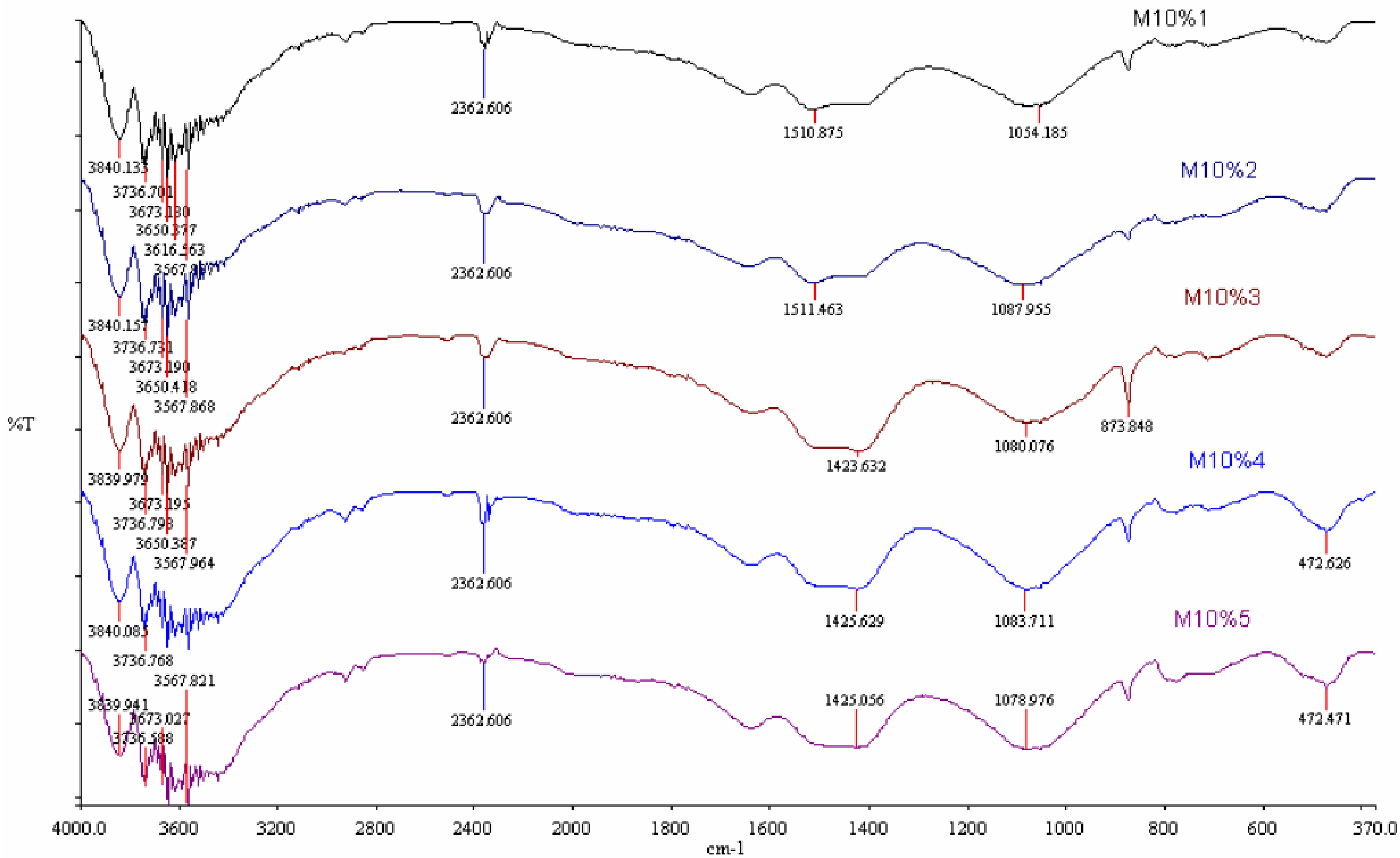

Figure 4.57: Infrared Spectrum of 10% EM – AS Mortar Cubes

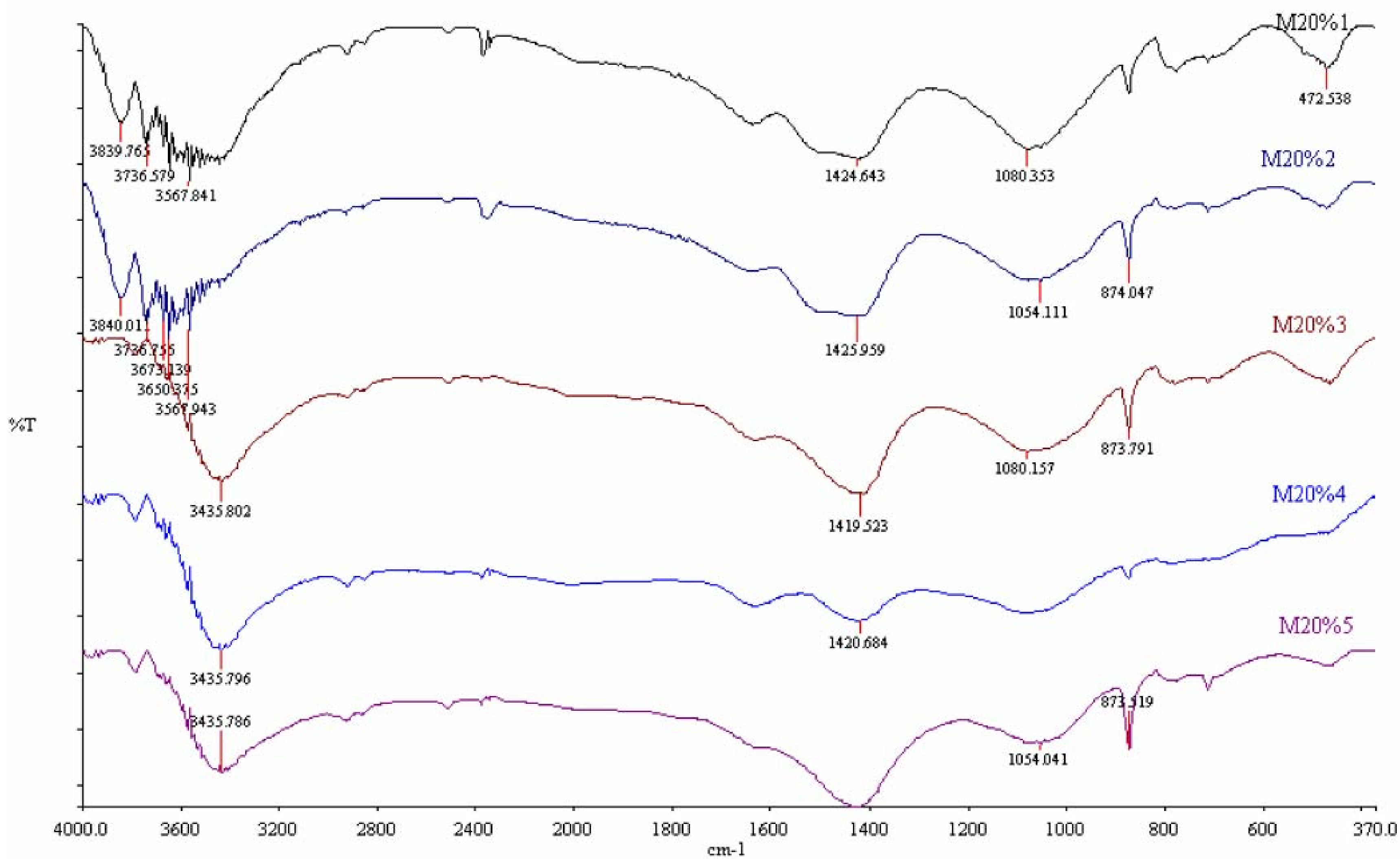

Figure 4.58: Infrared Spectrum of 20% EM – AS Mortar Cubes

4.3 Industrial Wastes as Admixture

4.3.1 Polymer-based Wastes

Physical properties of the elastomer-based adhesive waste in this study were processed and ready discrete form. It was yellow in color, bouncy solid particle with all passing 1.18mm sieve and with a round surface. After grinding by 3-Phase Grinder in polymer lab, the waste was pulverized to the particle sizes as shown in Figure 4.59.

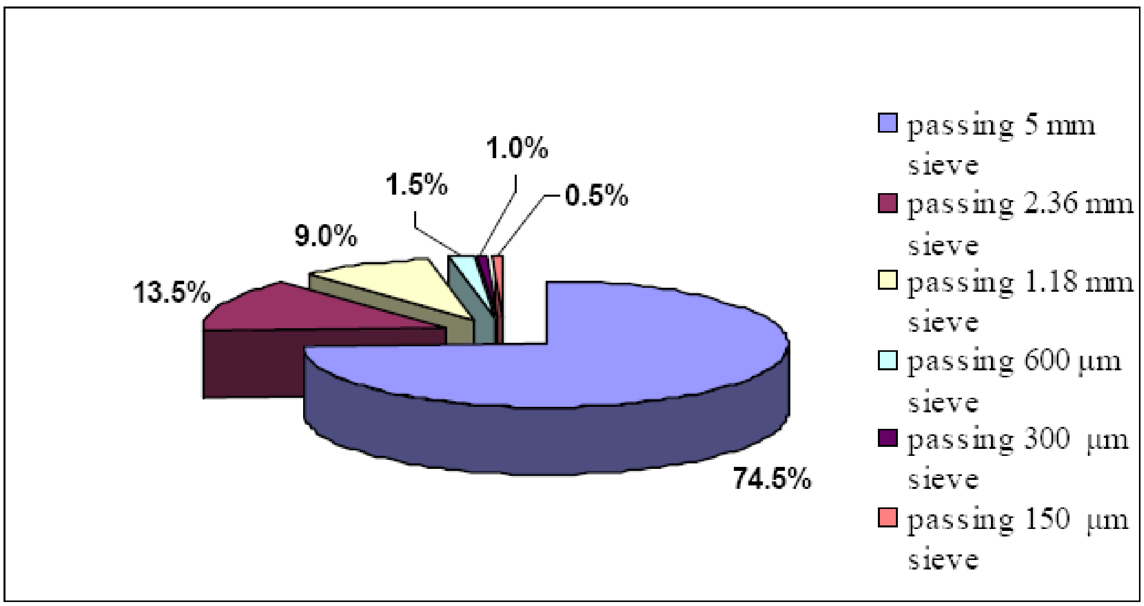

Figure 4.59: Chart of Particle Size Distribution of Elastomer-based Adhesive Waste

The size distribution percentages show that the material is non-brittle material that hard to crush into fine particles. It has a considerable influence on the behavior of polymer properties which has strong bond between their molecules. The density of the material was obtained and some calculations are shown as below.

$$\textbf{Density, } \rho = \frac{\mathbf{A}}{\mathbf{A\text{-}B}} \ \mathbf{x} \ \ \rho_o \qquad (\mathbf{g / cm^3})$$

Where, A = weight in the air (g)

B = weight in the water (g)

ρo = density of distilled water, 0.9968 g / cm^3 , by according to ambient temperature 26°C

$\rho = 0.4854 \times 0.9968 / (0.4854 – 0.0373)$

$= 1.0798$ g / cm^3

$= 1079$ kg / m^3

From the result, it shows that the density of the material is 1079 kg / m^3. The value is quite low if compare to normal weight fine aggregate which has density around 1520 kg / m^3 to 1680 kg / m^3.

On the other hand, XLPE waste was also in discrete form. It was white in color, hardness but ductile particle with all passing 1.18 mm sieve and in angular shape. The result of particle size distribution after pulverized by using the 3-Phase Grinder was as shown in Figure 4.60.

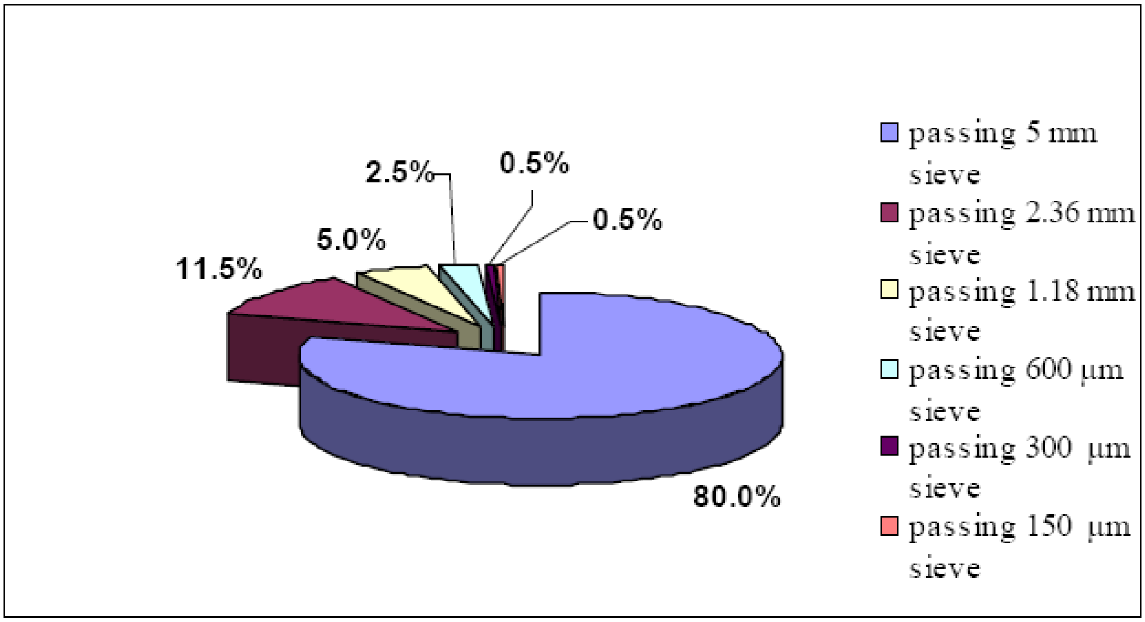

Figure 4.60: Chart of Particle Size Distribution of XLPE Waste

As a result, the interconnection of molecules which created a 3-dimensional network of molecule in the material caused toughness and it was hard to break. Both of these charts showed the wastes used in this study are well graded to reduce gap between aggregates in mortar mix. Similarly, the density of XLPE also was obtained by the same method as described before and the calculation was shown as below:

$$\textbf{Density, } \rho = \frac{A}{A-B} \times \rho_o \qquad (g / cm^3)$$

Where, A = weight in the air (g)

B = weight in the water (g)

ρo = density of distilled water, 0.9968 g / cm^3 , by according to temperature

ρ = 0.1446 x 0.9968 / (0.1446 – (- 0.013))

= 0.9146 g / cm^3

= 914.6 kg / m^3

The negative B value is due to the material float on the distilled water. Therefore, XLPE density is 914.6 kg / m^3 . It can be considered as a lightweight but strong material.

4.3.2 Density of Mortar

The density of all modified samples was compared to the control sample and the difference of both value are shown in percentage in Figure 4.61. The histogram indicated that densities of modified samples were reduced compared to control. The increase of waste content reduced the density of the sample significantly. There was about 17% reduction in density by both E15-M and X15-M. This can be explained that both Elastomer and XLPE are light material compared to mortar. When the material was added as filler in the mix, the lighter hardened mortar is newly introduced.

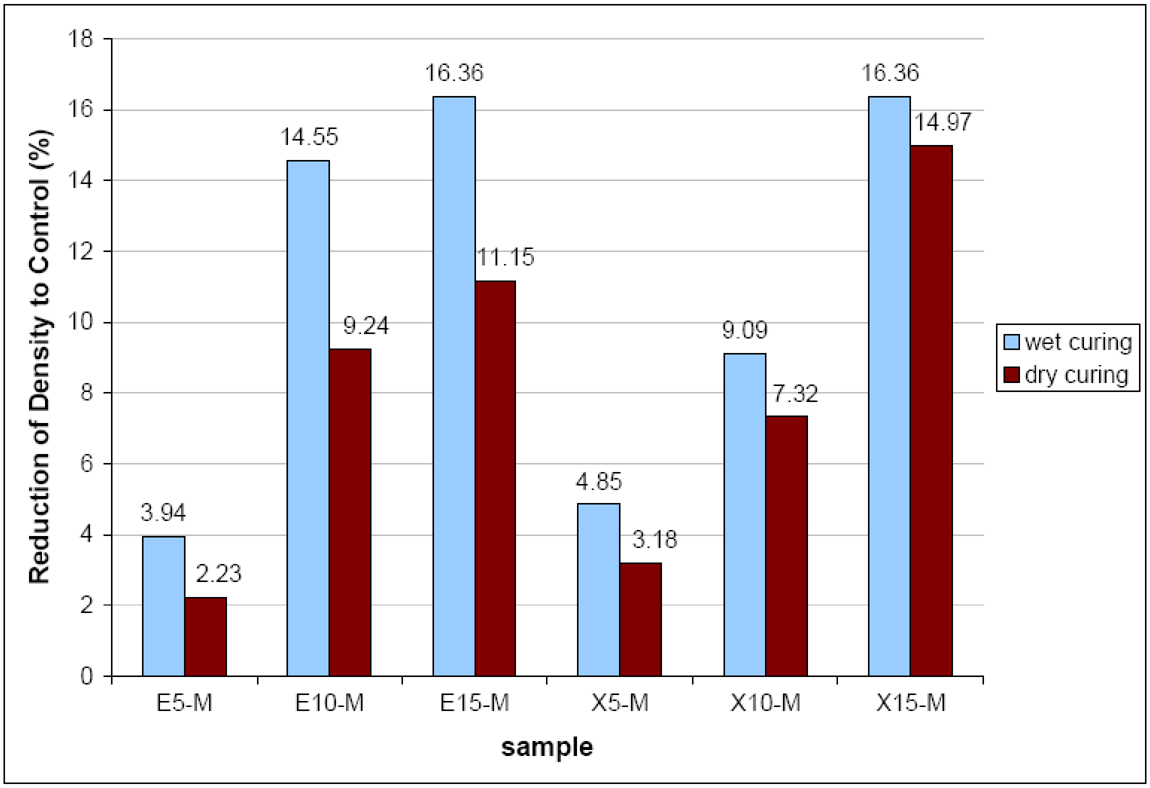

Figure 4.61: Reduction of Modified Mortar Density Compared to Control

4.3.3 Cement Consistency Test

Seven types of cement paste mix with a constant cement content shows a sharp increase of requiring water. The results are shown in Figure 4.62. X15-C required the highest water content, namely 41.7% while 34.5% of water was required by P0-C. Extra 36 g water needed to be added in the 15% of XLPE cement paste to achieve same consistency. The results in Figure 4.63 shows the cement paste with higher polymer waste content will require a higher water content to achieve the standard consistency and it is obviously showed by XLPE. This can be considered as blocking and trapping of water to reach through all the cement particles surfaces by the additional material because both of the wastes are not react with water molecules. Therefore, setting time of those mixed are be predicted to be higher than the ordinary cement paste.

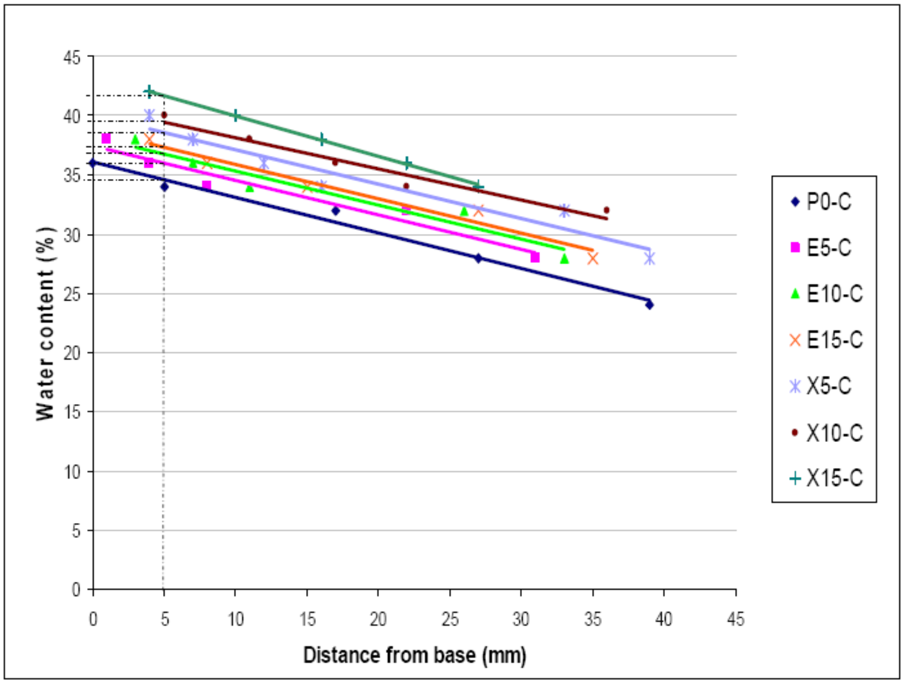

Figure 4.62: Graph of Cement Consistency Test Result

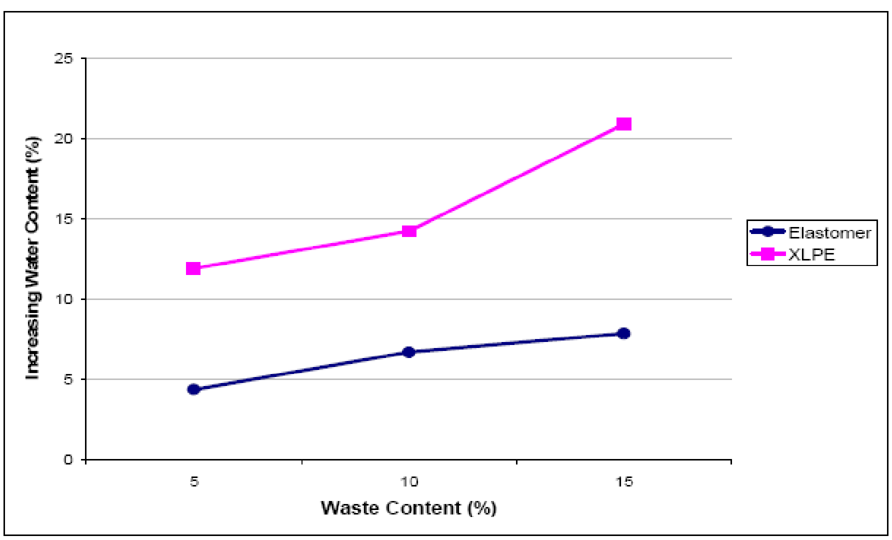

Figure 4.63: Influence of Waste Content on the Increasing of Water Content

4.3.4 Mortar Cube Compression Test

Compressive strength of mortar cube can be represented as the performance of mortar cube subjected to ultimate load. The mortar property is shown in Figure 4.64 to Figure 4.67. The tests were performed on mortar specimens varying from types of waste introduced; percentage of waste introduced; curing condition; and age at testing. Each point presented in the graphical plots was taken from the average of 3 readings.

4.3.5 Compressive Strength Development

Generally, the compressive strength of cementitous material as those samples will increase as time goes by. Proper curing and compaction will contribute to the principal of strength development of both ordinary and modified mortar. The compressive strength development of samples with wet curing and dry curing are given in Figure 4.64 and Figure 4.65.

The general trend of each mixed was similar, an increase of strength after 3 days up to 28 days. However, it showed that all modified mortars exhibited low compressive strength compared to ordinary mortar in wet curing condition. This trend was as same as result obtained by researcher namely H.A. Toutanji (1996). In dry curing method, the compressive strength of X5-M achieved higher strength than ordinary mortar.

From the analysis showed in Figure 4.66 and Figure 4.67, it was observed that the mortar added with XLPE waste have lower early compressive strength than mortar mixed with elastomer waste and also ordinary mortar. All samples achieved more than 90% of their characteristic strength at the age of 7 days accept those added with XLPE.

Strength gained slowly in high XLPE content, which can be seen clearly in X15-M, achieved only 62% at 3 days and 75% at 7 days with wet curing; and 68% at 3 days and 79% at 7 days with dry curing. Furthermore, mortar in dry curing gained their strength after 7 days as the water in the mixed was inadequate to continuously contribute the hydration process and thus, the strength stop gaining.

Figure 4.68 shows the comparison of modified samples compressive strength with the ordinary. It is clearly defined that all samples have lower compressive strength than ordinary mortar. However, the only condition shown by X5-M under dry condition will achieve higher compressive strength than ordinary mortar which also cured in dry condition at 28 days.

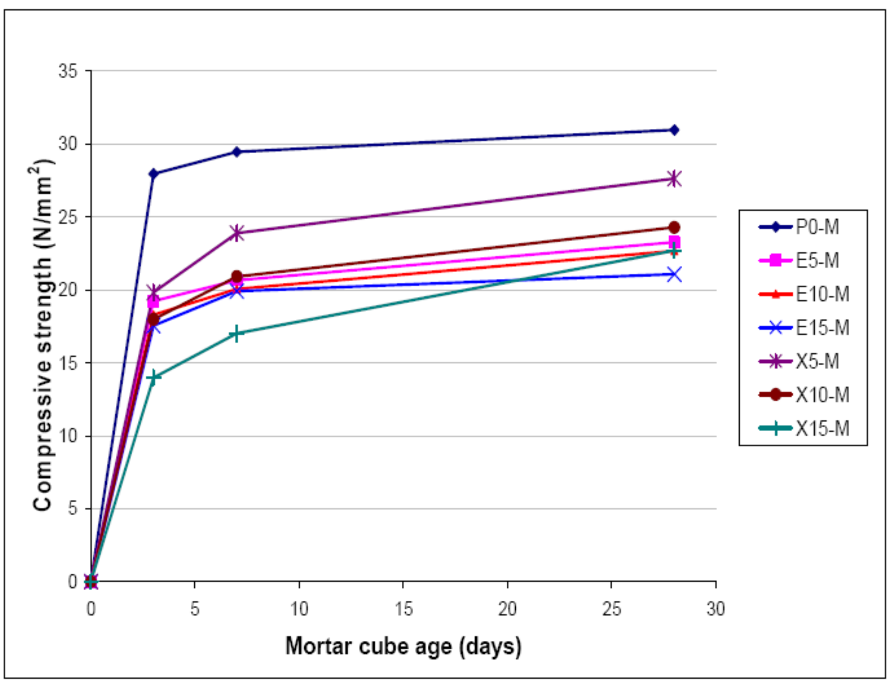

Figure 4.64: Compressive Strength of Mortar Cubes with Wet Curing at Different Age

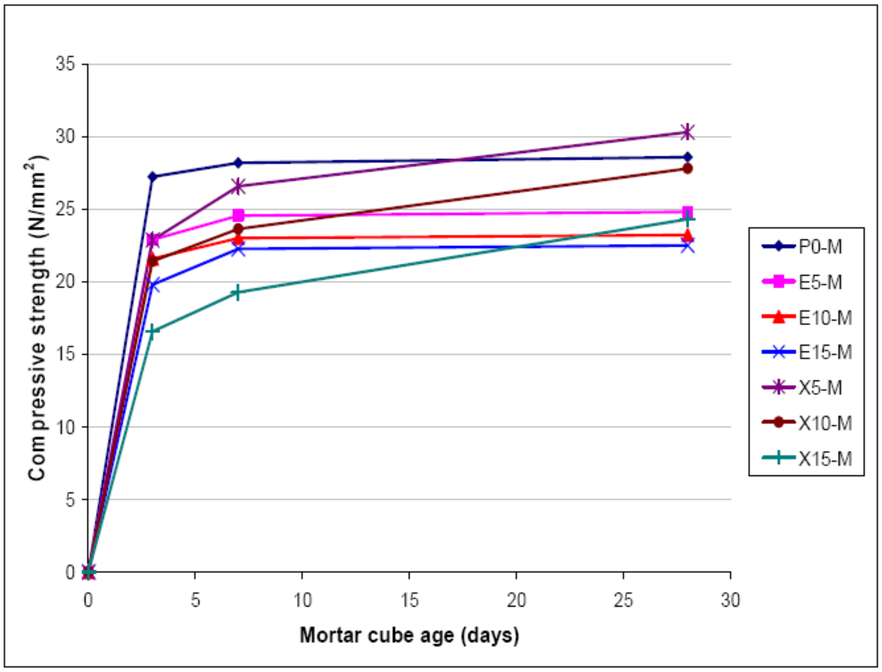

Figure 4.65: Compressive Strength of Mortar Cubes with Dry Curing at Different Age

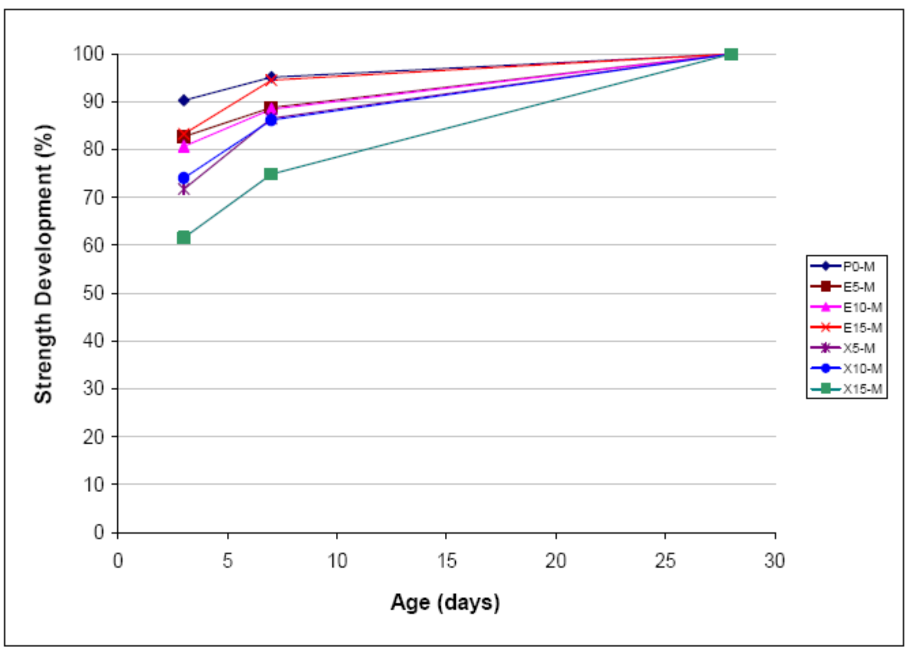

Figure 4.66: Characteristic Strength Development of Mortar Cubes in Wet Curing Condition

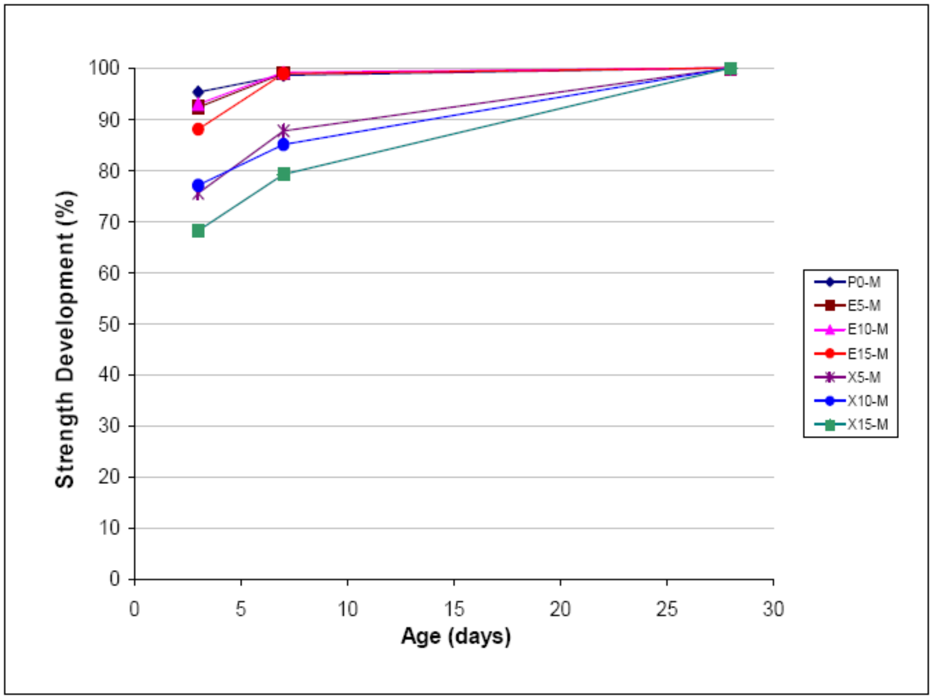

Figure 4.67: Characteristic Strength Development of Mortar Cubes in Dry Curing Condition

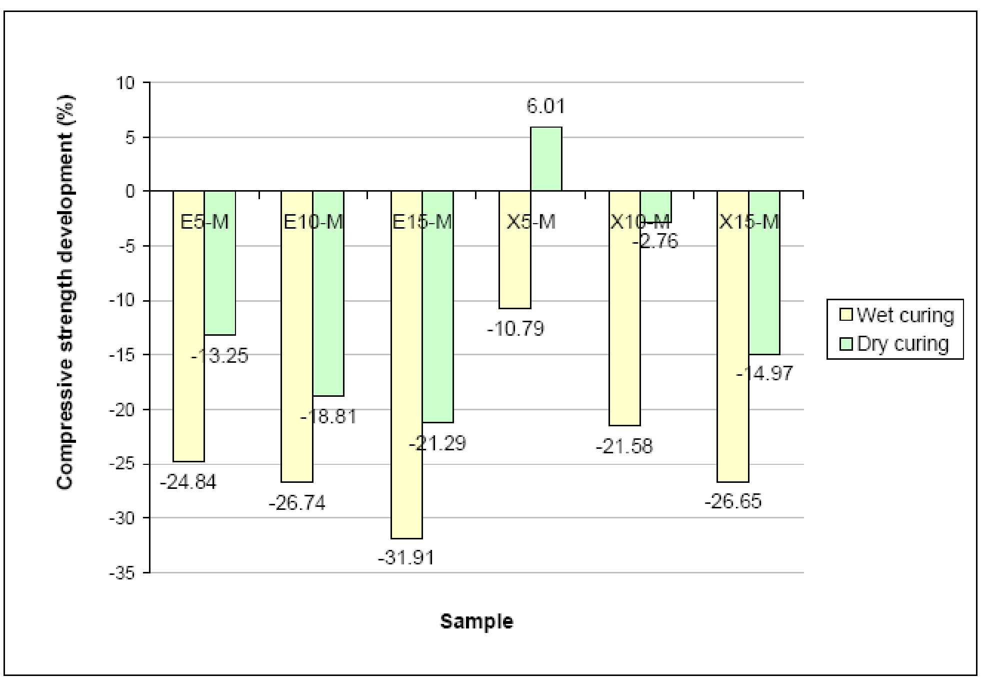

Figure 4.68: Compressive Strength of Modified Mortar Compared to Ordinary Mortar after 28 days

4.3.6 Effects of Curing Condition

Mortar cubes mixed with water for hydration process. Wet curing method was used to provide the additional water for further hydration. While, dry curing was used to maintain moisture in the environment of the cubes. Therefore, two types of curing method were used and the results were compared.

It can be seen from Figure 4.69 the modified mortars with dry curing exhibited higher compressive strength than wet curing. However, ordinary mortar presented in others way. In addition, Figure 4.70 indicates the difference compressive strength of sample in dry curing condition compared to wet curing. All samples exhibited positive value except for ordinary sample. X15-M performed the big difference for dry curing and wet curing with an increase of 15%.

Incomplete of hydration process of control samples provide less C-S-H gel when cured in dry condition compared to wet condition. Insufficient of water content was caused by the evaporation of moisture in surrounding of mortar. Modified samples exhibited porous physical properties when cured in wet condition and provided lower compressive strength than those cured in dry method. This is because there were voids between matrix and waste particles in wet condition, those voids were filled with water and contributed to a lower strength. As a result, modified samples with wet curing have weaker bonding of matrix with wastes and exhibited a lower compressive strength compared to dry curing cubes.

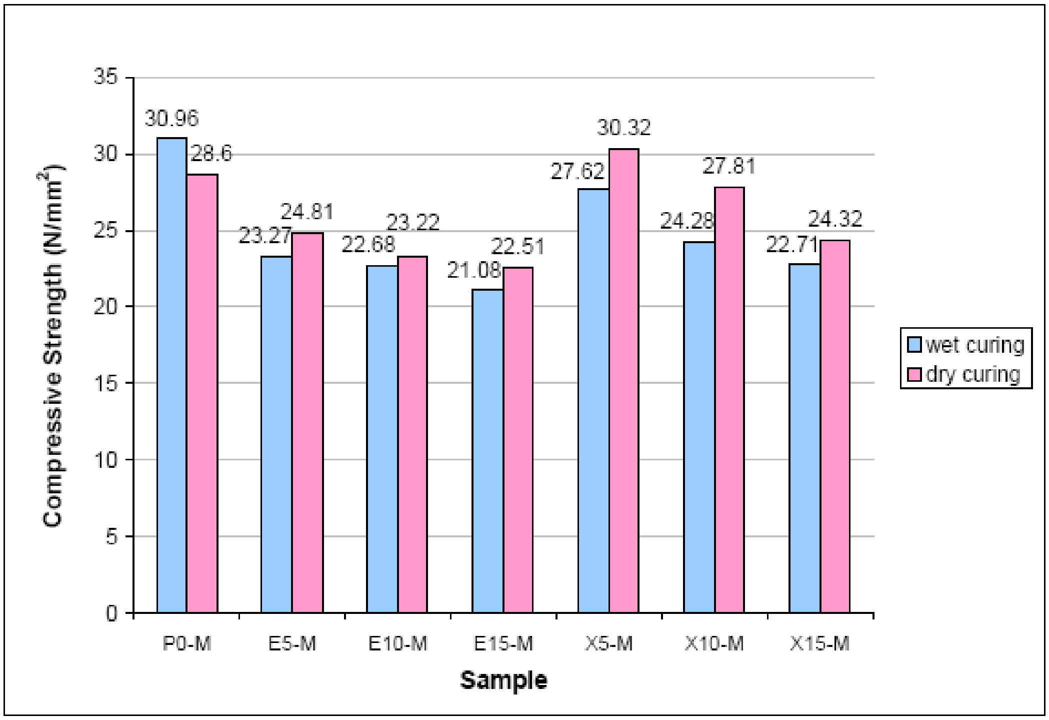

Figure 4.69: Compressive Strength of Sample after 28 days.

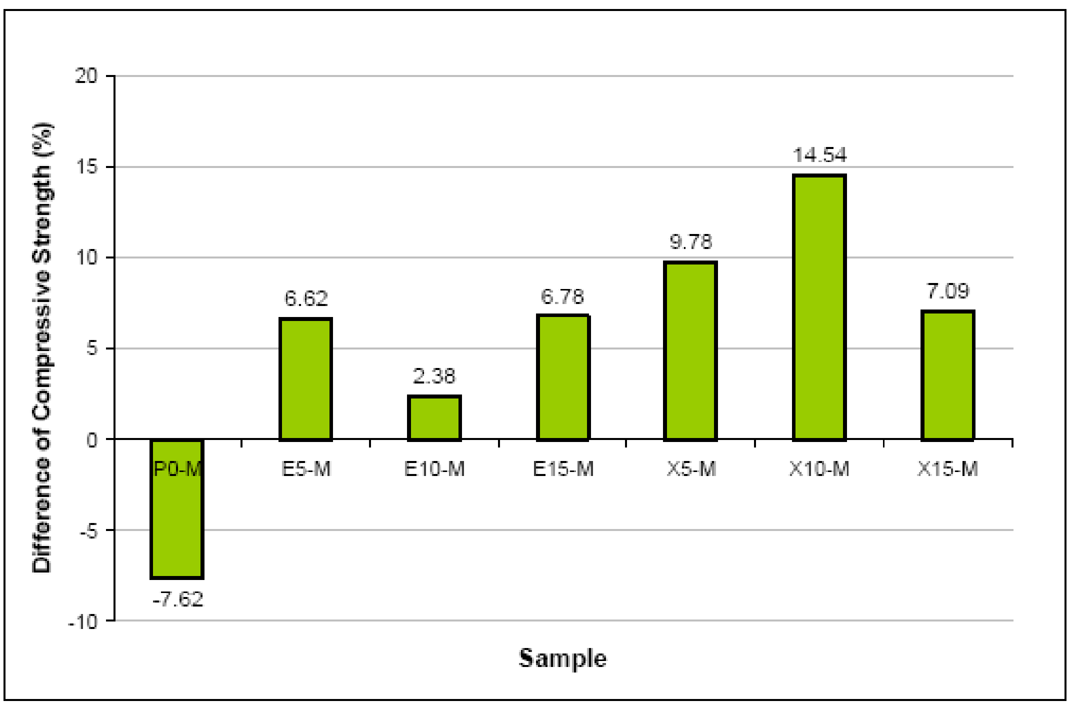

Figure 4.70: Compressive Strength of Dry Curing Mortar Compared to Wet Curing Mortar.

4.3.7 Effects of Waste Percentage

Modified mortar with higher waste content showed a decrease of compressive strength, for both elastomer and XLPE. Figure 4.71 shows the compressive strength of modified sample added with waste. If assumed the compressive strength versus waste percentage is in linear relationship, and intercept at y-axis are compressive of ordinary mortar in both curing condition respectively, the equations are showed in Figure 4.72, where elastomer waste is significantly reduced in compressive strength compared to XLPE waste, especially when the elastomer waste is introduced samples are cured under wet curing.

From all the analysis stated above, the strength gained in the modified mortar showed the waste is not the dominant character. On the other hand, Portland cement still played a vital role in compressive strength development, as the main chemical composition that boosts the hydration process is calcium oxide (CaO). It has a great influence on the hydration of mortar and affects the strength of mortar. The CaO can be found in all 4 major compounds of cement, which are tricalcium silicate (3CaO.SiO2), dicalcium silicate (2CaO.SiO2), tricalcium alluminate (3CaO.Al2O3), tetracalcium alluminoferrite (4CaO.Al2O3Fe2O3). When hydration process occurs, calcium oxide will react with the water molecules to produce cement gel and calcium hydroxide. Hence, it can be concluded that the strength of mortar depends on the cement gel.

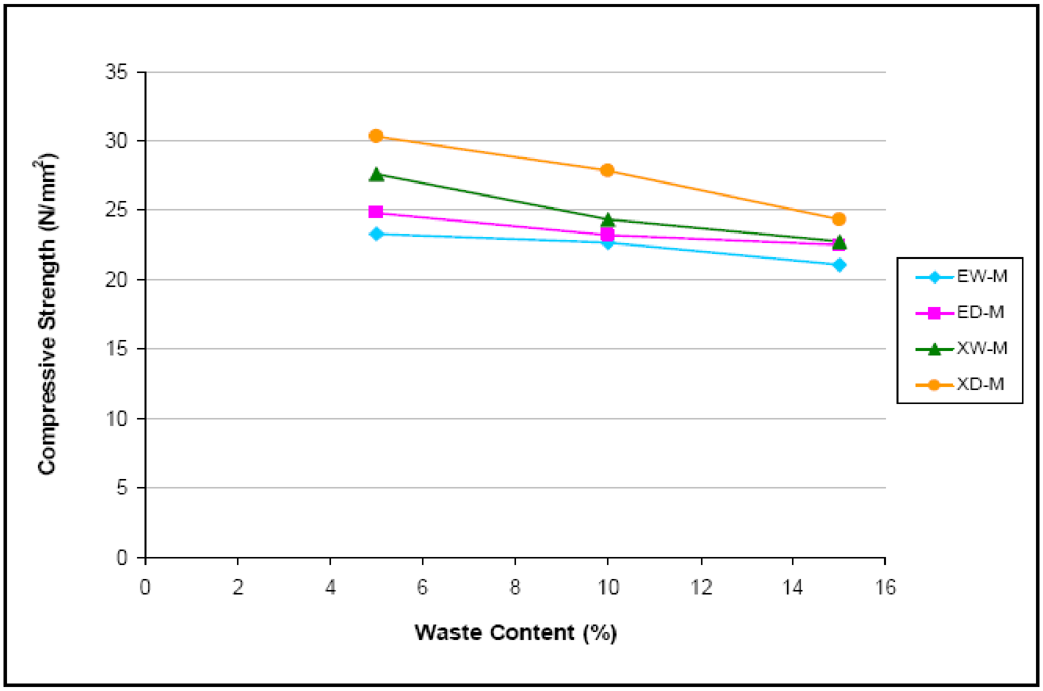

Figure 4.71: Effect of Waste Percentage on Compressive Strength of Modified Mortar after 28 days

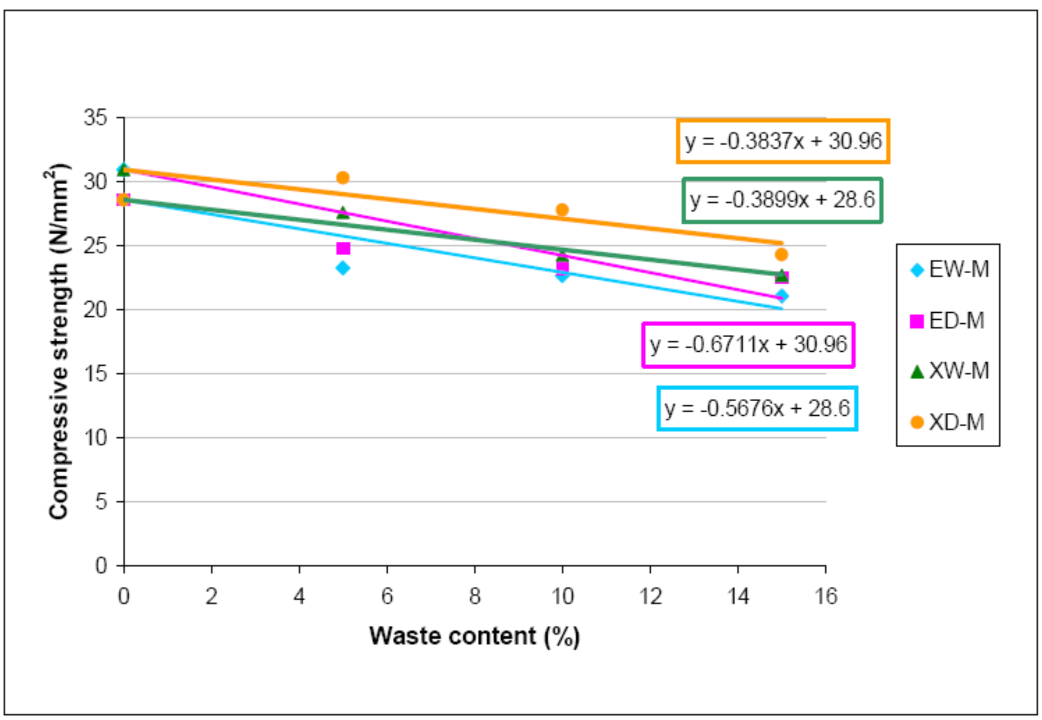

Figure 4.72: Compressive Strength of Modified Mortar to Waste Content in Linear Relationship after 28 days

4.3.8 Mortar Cylinder Compression Test: Elastic Properties

When a specimen is subjected to a load, it deforms. The change in length resulted from the applied load depends on the magnitude of the load and the properties of specimen. The modulus of elasticity of mortar cylinders, which represents the slope of the elastic portion of the stress-strain diagram, depends primarily on the modulus of the aggregates, modulus of the paste and the relative amount of aggregates and paste in the mix.

4.3.8.1 Secant Modulus

Stress-strain relationship of secant modulus mortar cylinders are shown in Table 4.16 and Figure 4.73 to Figure 4.76. The stress-strain relationship of mortar cylinders were obtain from 1/3 of it failure strength of P0-M E5-M E10-M E15-M, X5-M X10-M E15-M. The average secant modulus of each sample was obtained from 3 specimens.

The tests are done on mortar cylinders cured in water at all ages showed lower secant modulus values by comparing to mortar cylinder cured in moist air. This is also same as result obtained by H.A. Toutanji (1996). At the early age of 7 days, the secant modulus of all specimens is lower compared to 28 days. Besides, modified specimens present in lower secant modulus than control specimens in both ages for wet curing method. Samples contained with XLPE possess the lowest strain especially in amount of 10% at the early stage and 5% at the final stage. In another words, an increase in elastomer percentage added reduced the secant modulus of the sample in both parameters. The effect of waste becomes more significant using wet curing method; secant modulus tends to decrease with waste content.

Table 4.16: Secant Modulus of Sample in Both Curing Conditions and Both Ages

Sample	7days		28 days	
	Wet curing	Dry curing	Wet curing	Dry curing
P0-MC	1920	2260	2230	2270
E5-MC	1870	1950	1900	2150
E10-MC	1440	1920	1570	2000
E15-MC	1320	1680	1470	1960
X5-MC	1160	1940	1260	1920
X10-MC	1090	1570	1870	2200
X15-MC	1450	1600	1880	2080

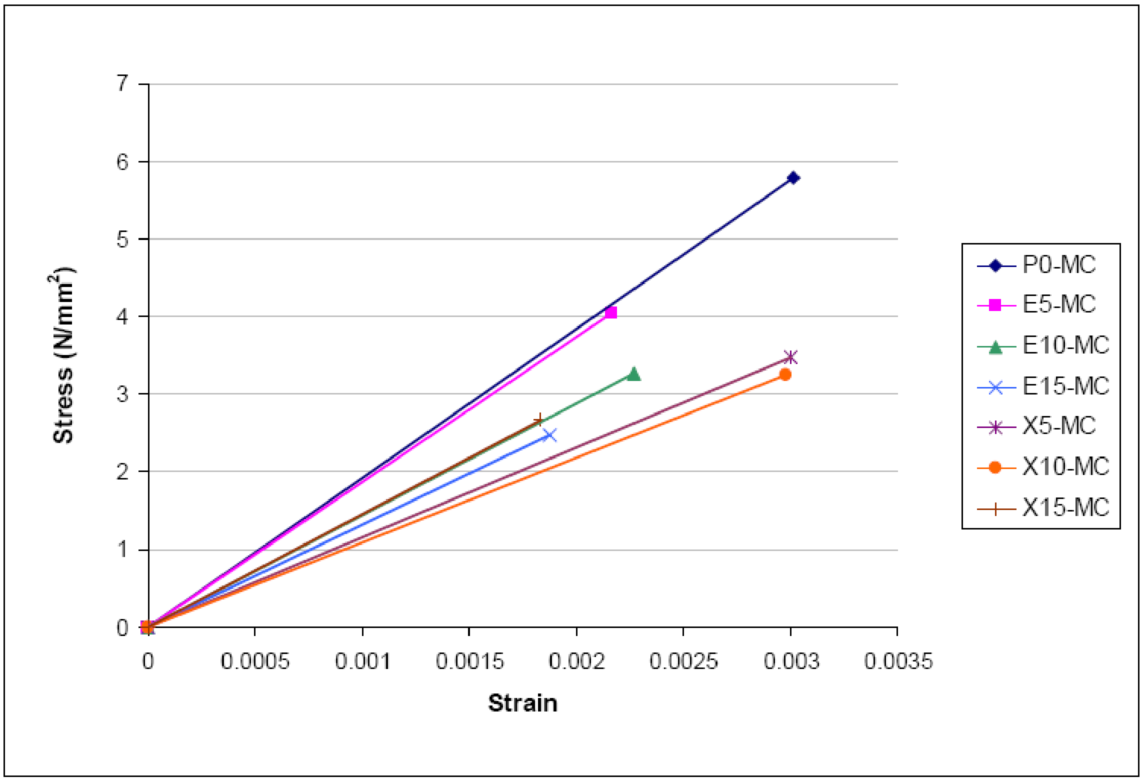

Figure 4.73: Stress-Strain Relationship of Mortar Cylinder in Compression with Wet Curing after 7 days

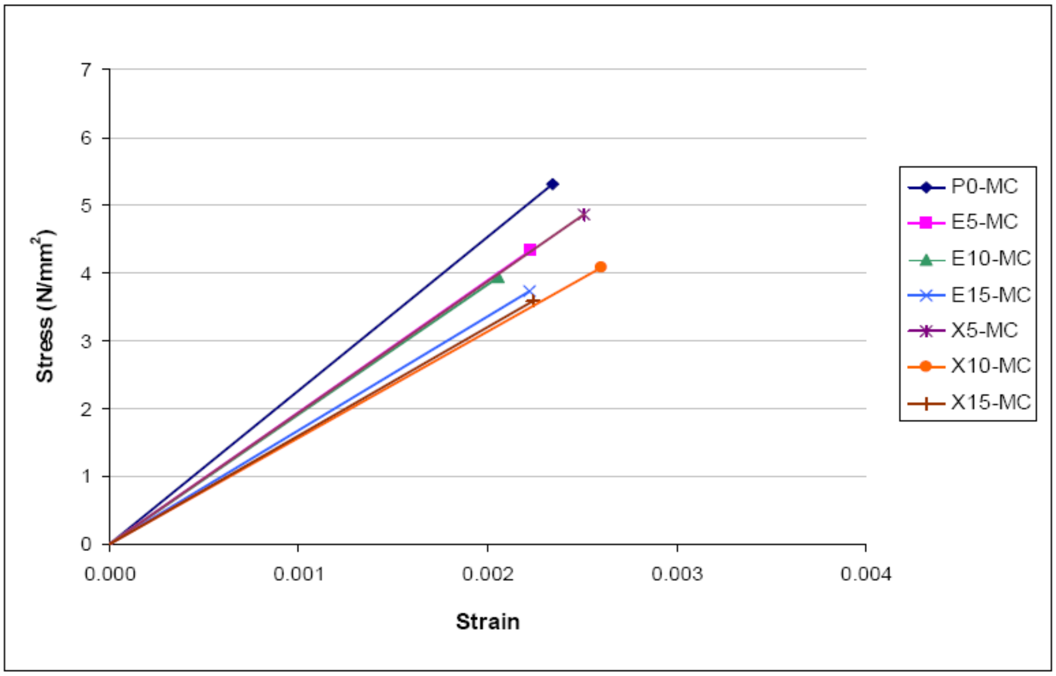

Figure 4.74: Stress-Strain Relationship of Mortar Cylinder in Compression with Dry Curing After 7 Days

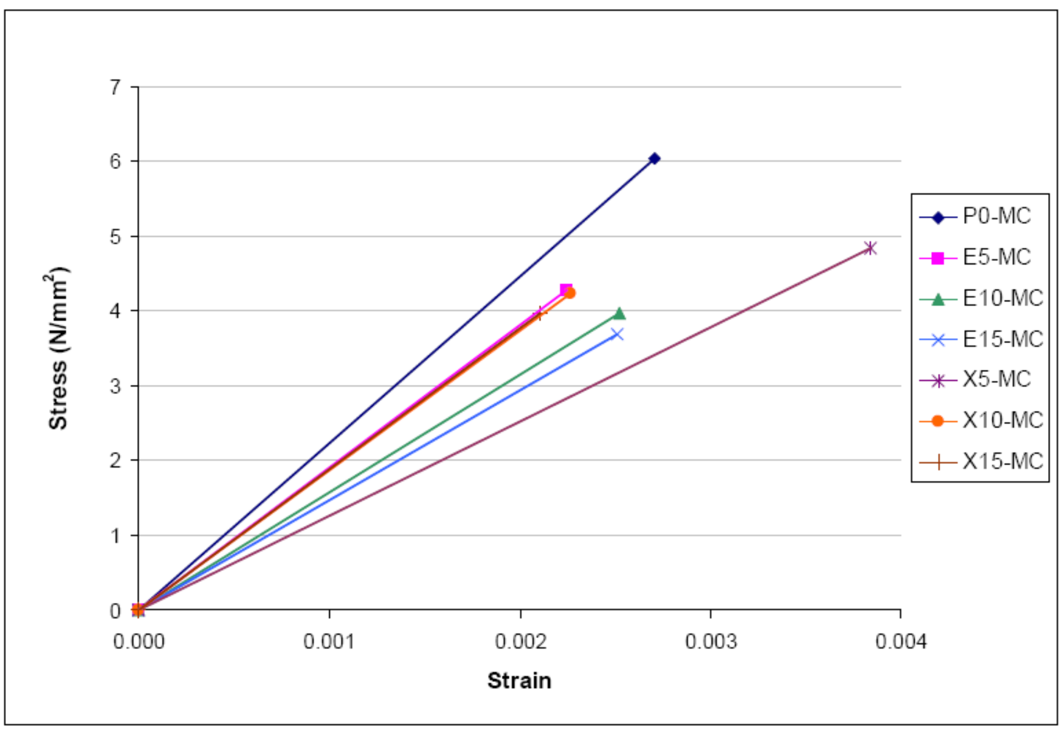

Figure 4.75: Stress-Strain Relationship of Mortar Cylinder in Compression with Wet Curing After 28 Days

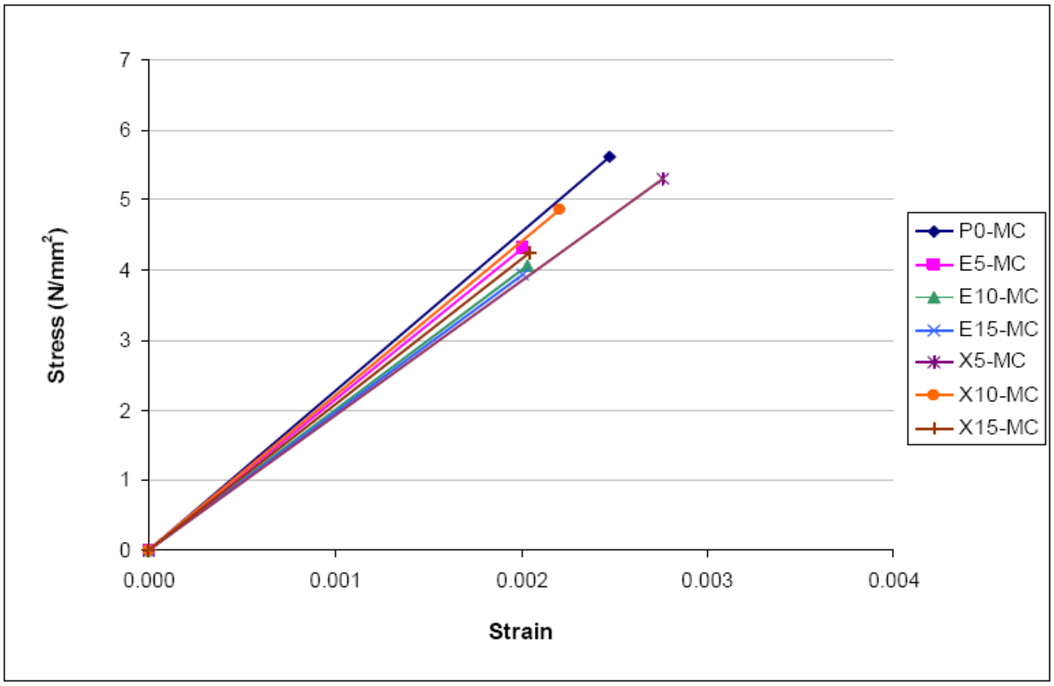

Figure 4.76: Stress-Strain Relationship of Mortar Cylinder in Compression with Dry Curing After 28 Days

4.3.8.2 Stress-Strain Relationship until Failure

Figure 4.77 to Figure 4.78 show the stress-strain relationship until failure of all specimens after 28 days in both curing conditions. Ordinary mortar shows sharp peak at the failure point while others modified mortar showed curve at the peak. This means that the failure of specimens containing elastomer and XLPE exhibited a more ductile behaviour compared to control specimens. The explanations are the specimens have a higher capacity to absorb energy. Before reach failure point, modified mortars reviewed many small cracks on the surface. When the cracks reached the waste particles, the waste particles tend to prolong a portion of the applied load because of their low elastic properties which lead to increase in the area of the failure surface (H.A. Toutanji, 1996). Figure 4.79 and Figure 4.80 show the failure modes of the control and modified mortars.

They are capable of withstanding a measurable post failure loads and undergoing significant displacement.

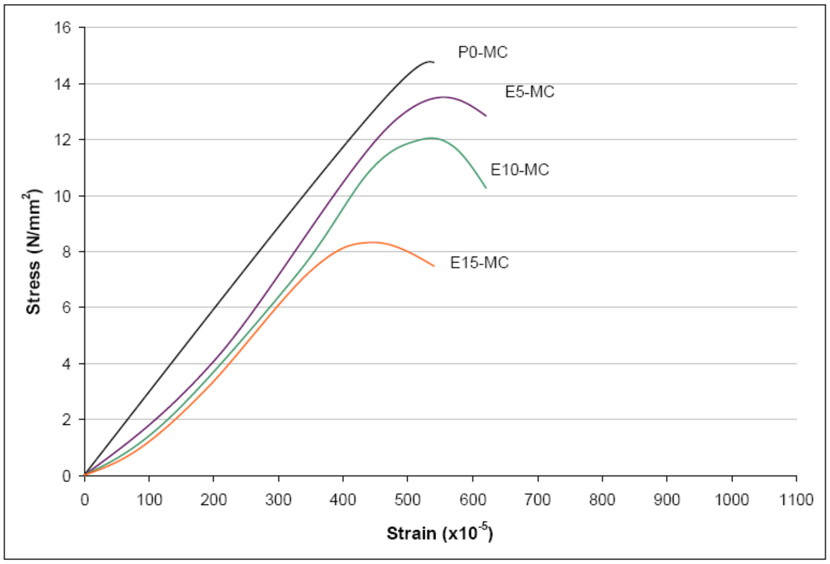

Figure 4.77: Stress-Strain Relationship until Failure of Ordinary Mortar Compared to Modified Mortar Contained Elastomer with Wet Curing After 28 Days

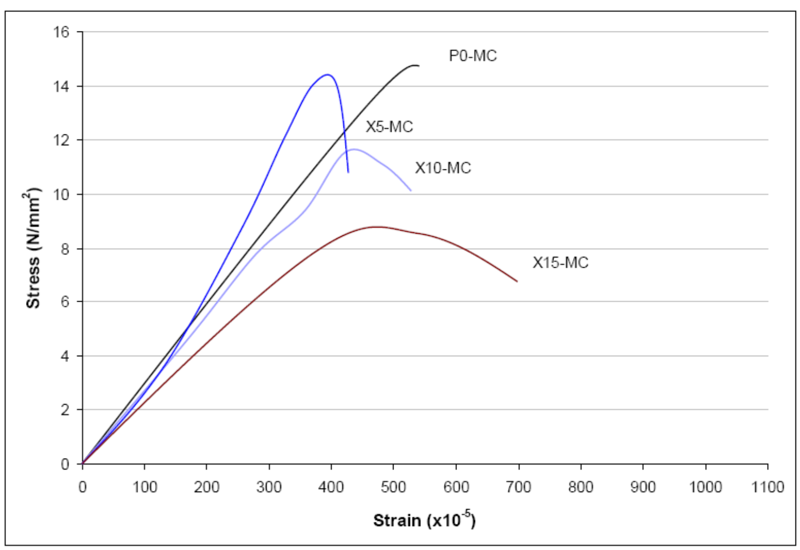

Figure 4.78: Stress-Strain Relationship until Failure of Ordinary Mortar Compared to Modified Mortar Contained XLPE with Wet Curing After 28 Days

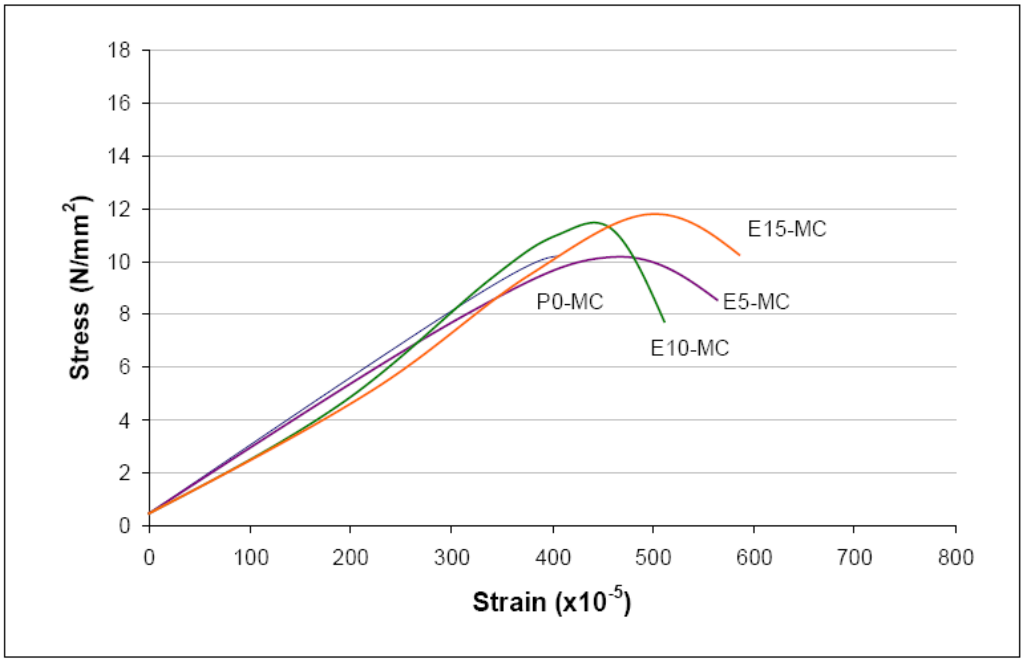

Figure 4.79: Stress-Strain Relationship until Failure of Ordinary Mortar Compared to Modified Mortar Contained Elastomer with Dry Curing After 28 Days

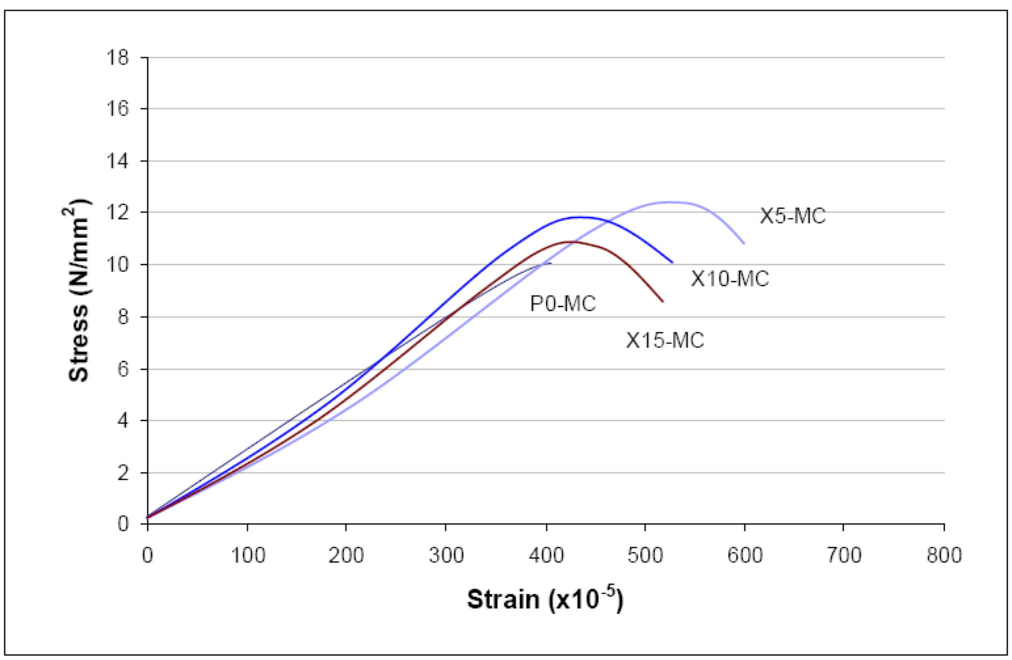

Figure 4.80: Stress-Strain Relationship until Failure Of Ordinary Mortar Compared to Modified Mortar Contained XLPE with Dry Curing After 28 Days

Figure 4.81: Failure Mode of Elastomer Modified Mortar Compared to Ordinary Mortar

Figure 4.82: Failure Mode of XLPE Modified Mortar Compared to Ordinary Mortar

4.3. 9 Properties of Fresh Concrete with Plastic Waste

Based on the observation on the fresh concrete mix containing 10% of plastic waste and control, in terms of its physical appearance, the difference can be seen when plastic waste is added. The plastic waste is brownish in colour, so it changes the colour of the concrete mix which is grey in colour to a more brownish colour. The colour change is much more obvious when a higher dosage as much as 30% of plastic waste is added into the mix. In terms of its reaction towards water, plastic waste does not mix well with water. It is as if the plastic waste does not allow water to react with the cement. Water seems to float on the mixture for a while before being able to mix with cement. This problem was solved by mixing the cement, plastic waste, and aggregates well before adding water. Furthermore, in terms of its workability, concrete mix with 10% plastic waste has better workability compared to mixes with 20%, 30% and 50% based on the slump test done. This is expected as the plastic waste does not allow water to mix well with cement, thus reduces the workability. It is important for water to mix with cement to help increase the workability. Overall, the slump of fresh concrete containing plastic waste is slightly lower compared to the slump of fresh control concrete. Low workability leads to difficulty in compaction of fresh concrete.

4.3.10 Environmental Effects

4.3.10.1 Compressive Strength after 7 days

The compressive strength of concrete cubes containing plastic wastes and the controls (without plastic wastes) after 7 days is shown in Figure 4.83 and Table 4.17.

For cubes containing plastic wastes, when compared to the strength of cubes exposed to the indoor environment, 13.55N/mm^2 (Also functioning as the control environments) showed higher strengths ranging from 14.37N/mm^2 to 17.48N/mm^2. Whereas cubes exposed to the alkali environment, NaOH, shows the highest strength which is 17.48N/mm^2. When comparing normal concrete cubes (The control which is cubes without plastic waste) in terms of strength to the strength of cubes exposed to INDR, 33.88N/mm^2 (which also at the same time acts as the control environment), the difference in strength is obvious especially cubes exposed to the outdoor environment, OUTDR, with strength at 26.54N/mm^2. The highest strength shown came from cubes exposed to the water environment, WTR. By comparing the concrete cubes containing plastic wastes to the controls, the strengths of concrete cubes containing plastic wastes were very low compared to the controls, where a difference as much as 61.39% was exhibited by cubes exposed to WTR. The lowest difference observed came from cubes exposed to OUTDR with a difference of 42.43%.

Table 17: Compressive Strength of Concrete Containing Plastic Wastes and the Control After 7 Days

Environment	7 – day Compressive Strength (N/mm^2)				Percentage of Difference As Compared to Concrete Cubes Without Plastic Waste (%)
	Concrete cubes with plastic waste		Concrete cubes without plastic waste		
	Compressive Strength, (N/mm^2)	Percentage of Difference As Compared to INDR (%)	Compressive Strength, (N/mm^2)	Percentage of Difference as Compared to INDR (%)	
HCL	15.57	14.91	33.07	-2.39	-52.92
NaOH	17.48	29.00	32.08	-5.31	-45.51
WTR	14.37	6.05	37.22	9.86	-61.39
INDR (Control)	13.55	0	33.88	0	-60.01
OUTDR	15.28	12.77	26.54	-21.66	-42.43

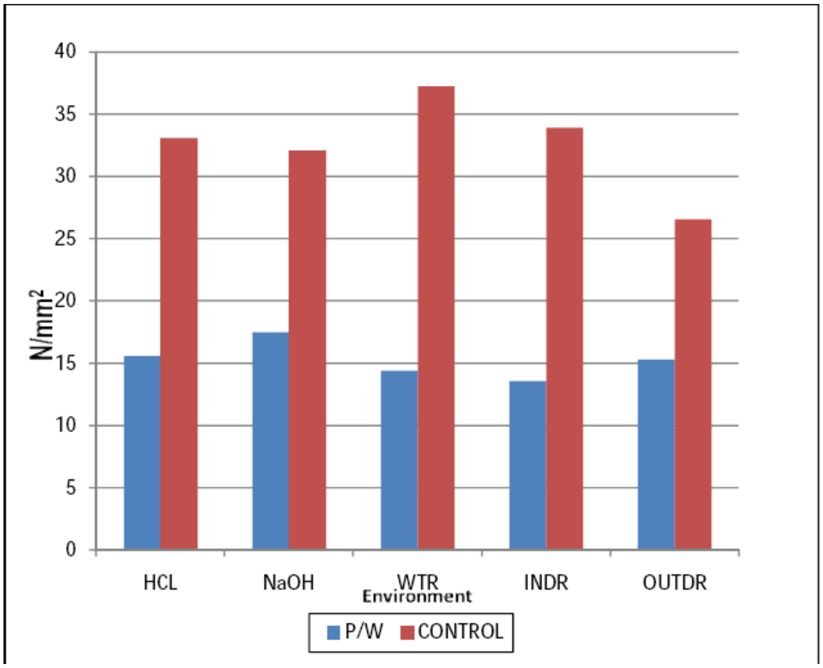

Figure 4.83: Compressive Strength of Concrete Containing Plastic Wastes and the Control After 7 Days

4.3.10.2 Compressive strength after 28 days

The compressive strength of concrete cubes containing plastic waste and the controls (concrete cubes with plastic wastes) after 28 days is shown in Table 4.18 and Figure 4.84. By comparing cubes containing plastic wastes and cubes exposed to INDR with strength, 17.88N/mm^2 which at the same time acts as the control, their strengths did not differ much and ranged from 17.88N/mm^2 to 21.01N/mm^2. Cubes exposed to WTR which is wet curing showed the highest improvement at 21.01N/mm^2 from the previous 14.37N/mm^2 at 7 days and also relatively showing the highest improvement after 28 days. Besides that, for the normal concrete cubes which are cubes without plastic wastes, when compared to the strength of cubes exposed to INDR, 33.39N/mm^2 (which at the same time acts as the control environment), the difference in strength was more obvious where the strength ranges from 29.86N/mm^2 to 44.23N/mm^2. The highest strength was exhibited by cubes exposed to WTR with strength of 44.N/mm^2. Lastly, by comparing concrete cubes containing plastic wastes to the controls, the strengths of cubes containing plastic wastes increased in strength but not even one exceeded the strength of controls even after 28 days.

Table 4.18: Compressive Strength of Concrete Containing Plastic Wastes and the Control After 28 Days

Environment	28 – day Compressive Strength (N/mm^2)				Percentage of Difference As Compared to Concrete Cubes Without Plastic Waste (%)
	Concrete cubes with plastic waste		Concrete cubes without plastic waste		
	Compressive Strength, (N/mm^2)	Percentage of Difference As Compared to INDR (%)	Compressive Strength, (N/mm^2)	Percentage of Difference as Compared to INDR (%)	
HCL	15.57	12.08	33.07	13.27	-47.01
NaOH	17.48	6.04	32.08	5.63	-46.24
WTR	14.37	17.55	37.22	32.37	-52.50
INDR (Control)	13.55	0	33.88	0	-46.45
OUTDR	15.28	7.44	26.54	-11.11	-35.28

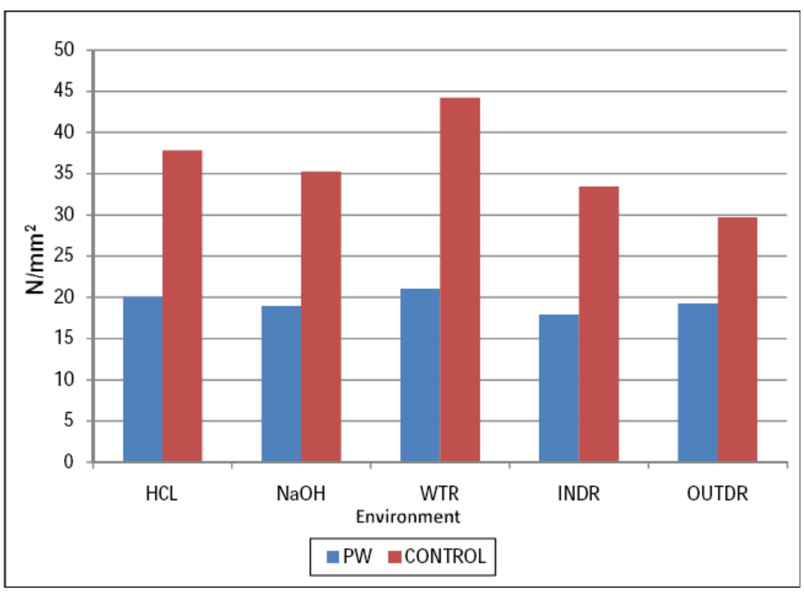

Figure 4.84: Compressive Strength of Concrete Containing Plastic Wastes and the Control After 28 Days

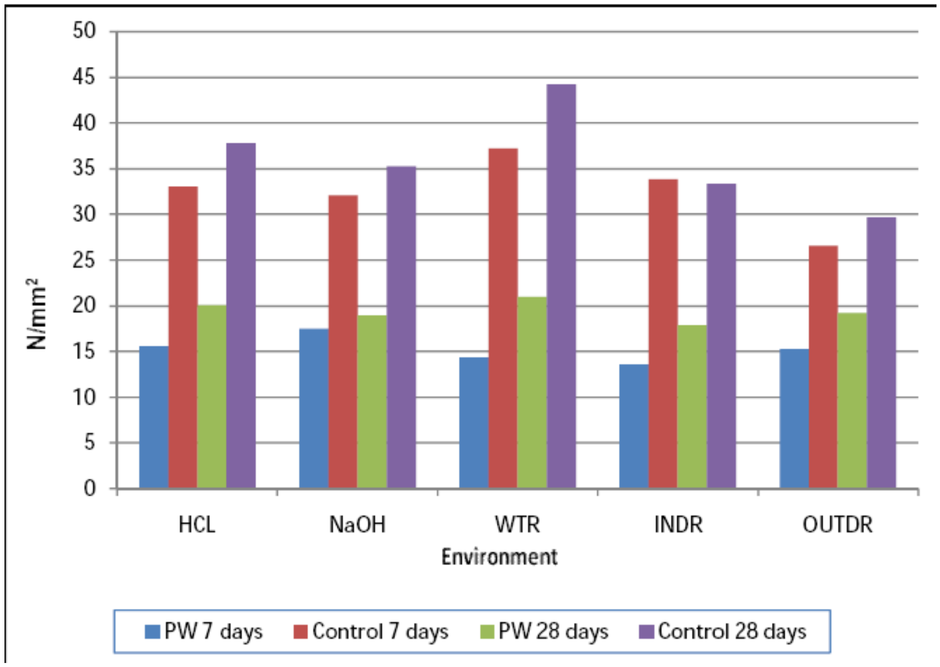

Figure 4.85: Compressive Strength of Concrete Containing Plastic Wastes and the Control After 7 and 28 Days

4.3.10.3 Effects of Plastic Waste on the Performance of Concrete

After tests were done on the concrete cubes containing plastic wastes and control after 7 and 28 days of curing, results from Figure 4.83, Figure 4.84, and Figure 4.85 were graphically analyzed to see how plastic waste affects the performance of concrete. It appears that the use of plastic waste in concrete has decreased in its compressive strength in all ages and environments by almost half of the strength of the normal concrete cubes. By comparing the compression results of concrete cubes containing plastic wastes on the 7th and 28th day of curing of cubes left in the WTR environment, the results shows the best improvement. This is probably because it is left to continue the hydration process which is the same as wet curing where the compressive strength, water tightness and durability is acquired through proper curing. But still, the strength acquired did not achieve the target strength and did not exceed the control cubes strengths. Furthermore, concrete cubes containing plastic wastes under all environments developed their strengths under a consistent manner and the increment in strength was not that drastic. For the normal concrete cubes, the increase in strength was consistent as the gap between the highest and lowest strength is not that obvious. Even said so, for the indoor environment which is also the control for the environments there is a decrease in strength but a very slight decrease and almost maintaining the same strength as the 7th day of curing. This shows that without the use of plastic waste in concrete, there is no difference in strength development from the 7th day to the 28th day.

With that, it can be concluded that plastic wastes used in this research does not improve the compressive strength of concrete. Factors which causes the weakness is probably because of how the plastic waste reacts when it is mixed with water. It repels the water added to the mix thus causing the water used to not mix well with the cement and retards the hydration process. It is speculated that the concrete mixed with plastic waste might get its strength later, where it could develop late strength. But after 28 days, the strength obtained still did not reach the desired strength. The fine particles of the plastic waste was thought to be able to help fill up the voids in the concrete cubes and help make the concrete denser and altogether exhibit higher compressive strength. But all that was not achieved and the real cause to why it did not achieve what was speculated should be investigated.

4.3.10.4 Effects of Environments on the Compressive Strength of Concrete Containing Plastic Waste

After discussing the effects of plastic waste on the strength of concrete cubes, it is clearly shown that it does not help in improving the strength of concrete cubes. But before concluding anything, the effects of environments on concrete containing plastic waste need to be analyzed. The exposure of the concrete cubes for 7 and 28 days to the environments does not affect the compressive strength of the concrete containing plastic waste. The graphs from Figure 4.86 to Figure 4.90 show how the strength development of concrete is affected under different kinds of environment.

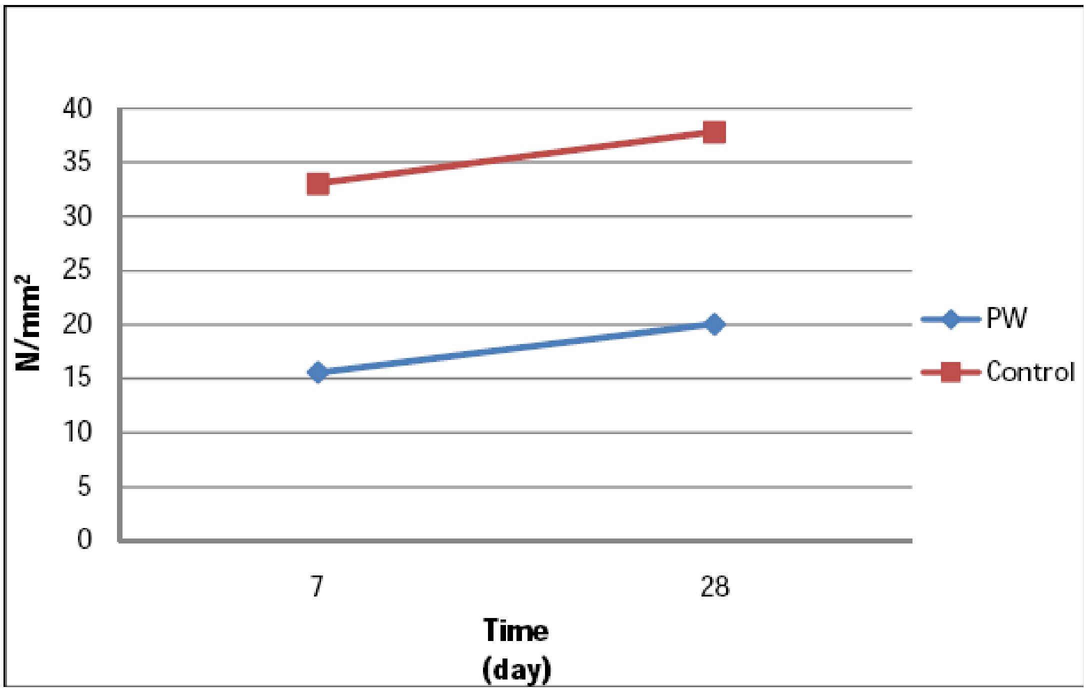

Figure 4.86: Strength Development of Concrete Containing PW and the Control in the Acidic Solution (pH 2)

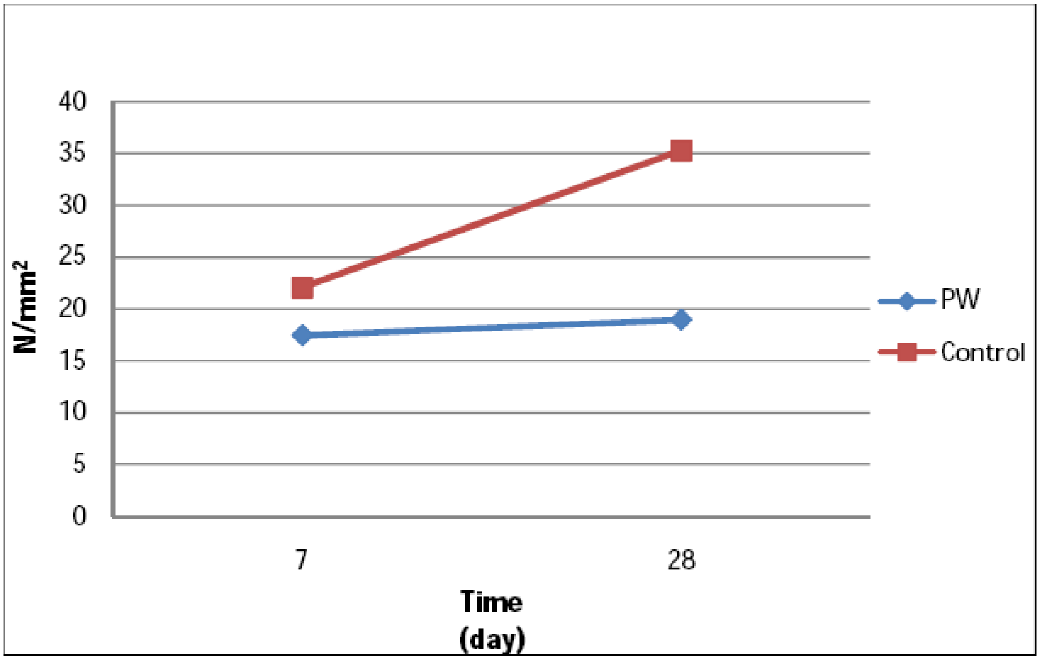

Figure 4.87: Strength Development of Concrete Containing PW and the Control in the Alkaline Solution (pH 12)

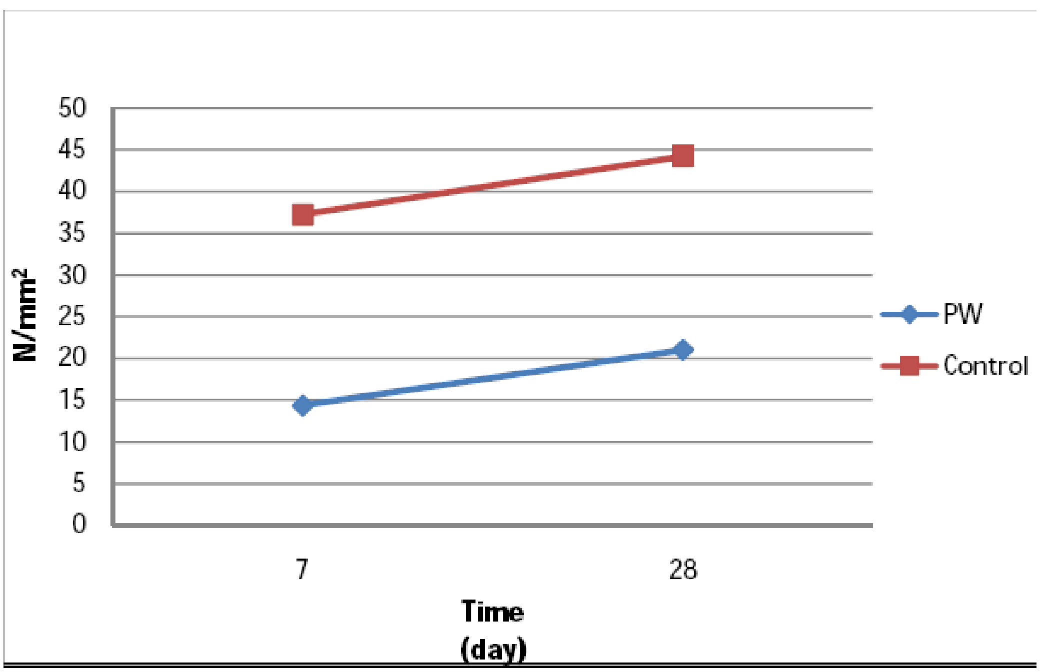

Figure 4.88: Strength Development of Concrete Containing PW and the Control in the Water Environment

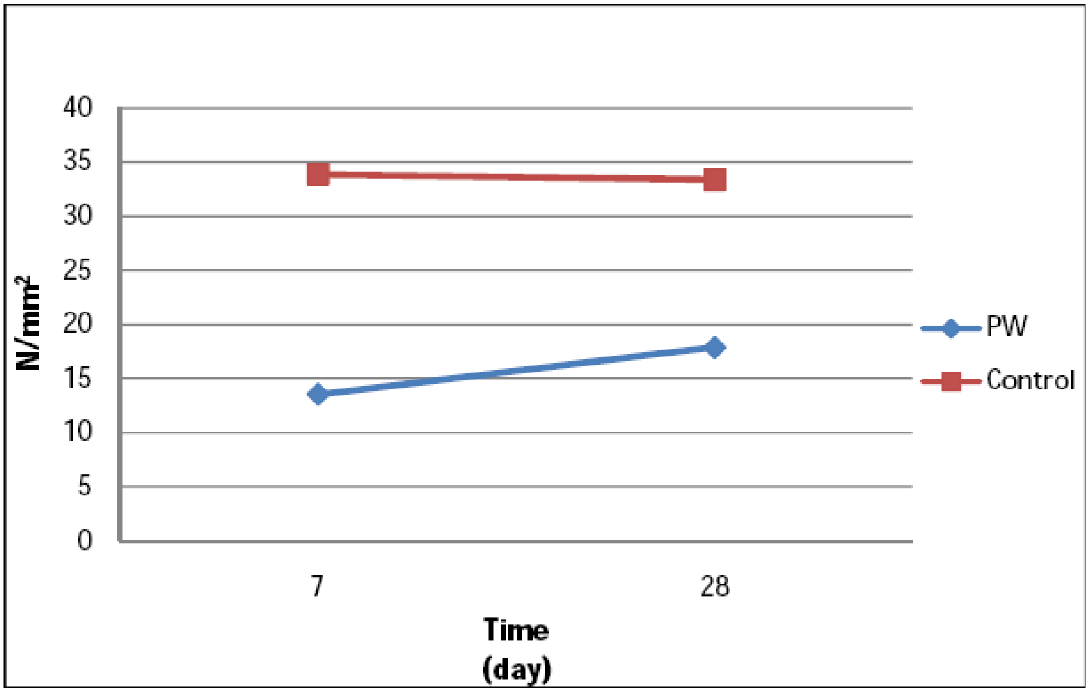

Figure 4.89: Strength Development of Concrete Containing PW and the Control in the Indoor Environment

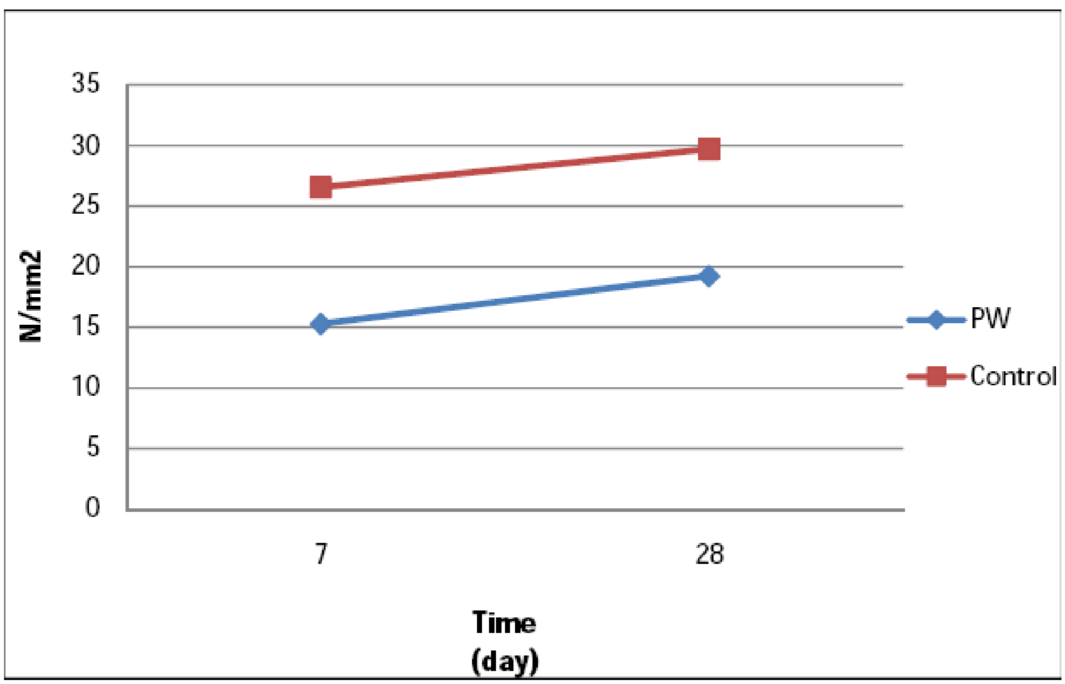

Figure 4.90: Strength Development of Concrete Containing PW and the Control in the Outdoor Environment

Concrete that has been exposed to the WTR environment shows the highest strength development compared to the other environments which is INDR, OUTDR, HCL and NAOH. The increase in strength for all the concrete cubes with plastic wastes under all environments was at a constant rate but concrete cubes with plastic wastes exposed to the alkaline environment did not show much increment from 7th to the 28th day compared to the other environments. The same goes to the normal concrete cubes where all the strength obtained were increasing at a constant rate but only for the INDR environment, there is a slight drop during the 28th day compressive strength result. No matter what, the strength of concrete containing plastic wastes kept on rising but still did not exceed the normal concrete cubes strengths. The highest increment came from concrete cubes exposed to the alkaline environment. Decisively, the concrete containing plastic wastes does not perform well under compression but under the environments, it shows constant increase in strengths especially in the OUTDR where the strength constantly increased but the normal control cubes did not increase as high as the other normal concrete cubes exposed to the other environments. With that, concrete containing plastic waste can be considered as a less reliable material as the strength does not exceed any of the strength of the control cubes, but shows some improvement under environments such as the OUTDR. To determine the environment where concrete containing plastic waste will be the best construction material to be used in, it should be the one where the normal concrete performs at is worst's and the concrete containing plastic wastes at its best, but there are no results coming from both the 7th and 28th day of curing. As a result, the OUTDR is where the concrete containing plastic waste performs at its best when compared to the control.

4.3.11 Trial Concrete Cube with Plastic Waste Testing under High Temperature

This test was obtained to find the optimum strength for different percentage (%) of plastic waste in concrete. The test had been done in 2nd of February 2009 to find the maximum strength of concrete. This test will be the asses for the whole testing in comparison between controls concrete (0% plastic waste) and concrete with plastic waste. Design mixture for the concrete is by volume, and the percentage of concrete test is 10, 20, 30 and 50 percent of fine aggregates. After 7 days, the strength of concrete cube was showed in table 4.4 and Figure 4.6.

Table 4.19: Strength of Concrete with Plastic Waste in 7 Days of Age

Plastic waste in concrete (%)	strength after 7 days of curing (N/mm^2)
10	22.76
20	12.11
30	6.57
50	0

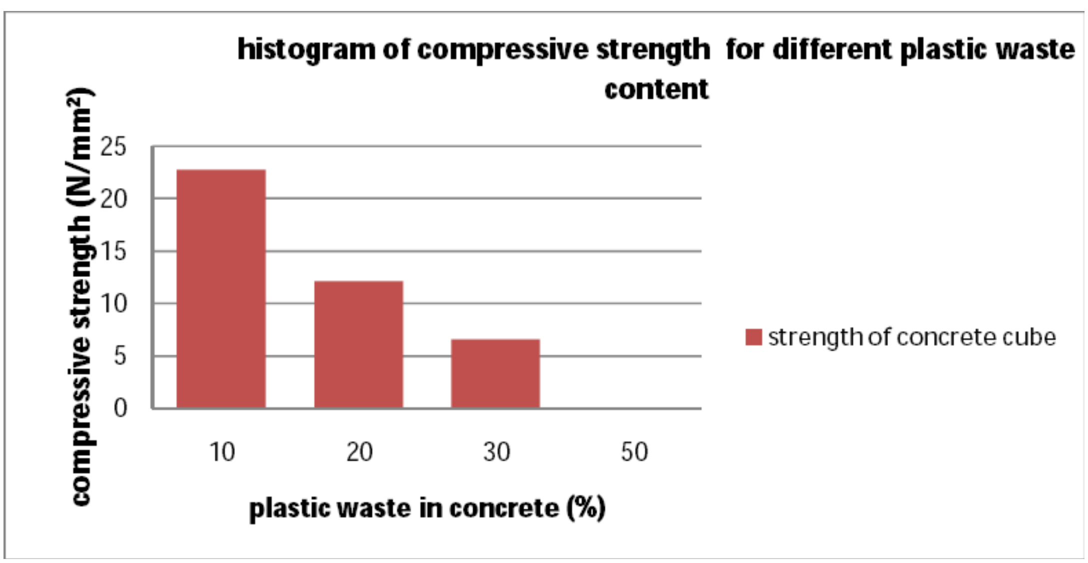

Figure 4.91: Strength of Concrete for Different Plastic Waste Content

From table 4.5 and figure 4.1, overall result proved that 10% of plastic waste content in concrete is the best strength after 7 days. The strength is 22.76 N/mm^2, more than 2/3 strength of ordinary concrete and trial concrete cube. 2/3 strength of ordinary design for 28 days is 20 N/mm^2 and the trial shown 21.3 N/mm^2 of strength. It is an impressive strength and my prediction is that the strength will be increase more than control cube, in 28 days of age. In 20% plastic waste content, 12.11N/mm^2 compressive strength recorded. Only 6.57 N/mm^2 of compressive strength shows in 30% plastic waste sample. The 50% content of plastic waste is not tested because the concrete is totally crushed and melt in the curing basin. All three samples that show lower compressive strength than 20 N/mm^2 proved that the overdose amount of plastic waste in concrete weaken the concrete strength. This is because the plastic waste is not react with cement and the increasing amount of plastic waste are decrease the amount of fine aggregates. After getting the result, 10% plastic waste content in concrete will be the parameter for in this research. This is the parameter of plastic waste content in concrete that will be comparing with ordinary concrete under high temperature.

4.3.11.1 Observation on Fresh Concrete

Figure 4.92: Properties of Concrete Mixture with 10 % Plastic Waste

Figure 4.93: Properties of Concrete Mixture without Plastic Waste (control)

Figure 4.92 and figure 4.93 was showed the different of fresh concrete between concrete with plastic waste and control concrete (without plastic waste). After the concrete materials shuffle, the mixture without plastic waste is better in workability, compare with the additional polymer. This is proving that the properties of polymer 49 are absorbing water faster than the cement. It is very important for the cement to react with water for workability, during mixture. That's why when done mixing the concrete material, concrete need to be test with slump test. The result for control mixture is in range of good workability, but the mixture with plastic waste is not good. To get the good workability, I add more milliliter of water, until the concrete is in range of good workability, which is 60-180 mm of slump. There are also different in color of concrete, for control concrete, the color is as usually grey. But different with the plastic waste concrete, it seems like more brown with grey.

4.3.11.2 Observation on Hardened concrete.

Figure 4.94: Concrete in Room Temperature (left) and Concrete in High Temperature (right)

Figure 4.94 was showed hardened concrete in room temperature and the high temperature concrete. From that picture, it shown that the concrete in high temperature is whiter and free of water, compare with the room temperature condition. The result shows that, concrete with plastic waste will burn and flow its plastic waste, but what I get is the concrete is still same with the control. This was showed that the concrete is already united with the plastic waste, insufficient age. When the concrete is expose in high temperature, the binding in the material is begin to weak, that’s why the concrete with high temperature is usually begin to crack a little bit.

4.3.11.3 Compressive Strength Test Result

The result for compressive strength of this research has been achieved after 28 days of wet curing. This research is not obtain the other age of concrete such as 7 days and 56 days because it focus on different strength of concrete with plastic and without, under duration of expose in high temperature. Data taken from the compression equipment screen is in unit N/mm2. There are three test sample upon percentage of polymer, 0% and 10%, temperature and different duration of expose under high temperature. Data present in Table 4.20 and figure 4.6.

Table 4.20: Strength of Concrete Cube under High Temperature

temperature (°C)	30	50	100	200	500
control cube without plastic waste	37.12	33.22	30.69	22.26	27.01
cube with 10% plastic waste	22.34	17.2	18.11	13.6	18.73
percentage of different (%)	39.8	48	40.9	38.9	30.7

From table 4.20, the lowest percentage of different between plastic waste sample and control is 30.7% in 500oC. But the highest percentage of different was showed 48% in temperature 50 ^{0}C. This means plastic waste in that temperature decreasing effectively the compressive strength of concrete.

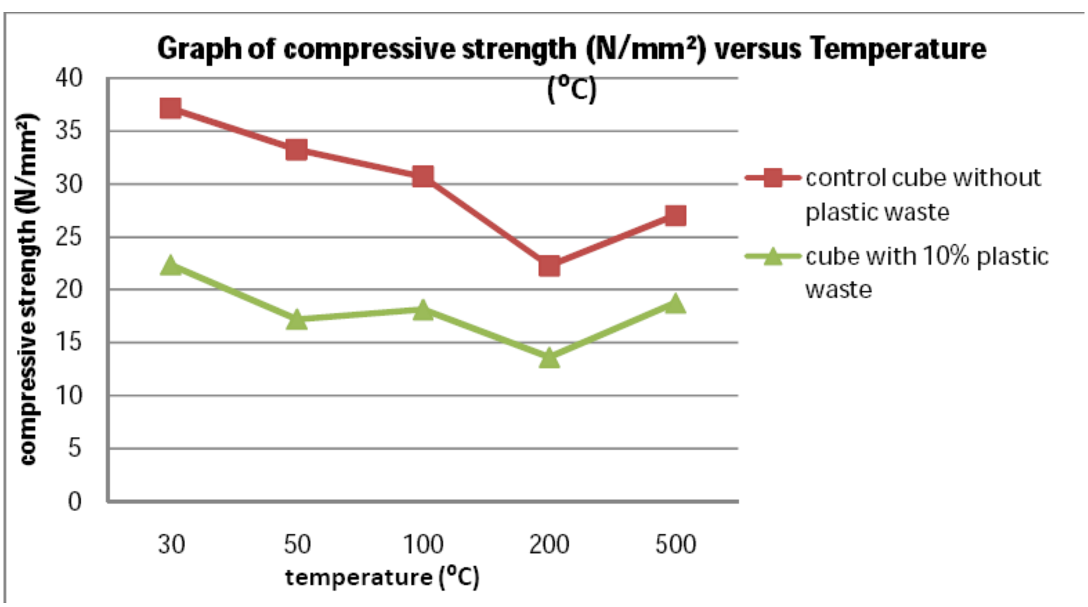

Figure 4.95: Strength of Concrete Cube under High Temperature

Figure 4.95 was showed for average strength for duration of exposes certain temperature (1 hour, 2 hour, and 3 hour). Overall result shows all strength for control concrete cube (without plastic waste is higher than cube with 10% plastic waste. The plastic waste sample is not achieving minimum compressive strength in 28 days, which is 30 N/mm2. This means that the plastic waste (rice wastes bio composite weaken the concrete cube strength. This shows that this test is failed to get the expected result, which is the composite strengthen the concrete. From the line graph of control cube, all strength of concrete is decrease when higher temperature is applied. But, different result for 500oC condition, the strength is higher than 200oC. This is different from research of Khoury (1999) that the temperature 200oC, shown strength of concrete will decrease when expose in higher temperature. Strength for concrete cube with 10% plastic waste also shown same pattern, but little bit different in 100oC, higher than 50oC. 100oC is the water boiling temperature, this maybe has dried the entire cube inside, thus produce more strength compare with lower temperature.

Table 4.21: Strength of Concrete under 50 ^{0}C Temperature

duration under 50°C temperature (hour)	1	2	3
Strength of control cube without plastic waste (N/mm^2)	34.7	34.5	30.47
Strength of cube with 10% plastic waste (N/mm^2)	19.78	15.81	16

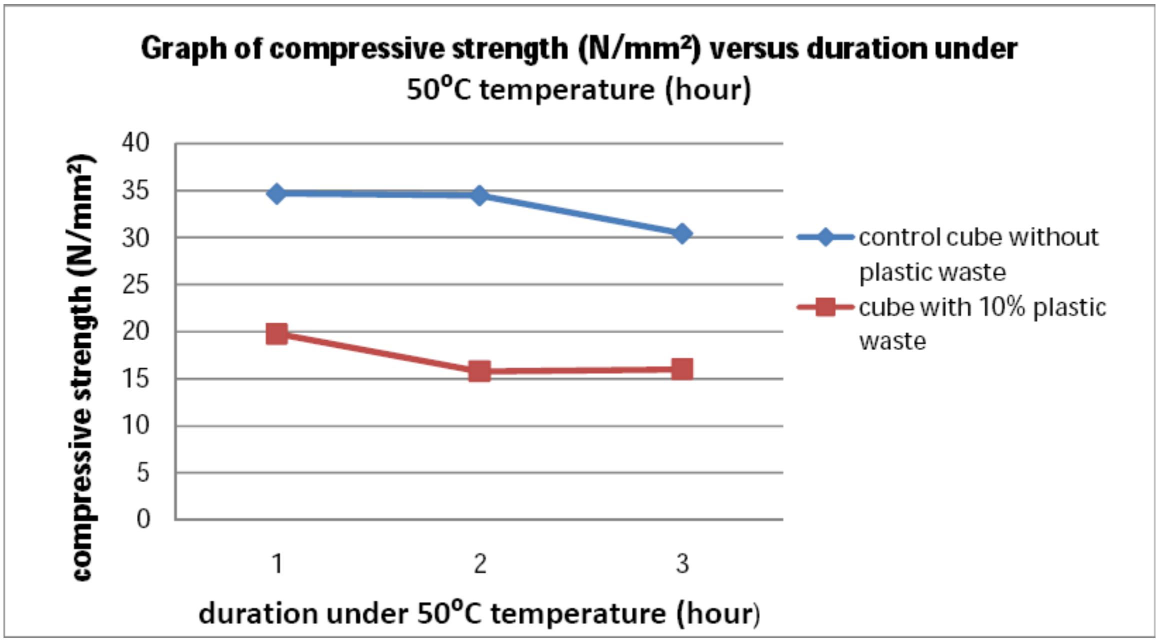

Figure 4.96: Strength of Concrete under 50 ^{0}C Temperature

The graph 4.96 was showed compressive strength versus duration under 50 ^{0}C temperature. The concrete cube for this temperature is place in oven (maximum temperature 200 ^{0}C). From what I can see, the result for this condition is not far different with room temperature, 30 ^{0}C; the control cube is higher strength than 10% plastic waste addition. In control cube, the strength is a little bit decrease when expose in 3 hour, compare with 2 hour. This is shown that the strength of concrete is starting to weaken, due to expanding of volume for the concrete cube. The expanding of volume will increase the void inside the concrete cube; therefore the strength will be weakening. The strength of concrete cube with 10% plastic waste is weaker than control, starting with 20 N/mm^2 in 1 hour expose. Then, the strength is slowly decrease, but seems maintain 16 N/mm^2 in 2 hour and 3 hour. From my opinion, the plastic inside, is starting to melt and cover the void inside the concrete cube. Strength of concrete will be increasing a little bit if the void inside decrease.

Table 4.22: Strength of Concrete under 100 ^{0}C Temperature

duration under 100^{0}C temperature (hour)	1	2	3
Strength of control cube without plastic waste (N/mm^2)	33.15	31.17	27.76
Strength of cube with 10% plastic waste (N/mm^2)	21.54	14.17	18.63

The graph in figure 4.97 was showed compressive strength (N/mm^2) of concrete cube versus duration under 100^{0}C temperature. From the expected result, control concrete cube is higher in strength compare with 10% plastic waste addition. The control concrete cube is decreasing in strength when expose in longer time, but not too obvious. But different case with cube with 10% plastic waste that the strength starts 22 N/mm^2 in 1 hour duration, decreasing to 14 N/mm^2 in 2 hour and increasing to 19 N/mm2 in 3 hour expose.100^{0}C is the boiling temperature for water. When exposed in longer duration, concrete starting to increase its compressive strength a little bit because all water inside is passed away from the concrete. Concrete with plastic waste is absorbing more water than control sample, when curing.

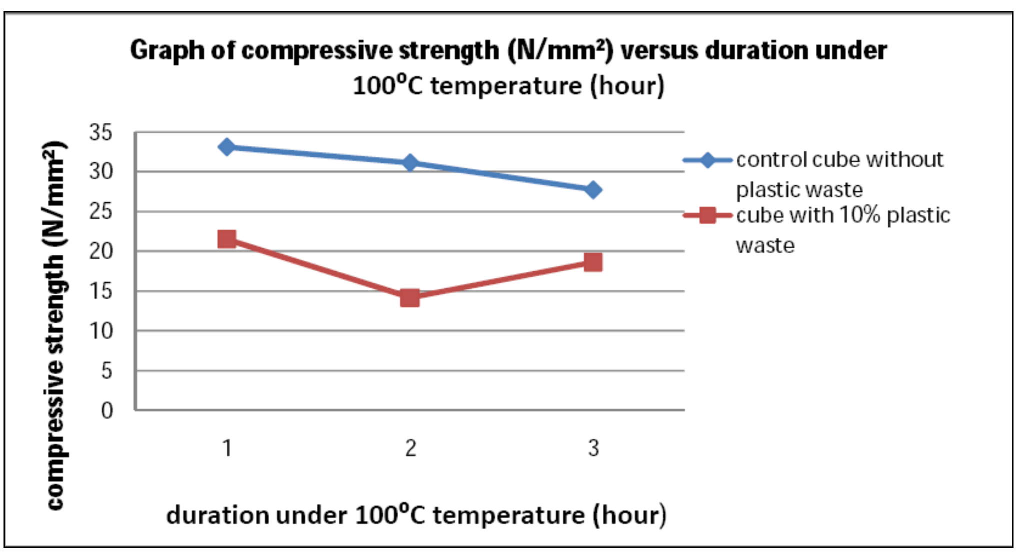

Figure 4.97: Strength of Concrete under 100 ^{0}C Temperature

There is also other reason why compressive strength in 3 hour is increasing under 100 ^{0}C temperature. The plastic waste inside starting to melt and provides more binder for the concrete. With the present of plastic waste, material inside concrete such as cement, fine and coarse aggregates starts to react. It gives extra glue and fills in the void inside concrete, thus give more strength to the concrete, even though its strength is lower than control concrete cube.

Table 4.23: Strength of Concrete under 200 ^{0}C Temperature

duration under 200^{0}C temperature (hour)	1	2	3
Strength of control cube without plastic waste (N/mm^{2})	24.06	20.92	21.8
Strength of cube with 10% plastic waste (N/mm^{2})	17.39	13.43	9.98

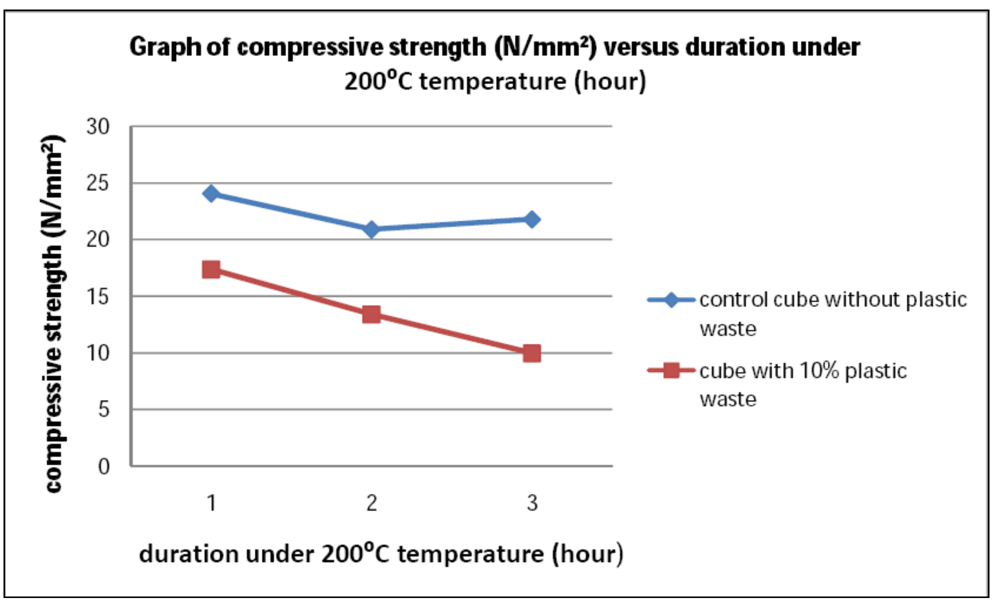

Figure 4.98: Strength of Concrete under 200 ^{0}C Temperature

The table 4.23 and graph 4.98 was showed compressive strength (N/mm^2) under 200 ^{0}C for 1, 2 to 3 hour of expose. From what I can see, the control concrete cube is higher strength for 1, 2, 3 hour; compare to 10% plastic waste. But, the strength for control cube, is not really same with normal, starting 24 N/mm^2 in 1 hour of expose, then decrease to 21 N/mm^2. For 3 hour of expose, the compressive strength is increase to 22 N/mm2. This is what I can predicted that the little increase is because the cube has lost the unwanted water inside cube; during curing, therefore strengthen the concrete a little bit. For 10% plastic waste, the line pattern is decreasing in linear form; starting from 17 N/mm^2 in 1 hour, 13 N/mm^2 in 2 hour and 10 N/mm^2 in 3 hour as expose. From the result, what I can say that the plastic waste is already melting and passed to the air produced more void to the concrete. With more void, the concrete is starting to decrease in term of strength and durability. If I resume the expose less than 4 to 5 hour, the strength will become so weak and maybe break/ fail automatically without compression test. This means that, if the concrete applied for construction, the structure will collapse when big fire is happened. Compared with other high temperature, 200 ^{0}C temperatures shows lowest compressive strength when tested.

Table 4.24: Strength of Concrete under 500 ^{0}C Temperature

duration under 500^{0}C temperature (hour)	1	2	3
Strength of control cube without plastic waste (N/mm^2)	23.5	27.75	29.78
Strength of cube with 10% plastic waste (N/mm^2)	15.31	22.1	18.77

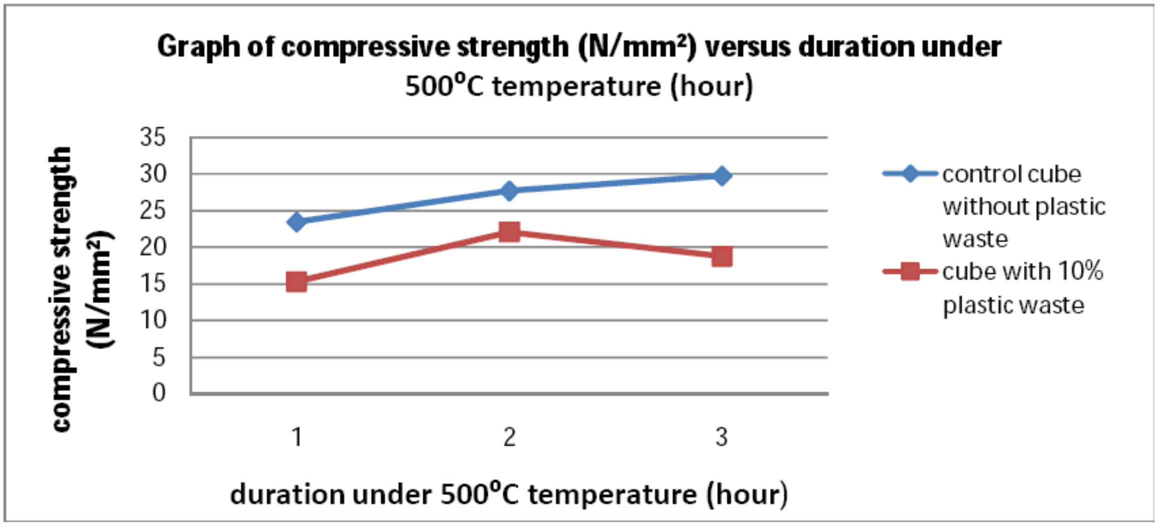

Figure 4.99: Strength of Concrete under 500 ^{0}C Temperature

The table 4.24 and graph in figure 4.99 was showed compressive strength under 500 ^{0}C temperature; for 1, 2 and 3 hour. The concrete cube is put into high temperature furnace; that can exceed 200 ^{0}C; with short period of time. From what the result shown, the control cube stills more strength than 10% plastic waste concrete. But, the pattern is different, compare with other temperature 50 ^{0}C, 100 ^{0}C and 200 ^{0}C. From this result, the strength of concrete is increase when expose longer, for control cube, 23 N/mm^2 in the 1$_{st}$ hour, to 28 N/mm^2 in the 2$_{nd}$ hour until 30 N/mm^2 in 3$_{rd}$ hour. From this result, I can analysis that the strength of concrete increase, due to expanding size of particle inside concrete, such as coarse and fine aggregate. When the particle increase it volume, the void inside will passed away from the concrete cube, this will give more compact concrete. Therefore higher strength of concrete will be produced. For concrete with 10% plastic waste, the line pattern is a little bit different with the control concrete. The strength of concrete starting with 15 N/mm^2 in 1 hour, increasing to 22 N/mm^2 in 2 hour; but decreasing to 18 N/mm^2 in 3 hour. In my opinion; the increasing shown in 1-2 hour is same reason with control; but the third hour decreasing; proved that the plastic waste is melt. After that it will scatter to the outside of concrete, therefore producing more voids. This means the concrete will loss it strength and durability.

CHAPTER 5

CONCLUSION AND RECOMENDATION

5.1 Conclusions

All the outputs and results of which have been introduced in this research. Based on the test result, the following conclusions can be drawn.

5.1.1 Admixture Based on Effective Microorganisms

With the understanding acquired from the literature reviews and also the experiment, a few conclusions can be drawn from this study. The conclusions are:

i. Cubes with EM – AS percentage lower than 30% recorded higher average compressive strength than control. While, the average compressive strength for cubes with 30% and greater EM – AS were lesser than control.

ii. Among all cement cubes with same water cement ratio, cubes with 10% EM – AS exhibited the highest compressive strength.

iii. In other hand, mortar cubes with 5% EM – AS showed the highest compressive strength value.

iv. From chemical analysis, it was proven that EM is inert. Thus it does not change nor affect the chemical properties of the cubes.

v. All the cubes were not suitable for wet curing method as they tend to dissolve in the water.

vi. In order to produce standard mix of cement paste, the water weight should be 35%from the dry cement weight.

vii. Meanwhile, the amount of EM –AS in standard mix was 32.7% from the dry cement weight.

viii. For all type of mixing, dry curing method showed that the compressive strength higher than wet curing method

ix. At the replacement of 10 % mixing water with EM-AS, the fresh concrete containing EM does not differ much than the fresh normal concrete in terms of physical appearance.

x. At the replacement of 10 % mixing water with EMAS, the rate of hardening of the fresh concrete containing EM is slower due to the molasses which acts as a retarder. It takes at least three days to harden completely.

xi. The effects of using EM in concrete are increment in compressive strength and better durability. A new substance is expected to be produced from the reaction between the alkaline cement paste and the acidic EM-AS, which contributes to the improvement. Other expectation is that the EM will use up the air for its aerobic activities which will result in denser concrete.

xii. Concrete containing EM is not suitable to be used in marine environment because the deterioration is worse than the normal concrete.

xiii. The alkaline environment is the friendliest environment for both types of concrete. In long-term consideration, both types of concrete can achieve higher strength in this environment than in other environments. The acidic environment is the best environment where concrete containing EM performs outstandingly as compared to the normal concrete. In this adverse environment, the concrete containing EM still manages to develop its strength when the strength of the normal concrete begins to drop drastically

5.1.2 Material Based on Industrial Waste

All conclusions stated upon here are based on the objectives and observations done throughout this study. The conclusions are being drawn from this study are follows:

i) Density of modified concrete decreased with the increment waste added percentage due to replacement of some higher density constituent, sand in concrete mix. The reduction can reaches approximately 8.4% compared to plain concrete.

ii) The substitution in fine aggregate with XLPE plastic waste in concrete results a reduction in compressive strength as the content of XLPE waste increased.

iii) Once the fine aggregate substituted with XLPE plastic waste increased from 0% to 30% the flexural strength and rapture modulus of this modified concrete slightly decreased respectively. For a given composition of 30% sand replacement, this decrease reaches about 72.4%.

iv) The XLPE concrete presents the higher flexibility characteristic with lower Young's modulus in compression compared to stiff ordinary concrete.

v) More ductile behavior is observed for XLPE concrete compared to plain concrete specimens under compression testing. Unlike plain concrete, the failure state in XLPE concrete does not occur quickly and does not cause any detachment in specimen's elements. Crack width in XLPE concrete is smaller than that of plain concrete and the propagation of failure symptoms is more gradual and uniform. The failure state in XLPE concrete compared to control concrete us characterized by more deformation.

vi) The 30% substitution of fine aggregate with plastic is proposed in order to give the higher value of elasticity and ductile behavior to the concrete mix.

vii) Density of modified mortar decreased with the increment waste added percentage in both wet and dry curing conditions due to the replacement of some higher density constituent, sand in mortar mix. The reduction can achieve about 17% to ordinary mortar for 15% addition both wastes respectively under wet curing condition.

viii) Cement paste contain higher percentage of both wastes respectively require higher water content to achieve standard consistency. XLPE added cement paste shows this term significantly compared to elastomer added cement paste. About extra 21% of water content for neat cement paste needs by addition 15% XLPE waste cement paste for standard consistency. This can be foreseen the belated setting of the waste added cementitious material.

ix) Ordinary mortar cube still present the highest compressive strength among all modified mortars by relating to wet curing requirement, however this state turns over by 5% of XLPE waste added mortar when curing condition is dry.

x) Increase of waste percentage decreasing compressive strength of modified mortar in both curing conditions, especially elastomer modified sample with dry curing.

xi) Modified sample presents higher flexibility characteristic with lower secant modulus in compression compared to stiff ordinary mortar. Secant modulus of 5% XLPE modified sample reduced about 44% compared to ordinary mortar both cured under wet condition.

xii) Modified mortars exhibit a more ductile mode of failure as compared to control. Many small cracks will first occur before modified mortar achieve ultimate compressive strength, after highly cracked, they are able to withstand some of the ultimate load before split into pieces.

xiii) The effects of adding plastic wastes into the concrete mix does not increase the compressive strength compared to the normal concrete cubes.

xiv) By replacing 10% of fine aggregates with plastic wastes, the fresh concrete containing plastic wastes has a little brownish colour compared to fresh normal concrete in terms of physical appearance.

xv) The replacement of 10%, 20%, 30% and 50% by volume of plastic waste does affect the strength and hardening process of the concrete. The more the replacement, the weaker the concrete gets. It takes about 3 days of dry curing for the concrete to be fully hardened to be handled.

xvi) Concrete with plastic waste left in the WTR environment shows very little improvement compared to the control concrete cubes. The strength of the normal cubes increased at a higher rate compared to concrete with plastic wastes which shows a very low increment in its compressive strength compared to the other environments which increased at a constant rate.

xvii) The WTR environment is the most compatible environment for both concretes. This is as expected as water is needed for curing and maintains the hydration process throughout the whole experiment.

xviii) The OUTDR environment proves to be of an advantage for the concrete containing plastic wastes as it still maintains its strength meanwhile the normal concrete cubes shows a lower strength increment compared to the other environments.

xix) Strength of concrete decreases when plastic waste (HDPE rice husk composite) is applied in concrete for 28 days of curing.

xx) For high temperature, concrete with and without plastic waste decrease in its strength; accept for 5000C where the strength is increased for a longer duration of temperature.

xxi) This plastic waste (HDPE rice husk composite) is not suitable as an addition in concrete because it lowers the strength of concrete, under any high temperature.

xxii) The plastic waste did change the properties of concrete such as color and lower the workability and concrete.

xxiii) Although, the existence of plastic waste decreases the strength of concrete, it is useful for fire resistance and more durable in high temperature, compared with ordinary concrete.

5.2 Recommendations for Future Study

Although this study has fulfilled its objectives, further studies on EM can be conducted to explore the effects of EM in other aspects. Few recommendations that can be applied in future are as follows;

i. The physical properties and behaviour of the cubes should be studied under high definition microscope. It is recommended to use Scanning Electron Microscope (SEM) as one of the tool to investigate the microstructure of the cubes.

ii. The contribution in the biological properties of the cubes can be done to study the effects of EM. This study can be pursued by using biological control method.

iii. Instead of conducting the compressive strength after 3 days and 7, the testing day should be extended to longer duration. Therefore, the fluctuation of the strength can be recorded and observed.

iv. A further study on the wet curing method can be conducted to clarify the reasons for the dissolving cubes. It is essential to identify the main factor of the behavior.

v. There is a significant need to carry out in-depth research on the microstructure of concrete containing EM so that to find out the actual reason for the increment in compressive strength.

vi. Similar study with different methodology should be carried out to obtain better result. For examples, the compression test using concrete cylinder provides more precise result than the one using concrete cubes, and extend the exposure duration of samples to the environments to 6 months to see more obvious long-term effects.

vii. The physical properties of concrete containing EM should be monitored such as the appearance and permeability.

viii. This study has its own limitations and therefore, the following recommendations are there to aid in future studies to continuously improve the current work for polymer-based industrial waste modified mortar.

ix. Testing dates to observe the properties of modified concrete are ntil 28 days. Therefore a longer age of concrete properties can be studied, which like 56 days or 100 days to determine the longer term performance and durability of XLPE plastic waste concrete.

x. This study was done for waste-cement ratio of 5%, 10% and 15%. It is recommended to increase the percentage of waste to be used in order to get a more flexible but with adequate strength to replace conventional mortar.

xi. The size of waste particle used in this study is passing 1.18mm sieve. Various sizes from very fine to coarser than this study are recommended to be used to recognize the best performance of both types of wastes to exist in mortar or concrete in order to improve bonding of waste with matrix and flexibility.

xii. Testing dates to observe the properties of modified mortar are until 28 days. Therefore a longer age of mortar properties can be studied, which like 56 days or 100 days to see the long term performance of both wastes respectively in mortar because when use for construction, it is essential that the material used are long lasting.

xiii. Other test than conducted in this study can be carried out, e.g. impact resistance test, abrasion test, chemical and environmental attack resistance test etc.

xiv. Flexibility characteristic of polymer-based industrial waste may be a good constituent in cementitious material to assist in stress absorption so that can be used as jogging pavement construction material, to reduce the impact strength reflects on jogger knee.

xv. Further research on the microstructure of the concrete needs to be done to see how does the plastic wastes settle itself into the concrete mix which affects the compressive strength of the concrete

xvi. Longer periods should be carried out such as 91 days or more, to see the long term effects of the concrete cubes with plastic wastes under different environments.

xvii. Research should also be done on the porosity and permeability which is the physical properties of the concrete with plastic wastes

xviii. Since the use of 10% of plastic wastes does not increase the compressive strength of the concrete cubes, lower quantities of plastic wastes could be used such as 2%, 4% 6% and 8% to find the optimum content of replacement.

xix. This research is focused only on the concrete with Grade 30, so higher strength concrete can be researched on Structural components such as beams and columns made of concrete with plastic waste should be exposed to different environments.

xx. Concrete usually needs reinforcement to be tested on its tensile strength so it is suggested that research is done by producing beams with reinforcement in it.

xxi. Used different percentage of dose for plastic waste in concrete, so that more result can be analyzed.

xxii. Used other plastic waste such as plastic wrap, plastic bottle, polystyrene and many more as an addition in concrete.

xxiii. Test the concrete in other high temperature and longer the exposed under high temperature, so that more graph can be produced. (more than 500 ^{0}C)

xxiv. Test the concrete with other destructive testing such as indirect tension test and flexural strength test, so that we can know the other effect of concrete, other than compressive strength.

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