A STUDY ON THE POTENTIAL OF POLYSTYRENE LIGHTWEIGHT AGGREGATE IN CONCRETE

By

Fetra Venny Riza
0630410118

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SEBUAH KAJIAN MENGENAI POTENSI AGREGATE RINGAN POLISTERIN DI DALAM KONKRIT

ABSTRAK

Perkembangan ekonomi kini menyebabkan penggunaan polisterin meningkat setiap tahunnya. Oleh yang demikian, bahan buangan polisterin ini akan meningkat dari hari ke hari. Sebaliknya sumber agregat semulajadi tidak boleh diperbaharui. Kesedaran umum untuk menyelamatkan alam sekitar selalu diberi pendedahan melalui media cetak dan elektronik untuk menggunakan semula, mengurangkan atau mengitar semula.

Penyelidikan ini memuat tentang usaha untuk menghasilkan agregate ringan dari sisa polisterin yang semakin bertambah atau dikenali sebagai busa polisterin yang boleh didapati di sekeliling kita sebagai pembungkusan alatan elektronik. Proses pembuatan agregat ringan polisterin ini adalah sangat mudah, ianya hanya perlu dipotong sebelum dipanaskan pada suhu antara 130°C hingga 180°C.

Pencirian dari agregat polisterin ringan ini dilakukan melalui beberapa eksperimen yang melibatkan pengukuran penyusutan, ketumpatan pukal, kadar penyerapan air, kekuatan mampatan, juga pemerhatian menggunakan mikroskop cahaya, mikroskop imbasan elektron dan juga pemerhatian dengan mata kasar.

Kajian ini juga mempelajari penggunaan agregat ringan polisterin di dalam konkrit. Pencirian konkrit dilakukan sama dengan pencirian untuk agregat dengan pertambahan ujian turun, ujian mampatan dan ujian lenturan. Hasilnya telah menunjukkan bahawa suhu yang terbaik untuk menghasilkan agregat dengan kekuatan mampatan yang paling tinggi sebesar 69.2 MPa adalah 170°C di mana kadar penyerapan air hanya 2.4% dan ketumpatan pukal ialah 154.6 kg/m^3. hasil daripada ketumpatan pukal ini memenuhi pengelasan agregat ringan berdasarkan ASTM C 330.

Tetapi, kekuatan mampatan agregat polisterin ringan ini hanya 9.8 MPa, tidak mencapai kehendak kekuatan untuk struktur konkrit dimana kekuatan mampatan pada 28 hari sebesar 17 MPa. Oleh yang demikian, penggunaan agregat polisterin ringan ini hanya terhad pada penggunaan bukan struktur sahaja.

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ABSTRACT

Economic reason caused the used of expandable polystyrene increasing every year. The consequence is that the polystyrene wastes also mounted day by day. On the other hand, the source of natural aggregate is non-renewable. Public awareness to save the environment is always be campaigned through all kind media to reuse, reduce or recycle.

This research comprised the effort to produce lightweight aggregate concrete from waste expandable polystyrene or also known as polystyrene foam that can be found easily around our neighborhoods as electronic packaging. The polystyrene lightweight aggregate was produce on reducing the size into several mm and prior to heat treatment at temperature ranging from 130°C to 180°C.

Characterization of this polystyrene lightweight aggregate were done by several experiments that includes shrinkage measurements, bulk density, water absorption level, compressive strength, also utilized the observation of light microscope, scanning electron microscope, even just visual observation by human eye.

In this work, the polystyrene lightweight aggregate product was incorporated in concrete. Concrete characterization was conducted similar to those for aggregate with additional the slump test, compression test and flexural test. The results showed that the best temperature to produce aggregate with highest compressive strength 69.2 MPa was 170°C where the water absorption levels only 2.4% and its bulk density 154.6 kg/m^3. This result of bulk density satisfied the classification of lightweight aggregate concrete according to ASTM C330.

Unfortunately, this lightweight aggregate concrete compressive strength only 9.8 MPa was not reached the requirements strength for structural concrete which is 17 MPa for 28-day compressive strength. Thus, the used of this polystyrene lightweight aggregate concrete limited for non structural purpose only.

CHAPTER ONE

INTRODUCTION

1.1 Research Background

Estimation of the present consumption of concrete in the world is of the order of 11 billion metric tons every year (Mehta and Monteiro, 2005). Man consumes no material at this amount except for water. Unlike cement, although the aggregate in concrete occupies 60% to 80% of the volume, it is frequently looked upon as inert filler and therefore not much attention is given to its possible effect on properties of concrete. The considerable influences that the aggregate component can exercise on the strength, dimensional stability and durability of concrete. Besides that, the aggregate also plays a major role in determining the cost and workability of concrete mixtures; therefore, it is inappropriate to treat the aggregate with any less respect than cement.

In recent years, more attention has been paid to the development of lightweight aggregate concrete (LWAC). Lightweight aggregate concrete reduces building costs, eases construction and has the advantage of being relatively ‘green’ building material (Lo et al., 2007). The uses of lightweight concrete has been increasing especially in the construction of high rise building, off shore structures and long span bridges due to the advantage of its low density, which results in a significant benefit in terms of load bearing elements of smaller cross section and a corresponding reduction in the size of the foundation (ACI Committee 213 R-87).

Lightweight aggregate is an important material in reducing the unit weight of concrete (Choi et al., 2005). Lightweight aggregate concrete, popular through the ages was reported to have a comparable or some times better durability even in severe exposure conditions (Zhang and Gjorv, 1991).

One of the main problems associated with the use of conventional lightweight aggregate produced from clay, slate and shale in concrete is absorption of large water quantity due to high porosity which affects the performance of the concrete, apart from the fact that it is difficult to maintain specific water content during the casting. Beside that additional water will be required to maintain the slump at acceptable levels. The increased water content necessitates higher cement contents, even without benefit of higher strength. Also the durability of any concrete is primarily controlled by the permeability and a better understanding of moisture transfer can therefore reduce or prevent the damage building materials (Goual et al., 2000).

Lightweight polystyrene aggregate is relatively new; nevertheless it has many advantages such as minimal absorption, compared to normal lightweight aggregate concrete difficult (Babu et al., 2006).

1.2 Problem Statement

In view of escalating environmental problems faced today and also considering the rapid depletion of conventional aggregates, the use of aggregates from by-products and/or solid waste materials from different industries are highly desirable (Teo et al, 2007).

Substitution of waste materials will conserve dwindling resources and avoid the environmental and ecological damages caused by quarrying and exploitation of the raw materials for making cement. To some extent, it will help to solve the problem otherwise countered in disposing of the waste (Chandra and Berntsson, 2002).

One of the world environmental issues nowadays is about non-renewable nature's source such as oil, coal, mineral including raw material for conventional aggregate concrete that will be deplete soon with the recent rapid world development. Another issues is the increased of plastic wastes which grew higher every year. Plastic wastes are becoming a major environmental concern due to its large production quantities and non-biodegradable nature which means it takes a very long period to decompose.

In order to reduce the dependence on natural source as raw materials for conventional aggregate concrete and to preserve environment from plastic wastes at the same time, there are many works have been carried out to find the replacement for conventional aggregate concrete such as rubber waste, ceramic waste, oil palm shell waste, recycled concrete and municipal waste including the use of thermoplastic waste.

Among the various thermoplastic is polystyrene. Polystyrene foam and its waste has been used widely in food packaging, architecture models, amusement park, movie sets, airplane construction and much more.

A review of earlier research shows that industrial as well as other wastes were used in concrete-making to improve the properties of concrete and to reduce cost (Senthamarai and Manoharan, 2005).

From the Rubbish Report: Major Sources of Rubbish (2006) it has been reported that plastic wastes in Australia 33.7% from all solid waste. Such a tremendous number since it's the largest contributor to the municipal solid waste due to its extensive uses in daily activities. The world consumption of expandable polystyrene in 2004 showed that almost 30% goes to construction field, 15% goes to packaging field and the rest 55% goes as others as shown in figure 1.1.

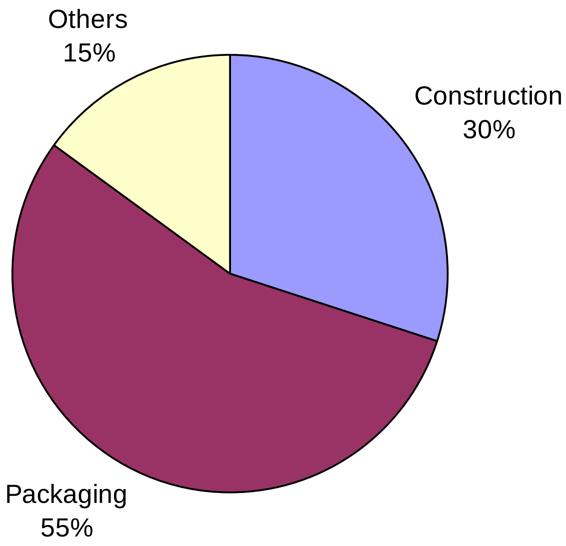

Figure 1.1. World Consumption of Expandable Polystyrene in 2004
(www.cleanup.org.au, retrieved 28 July 2008)

1.3 Objectives of Research

The main objective of this work is to find out the potential of using polystyrene lightweight aggregate as potential filler material in concrete to replace conventional lightweight aggregate.

The measurable objectives are:

- To determine the physical and mechanical properties of polystyrene lightweight aggregate.
- To determine the mechanical properties polystyrene lightweight aggregate concrete.

1.4 Scope of Work

This research attempted to produce lightweight aggregate from polystyrene waste and furthermore tried to produce lightweight concrete out of it. Normal expanded polystyrene (EPS) waste was used in this project as the aggregate of lightweight concrete (LWC). The EPS waste is obtained from Unimap's electronic packaging waste. The EPS waste has undergone certain heat processes in terms of its hardness. So when it becomes the aggregate, the polystyrene was called Modified Polystyrene (MPS).

Initial work was produced the aggregate from polystyrene foam. The polystyrene was modified by heating it at an optimum temperature to transform the initial soft polystyrene foam into a rigid and lightweight aggregate. At this stage a series of tests would be conducted to measure its strength, dimension, water absorption, shrinkage, and density of the lightweight aggregate concrete.

The scope of the work includes modifying polystyrene from electronic waste packaging to polystyrene lightweight aggregate by means of heat treatment. These modified aggregate will be treated for its physical and mechanical properties. The modified polystyrene lightweight aggregate's performance will be tested in concrete and the concrete properties will be determined.

CHAPTER TWO

LITERATURE REVIEW

2.1 History of Lightweight Aggregate Concrete (LWAC)

Although the origin of the lightweight aggregate concrete is difficult to assessed, it would not be an exaggeration to say that its roots were from the ancient periods. The use of lightweight aggregate concrete (LWAC) can be traced to as early as 3000 BC, when the famous towns of Mohenjo-Daro and Harappa as shown in Figure 2.1 were built during the Indus Valley civilization, where natural lightweight aggregate such as pumice, scoria, etc was used. The Sumerians also used this in building Babylon as shown by Figure 2.2 in the third millennium BC. In Europe, earlier use of LWAC occurred about two thousand years ago when the Romans built the Pantheon temple as shown in Figure 2.3 which was erected in the years ca A.D. 118 to 128; the prestigious aqueducts Pont du Gard as shown in Figure 2.4 was built in A.D. 14; the great roman amphitheatre Colosseum as shown in Figure 2.5 in Rome was built between A.D. 70 and 82; and the St Sofia Cathedral or Hagia Sofia as shown in Figure 2.6 in Istanbul, Turkey, that built by two engineers, Isidore of Miletus and Anthemius of Tralles, commissioned by the Emperor Justinian in the 4th century A.D. In addition to building constructions, the Romans used natural lightweight aggregates and hollow clay vases in order to reduce the weight. This was also used in the construction of the Pyramids as shown in Figure 2.7 during the Mayans period in Mexico (Chandra, 2002).

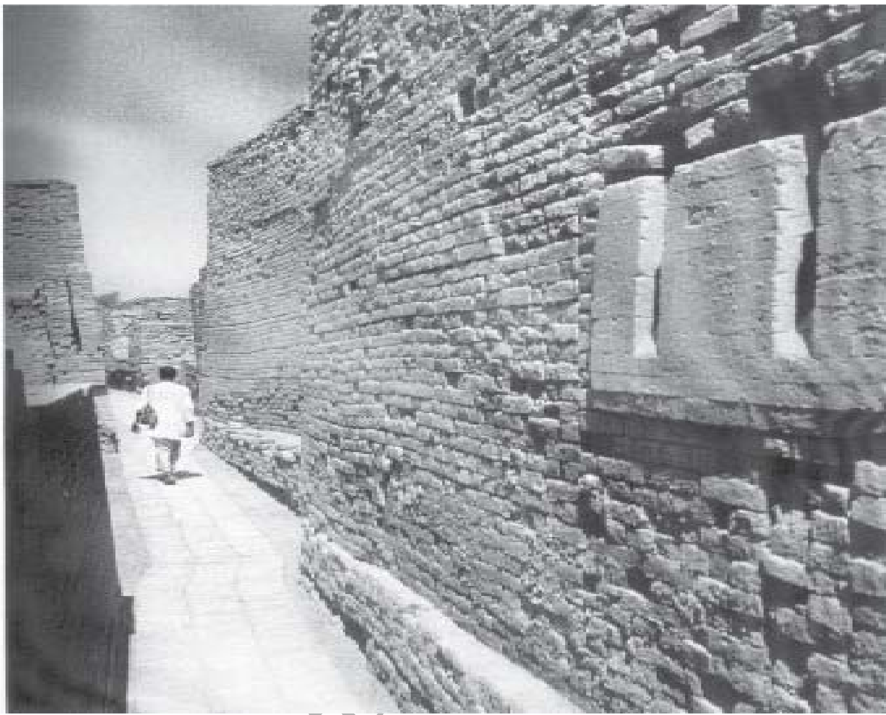

Figure 2.1. Mohenjo-Daro and Harappa built in 3000 B.C.
(Lightweight Aggregate Concrete : Science, Technology and Applications, Chandra, S., and Berntsson, L.)

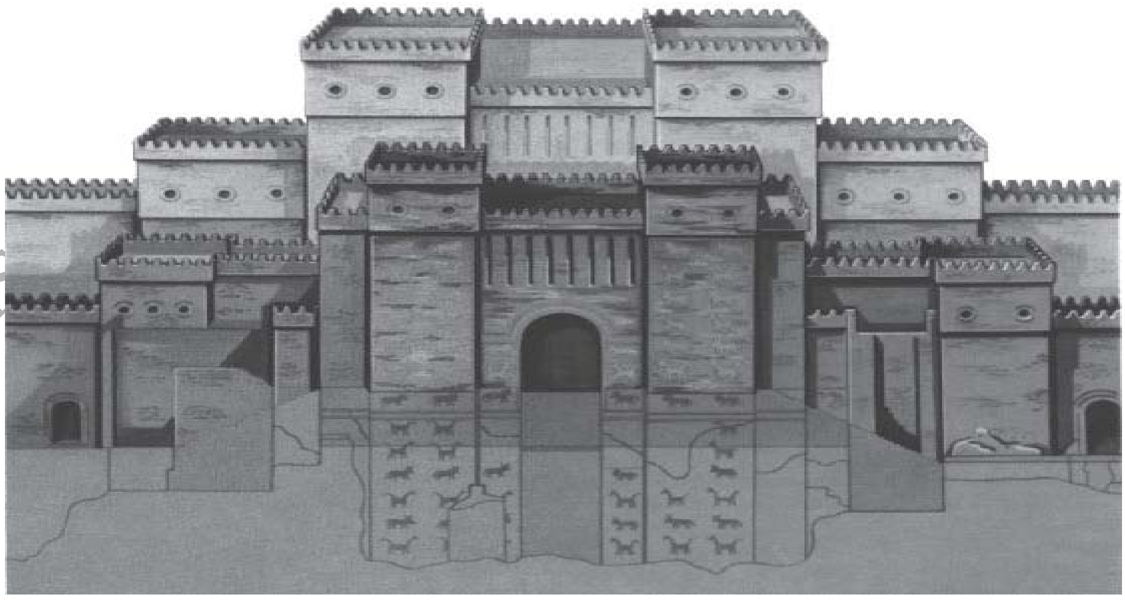

Figure 2.2. Babylon, Iraq, built by Sumerians in the 3rd millennium B.C.
(Lightweight Aggregate Concrete : Science, Technology and Applications, Chandra, S., and Berntsson, L.)

Figure 2.3. The Roman temple, Pantheon, built in A.D. 118.
(Lightweight Aggregate Concrete : Science, Technology and Applications,
Chandra, S., and Berntsson, L.)

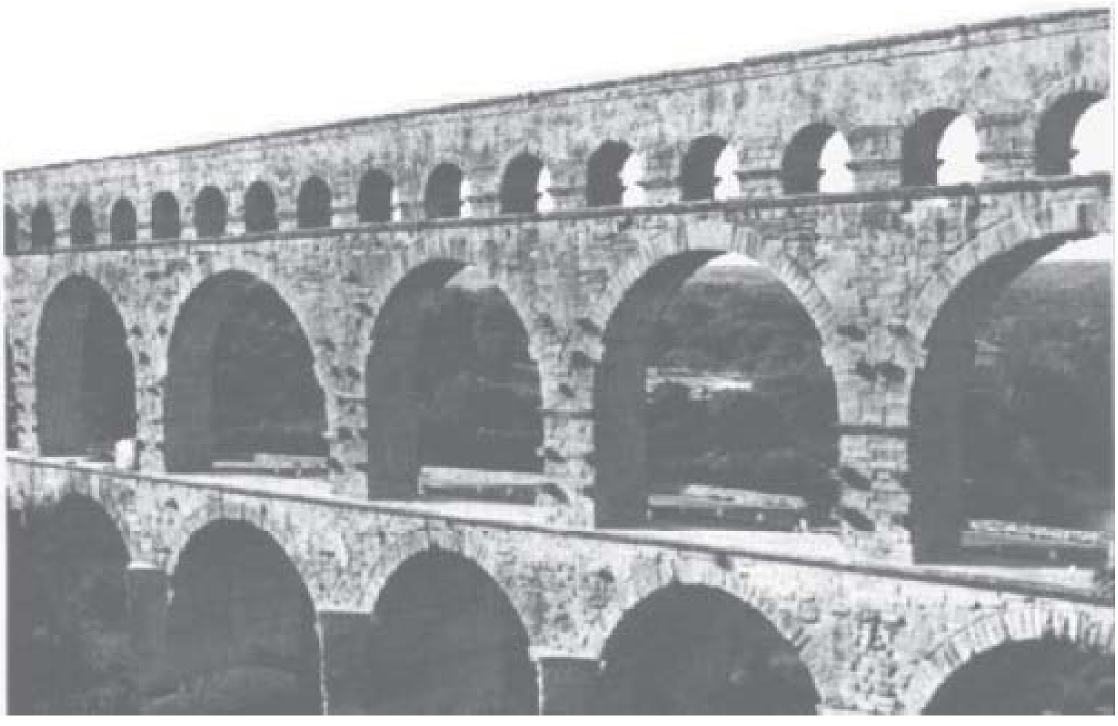

Figure 2.4. The prestigious aqueduct Pont du Gard, built in ca A.D. 14.
(Lightweight Aggregate Concrete : Science, Technology and Applications, Chandra, S., and Berntsson, L.)

Figure 2.5. The great Roman amphitheatre, Colloseum, built between A.D. 70 and 82. (Lightweight Aggregate Concrete : Science, Technology and Applications, Chandra, S., and Berntsson, L.)

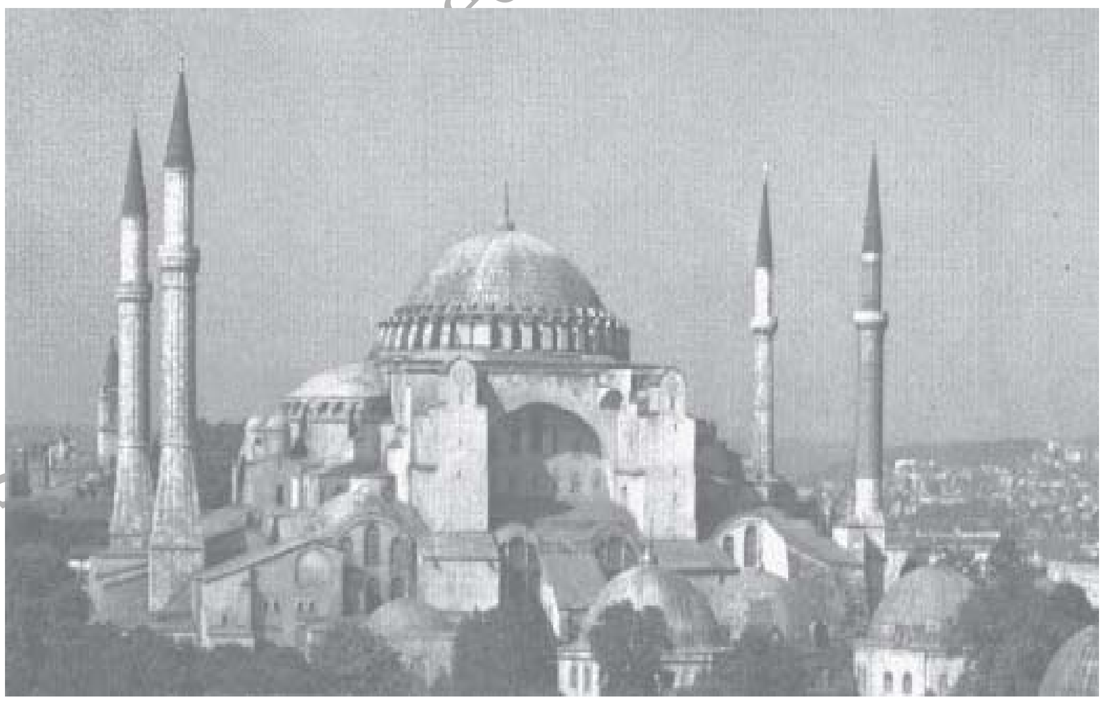

Figure 2.6. St Sofia Cathedral or Hagia Sofia, commissioned by the Emperor Justinian in the 4th century A.D. in Istanbul, Turkey.
(Lightweight Aggregate Concrete : Science, Technology and Applications, Chandra, S., and Berntsson, L.)