AN EXPERIMENTAL STUDY ON MODULUS OF RUPTURE AND WATER ABSORPTION OF CEMENT-SEASHELL POWDER MORTAR

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Report submitted in partial fulfillment of the requirements

for the award of the degree of

B. ENG (HONS.) CIVIL ENGINEERING

Faculty of Civil Engineering and Earth Resources

UNIVERSITI MALAYSIA PAHANG

June 2014

ABSTRACT

The usage of cement itself in the industry is inadequate as the strength of the mortar produced is dependent on the properties as cement used. Seashell is a major of calcium carbonate compound and found to be a natural pozzolan. In this research, the use of seashell powder as additive to cement mortar is investigated. The effect of using seashell powder as additive on the modulus of rupture, force against deflection and the rate of water absorption of the mortar are investigated using varying percentage of 1%, 2%, 3% and 4% from the cement weight respectively.30 mortar beams with different percentage of seashell powder of 100mm x 100mm x 500mm were moulded and cured for 7 and 28 days respectively. Findings revealed cement-seashell powder mortar has higher modulus of rupture than controlled beam. The modulus of rupture decreases with the increase of the percentage of seashell powder of 4%. In addition, the mortar beam containing seashell powder can withstand higher forces compared to the controlled beam. All mortars containing seashell powder yielded lower porosity compared to the conventional mortar. This indicates that seashell powder has potential to be used as additive in cement replacement. Moreover, this study also concern of managing disposal of seashell waste in the future for conservation of environment.

ABSTRAK

Penggunaan simen dalam industri adalah tidak mencukupi kerana kekuatan mortar yang dihasilkan adalah bergantung kepada ciri-ciri simen yang digunakan. Komponen kulit kerang merangkumi kalsium karbonat dan merupakan pozolan semula jadi. Dalam kajian ini , penggunaan serbuk kerang sebagai bahan tambah untuk mengukuhkan mortar telah disiasat . Kesan penggunaan serbuk kerang sebagai bahan tambahan ke atas sifat kelenturan,kekuatan terhadap pesongan dan kadar penyerapan air mortar disiasat menggunakan 1% , 2% , 3% dan 4% dari isispadu simen.30 rasuk mortar berdimensi 100mm x 100mm x 500mm dengan peratusan serbuk kerang yang berbeza pada usia 7 dan 28 hari. Kajian menunjukkan simen- kerang mortar mempunyai sifat kelenturan yang paling tinggi berbanding rasuk biasa. Sifat kelenturan berkurangan dengan peningkatan peratusan serbuk kerang sebanyak 4%. Di samping itu, rasuk mortar yang mengandungi serbuk kerang boleh menahan kekuatan yang tinggi berbanding dengan rasuk mortar yang dikawal. Mortar yang mengandungi serbuk kerang menghasilkan keliangan yang lebih rendah berbanding dengan mortar konvensional. Ini menunjukkan bahawa serbuk kerang mempunyai potensi untuk digunakan sebagai bahan tambah dalam simen. Selain itu, kajian ini sekaligus menguruskan pelupusan sisa kerang pada masa akan datang untuk pemuliharaan alam sekitar.

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LIST OF SYMBOLS

$CaCO_3$	Calcium Carbonate
μ	Micro
%	Percent
°C	Degree Celsius
kN	Kilo Newton

LIST OF ABBREVIATIONS

ASTM	American Society for Testing Materials
OPC	Ordinary Portland Cement
UTM	Universal Testing Machine

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Agriculture waste disposal has become one of the most serious of modern environmental problems all over the world. This is due to the growing of the population which may leads to an increase in consumption. One of the preferred methods of dealing with this kind of environmental problem is to analyse and using the waste as enhancement in construction industries. In this study seashell would use as additive in construction of cement mortar. The chemical composition of shells is more than 90% calcium carbonate (CaCO3) by weight (Falade, 1995;Yoon et al., 2003,2004;Yang et al.,2005;Ballester et al., 2007;Mosher et al., 2010). This composition is similar to limestone powder or dust-like stone powder from grinding limestone to produce Portland cement. Ground seashells also are used as an ingredient of cement or sand replacements in concrete production to save costs. According to Michael (1992), additive in concrete can improve its workability, hardening, or strength characteristics and generally result in a reduction in the cost of concrete construction. Therefore this research is proposed to study the mechanical properties and water absorption of cement mortar when added with seashell powder. The cement-seashell mortar sample will be tested using flexural strength test and water absorption test in order to determine the behaviour and properties.

In addition, reusing solid wastes seashell is a good solution for saving the environment by preventing incineration and stockpiling in landfills that may become breeding places of disease vectors such as Aedes. The use of these waste materials would reduce usage of cement in construction industries as well as preserving the environment to achieve sustainable industrial by-product for stabilization of concrete.

1.2 STATEMENT OF PROBLEM

Ordinary Portland cement is normally used in concrete making materials. Today many researches are ongoing into the use of Portland cement replacements using natural admixture which has been introduced to further improve the cement properties. Seashell is made of 90 percent of the calcium carbonate (CaCO3) which defined as natural pozzolan (Mosher et al., 2010). This composition has similar properties with limestone powder or dust-like stone powder which acts as natural pozzolan in producing Portland cement. Thus the addition of the admixture in mortar could enhance the time for hardening, workability, strength characteristics and generally result in a reduction in the cost of masonry or concrete construction.

Malaysia is having 1055 number of farmers working on cockle shell cultivation agriculture which involving 6000 hectare of cultivation area (Izura & Hooi, 2008) . The availability of the unused seashell would be generated as waste and may create odour and endanger the environment. Therefore the use of seashell as admixture would not only to enhance the properties of cement, but this study also concern of managing disposal of seashell waste in the future for conservation of environment as well as developing trustable construction materials.

1.3 RESEARCH OBJECTIVES

The research objectives of this study are:

i. To examine the modulus of rupture of controlled cement mortar and cement mortar containing different percentage of seashell powder
ii. To investigate the relationship between force and deflection of the mortar beam
iii. To determine the rate of water absorption from various percentage of seashell powder with cement

1.4 SCOPE OF STUDY

This study mainly focuses on the research of the Ordinary Portland Cement (OPC) inter ground with seashell powder. The parameters are the proportion of seashell powder used as natural additive in cement mortar. The OPC are blended with water, sand and seashell powder content of 1%, 2%, 3% and 4% from the cement weight respectively. The effect of the seashell powder on flexural strength of cement-seashell powder mortar is one of the major studies. Other testing includes deflection against force applied and the rate of water absorption from different percentage of cement-seashell powdered mortar. The OPC are blended with water, sand and seashell powder content of 1%, 2%, 3% and 4% from the cement weight respectively.

1.5 EXPECTED OUTCOME

The important parameters of cement mortar mix are the different percentage of ground seashell used as additive. From the observation, it is obvious that when cement is mixed with seashell powder, the paste of the mortar mix with ground seashell is found to be smoother and thickens due to pozzolanic reaction. In addition, mortar with higher percentage of seashell powder would present higher porosity and water absorption. The use of seashell powder as additive in mortar increases the strength and thus the mortar beam that contains the highest percentage of seashell powder is expected to sustained greater force compared to control mortar beam. Apart from that, the modulus of rupture would be higher conventional mortars. When seashell powder is mixed with mortar, there is a considerable environmental and economic benefit.

1.6 SIGNIFICANCE OF STUDY

The standard test method using Universal Tensile Machine (UTM) is useful in indicating the difference in modulus of rupture between various percentages of seashell powder additives. Using seashell powder in mortar offer a series of benefits protects the environment and eliminates the disposal of wastage due to the properties of seashell is that they are unusable in other cycles of production. In general, the seashell powder satisfies the index requirement used for mortar where it allows them to flow and blend freely in mixtures. The pozzolanic material will prevent water penetration during the early drying out period. Moreover, pozzolans continue to combine with free lime, increasing structural strength over time. The mortar can be used for a number of applications, such as plastering over bricks or other forms of masonry. Although the cost of additive is not very expensive and there are other varieties of additives other than seashell powder, it becomes important and practical in future when there is a shortage of other additives.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will discuss in detail about feasibility of additive available, the materials used for research, mechanical properties and methods to test for the samples.

2.2 SEASHELL PRODUCTION IN MALAYSIA

Cockle shell in Malaysia is abundantly produced as waste generation in seafood industries. According to Annual fisheries statistics 2012, cockle shells have increasing production which is 42,132.03 metric tonne with 1004 culturist cultivating 10,740.20 hectare in Malaysia. Most of the shells are discarded with no further use or deteriorates in landfills. Therefore, this shows that the availability of the seashell will increases by years. Nowadays, the variety of waste materials has been suggested as viable, or even beneficial, additives to concrete. Seashell is one of the waste materials investigated for its potential use in the construction field.

2.3 MATERIAL

According to the type of binder used, there are many different kinds of mortar. In concrete construction, the Portland cement mortar is utilized the most. Thus, in our course, the term concrete usually refers to Portland cement mortar. For this kind of mortar, the composition can be presented as follows:

Cement + (Admixture) + Water →Cement paste

+ Fine aggregate → mortar

Here we should indicate that admixtures are almost always used in modern practice and thus become an essential component of modern mortar. Admixtures are defined as materials other than aggregate (fine and coarse), water, fibre and cement, which are added into concrete batch immediately before or during mixing. The widespread use of admixture is mainly due to the many benefits made possible by their application. For instance, chemical admixtures can modify the setting and hardening characteristic of cement paste by influencing the rate of cement hydration. Water-reducing admixture can plasticize fresh mortar mixtures by reducing surface tension of water, air-entraining admixtures can improve the durability of mortar, and mineral admixtures such as pozzolans (materials containing reactive silica) can reduce thermal cracking.

2.3.1 Mortar

Mortar is made from a properly proportioned mixture of hydraulic cement, sand, water and often chemical or mineral admixtures. The mortar can be used for a number of applications, such as plastering over bricks or other forms of masonry. Clay mortars were often used where the construction was not expected to be exposed to moisture, such as in chimneys below the roofline, and where it could be protected from moisture by broad roof overhangs (Schnabel, 2008). Sometimes referred to as sand cement, mortar blends today often incorporate different grades of plastics to create various types of polymer cement mortars.

Mortar has been used for centuries as a means of adhering bricks or concrete blocks to one another. Cement mortar continues to be used in many different types of construction. Professional building projects often employ mortar as the binder between bricks in walls, fences, and walkways. Around the house, this product is often employed to make quick repairs in patio slabs and reset loosened stones or bricks in a walkway or retaining wall. Besides, in comparison of many other binders, mortar is quite cheap and can be moulded to any required shape easily.

The most common hydraulic cement used in construction today is Portland cement. Portland cement is a finely grey powder which made up of calcium oxide (CaO), silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3) (Charles n.d). The abundant raw materials are then blended with lime stone and clay in kiln of 1400° C to 1600°C. In the mortar mix, a pozzolanic material such as calcined clay or seashell powder dust may be added to the mortar mix. This would make the mortar to be set reasonably quickly by reaction with the water in the mortar.

2.3.2 Seashell as Natural Additive

In various studies of other seashell types like oysters, scallops and mussels revealed that they are quite well developed and applied in diverse industry around the world for fertilizers, construction materials, cement clinkers and tiles (Barros, 2004). Seashell is considered as a part in construction materials because of their properties acts as additive for cement hydrating. Michael (1992) states that additive in concrete can improve its workability, hardening, or strength characteristics and generally result in a reduction in the cost of concrete construction.

According to Falade (1995) and Yoon (2003), seashell component consist of more than 90 percent of calcium carbonate and they summarized that this composition is similar to limestone powder or dust-like stone powder from grinding limestone to produce Portland cement. Ground seashells also are used as an ingredient for cement or sand replacements in concrete production benefit of cost savings. In addition, the crystal structures of cockle shells are largely composed of aragonite and calcite that have higher strengths and densities than limestone powder (Mosher et al., 2010). Beside the compound properties of seashell as additive are not significantly different from those pozzolanic additives.

Thus, seashell wastes from seafood and agriculture industries are one of the waste materials investigated for its potential use in construction field. The use of these agricultural materials not only helped to reduce waste as well but also improve the, workability, hardening and strength characteristic of the concrete. Hence, the use of ground seashell as an additive in cement mortar will therefore necessitate investigation of changes in properties of mortar, both in fresh and hardened states and also determine the flexural strength of mortar by different percentage of the additive used.

2.3.3 Effect of nonpozzolanic and pozzolanic mineral admixtures on the hydration behavior of ordinary Portland cement

The cement would not produce a better workability without additional additives. Moreover there are differences in the behaviour of cement depending on the properties of additives itself. The effects of non pozzolanic (marble dust) and pozzolanic (rice husk ash) mineral admixtures on the hydration behavior and mechanical properties of ordinary Portland cement (OPC) have been investigated by Jain (2011). According to Jain, the decreases in strength with increase in marble dust dose indicates that excessive marble dust containing calcium carbonate does not participate in hydration reaction and worked as filler. However Rice Husk Ash, (RHA) blended samples show that increase in strength as compared to control and strength continues to increase up to 360 days.

This may be due to formation of secondary C–S–H gel by the pozzolanic activity of RHA. Nevertheless, both of the additives still influence the hydration behavior and strength characteristics of OPC greatly. Addition of marble dust and rice husk ash also accelerates the setting as compared to control.

2.4 METHOD

2.4.1 Flexural Strength Test

Flexural strength (sometimes called the modulus of rupture) is actually a measure of tensile strength in bending. Flexural Strength is carried out on a beam with standardize dimension and then is loaded at its center point until failure. It measures the highest flexural force that concrete can withstand before it fails.

Flexural strength is typically used in Portland cement mix design for pavements because it best simulates slab flexural stresses as they are subjected to loading. Because the flexural test involves bending a beam specimen, there will be some compression involved, and thus flexural strength will generally be slightly higher than tensile strength measured using a split tension test. Usually, mix designs are typically tested for both flexural and compressive strength and they must meet a minimum flexural strength.

There are two basic flexural tests: the third-point loading and the center-point loading). The beam is supported on each end and loaded at its third points (for the third-point loading test) or at the middle (for the center-point loading test) until failure. The modulus of rupture is then calculated and reported as the flexural strength. The third-point loading test is preferred because, ideally, in the middle third of the span the sample is subjected to pure moment with zero shear (Mindess and Young, 1981).In the center-point test, the area of eventual failure contains not only moment induced stresses but also shear stress and unknown areas of stress concentration. In general, the center-point loading test gives results about 15 percent higher (ACPA, 2001). However, Sprung and Siebel (1991) found that the use of pozzolanic materials does not produce additional increases in strength with continued curing.

2.4.2 Properties of cement paste with pozzolanic additives

Pozzolanic materials, either naturally occurring or artificially made, have long been in practice since the early civilization. In recent years, the utilisation of pozzolanic materials in concrete construction has become increasingly widespread, and this trend is expected to continue in the years ahead because of technological, economic and ecological advantages of the materials According to Mehta and Aitan (1990), the small particles of pozzolans are less reactive than Portland cement but when discrete in paste they generate a large number of nucleation sites for the precipitation of hydrocarbon products. Therefore, the mechanism makes the paste more homogenoust and condensed, because of the pozzolanic reactions between the amorphous silica of the minerals added and the calcium hydroxide produced by the cement hydration reactions. The physical effect of finer grain particle allows compact packing within the cement and reduces the wall effect in the transition zone between the paste and the fine aggregates.

2.4.3 Water Absorption Characterictics

The water absorption of mortar is affected in different ways, depending on the type of additives and dose used. Generally, pozzolanic concrete and mortar performed better than the conventional one and shows enhancement in terms of lower rate of water penetration through capillary suction particularly under hot weather (Talah et al.,2012). This reduced water absorption rate reflects a finer pore structure that would, for example, inhibit ingress of aggressive elements into the pore system. Several researchers showed the effectiveness of the mineral additions on the absorption rate of the concretes and mortars (Dias et al.,2003). This reduction in the water absorption with age indicates better performance of pozzolanic blended cement paste over reference cement paste.

A higher pozzolanic additive to cement ratio possess lower rate of water absorption. This is because the additives would fill up the voids in mortar thus there are no voids for the water to penetrate through (Prinya et al., 2007). According to research made by Sivakumar and Tan (2013) on effect of fly ash(pozzolanic) on the performance of cement mortar, it indicates that the higher flyash/cement ratio, the lower the rate of water absorption. This is because when the volume of fly ash is increasing, it will fill the voids, increasing the density and hence preventing water absorption.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will discuss on the materials preparation to produce beam samples with dimension 100mm x 100mm x 500mm. Materials such as Ordinary Portland Cement will be provided by the Concrete Laboratory whereby additives and sands would be taken from Kuantan areas. The method used to perform the research in term of flexural strength test, force against time and force against deflection which the equipments are readily available. The procedures and flowchart will be conducted as well.

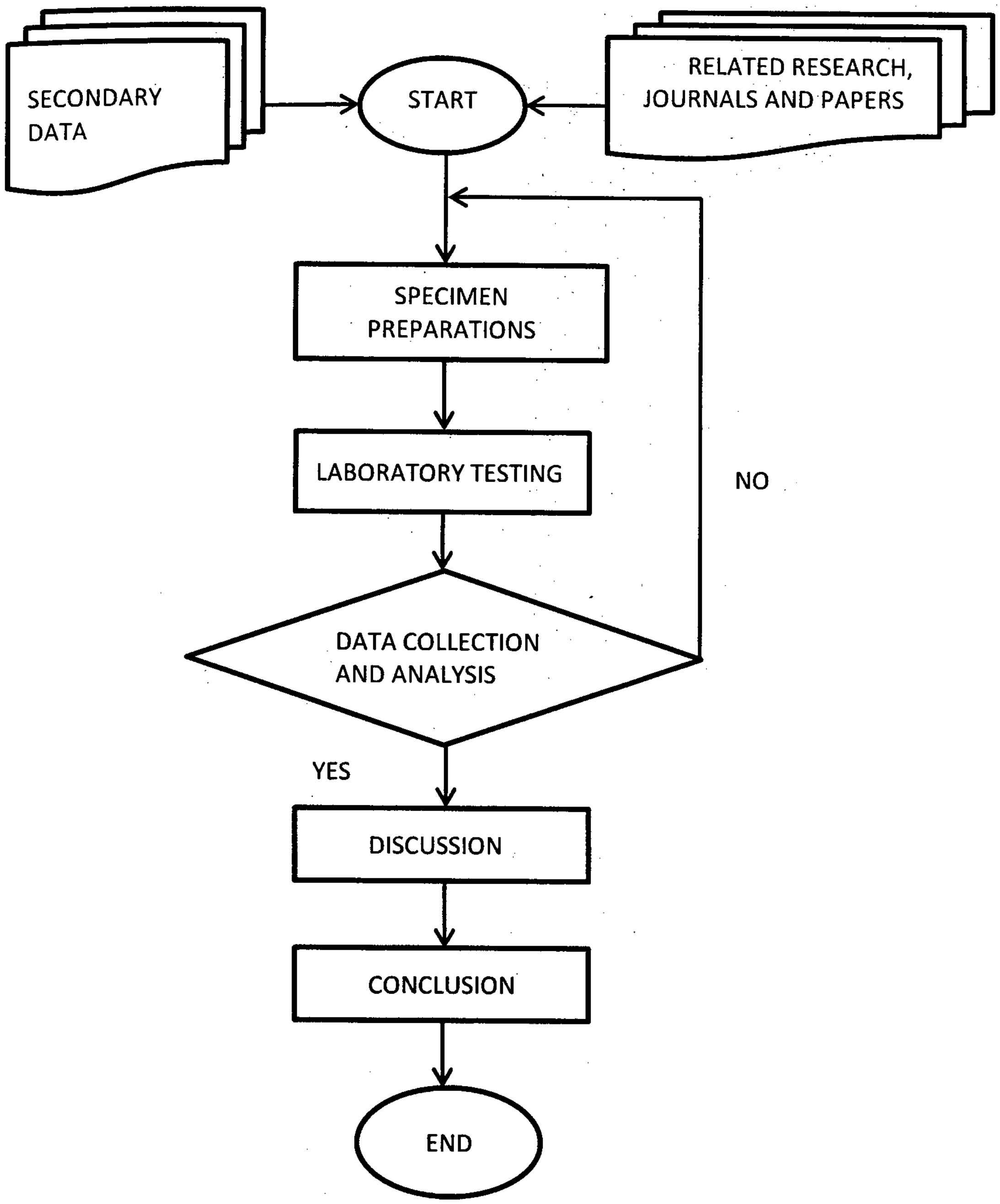

Figure 3.1: Flow of research works

3.2 RESEARCH DESIGN

The research design which will be used is experiment related to our purpose of study. The purpose of this study is to examine the modulus of rupture of controlled cement mortar and cement mortar containing different percentage of seashell powder. This research is done to investigate the relationship between force and deflection of the mortar beam. In addition, rate of water absorption in percentage of mortar beam will be determined.

3.3 MATERIAL PREPARATION

The raw materials used in mortar to produce mortar beams will comprise of Ordinary Portland Cement (OPC), water, sand (fine aggregate) and seashell powder. The mix design is calculated and shown in Appendix A.

3.3.1 Water

Water that is tap water will be used in concrete mix and for curing process. The function of water is to utilize for hydration of cement causing it to set and harden. The remaining water must be kept to the minimum, as too much water reduces the strength of concrete. The water-cement ratio that would be used for the experiment is 0.4.

Water is used in curing process of the samples for 7 and 28 days. Besides, Surahyo (2002) also noted that water used in concrete mix should be clean and free from objectionable quantities of organic matter, silt, clay, acids, alkalis and other salts and sewage. Generally, water with pH of 6.0 to 8.0 which does not taste saline is suitable for use.