DEVELOPMENT OF COMPOSITE CEMENT REINFORCED WITH COCONUT FIBRE

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UNIVERSITI MALAYSIA PERLIS
2012

Development of Composite Cement Reinforced With Coconut Fibre

by

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A thesis submitted in fulfilment of the requirements for the degree of Master of Science (Materials Engineering)

School of Materials Engineering
UNIVERSITI MALAYSIA PERLIS

2012

ACKNOWLEDGEMENTS

I want to thank God for this opportunity to complete my Master of Science study. Million thanks as well for those who are involved direct or indirectly in the process of completing this thesis. Completion of this thesis marks the conclusion of my life as a postgraduate student in School of Materials Engineering at Universiti Malaysia Perlis.

First and foremost, I would like to take this opportunity to express my sincere appreciation to my project supervisor; Prof. Dr. Shamsul Baharin Jamaludin and my co-supervisor Dr. Mazlee Mohd Noor for their help, guidance, chance and all sorts of support. Without their guide, the present study would have been impossible. I believe I gain a lot of self confidence throughout this work and the experience that I have is invaluable. I have enjoyed their mentorship and friendship, and have learned about life as well as research from them. This gratitude is also goes to Dr. Khairel Rafezi Ahmad, Dean of School of Materials Engineering for his supported and concerned.

A special thanks to my family especially my mother Mrs. Che Mek Saman for her support that never stops and guides me along the correct path of education with much sacrification and determination. Special thanks also go to my siblings who were supportive of all this work. My family has always stood by me, through all the ups and downs, and has been very patient and encouraging in everything I have ventured to do. I could not make this far without them.

I am extremely grateful to the advisor such as Mr. Mohd Mustafa and Assoc. Prof Che Mohd Ruzaidi for their concerned and showing interest in my research and also offering valuable suggestion during various stages of my studies. I have learned a great deal about construction materials from discussion with such an intellectually gifted individual. I am grateful for their guidance and encouragement. They have provided me with a solid educational background.

Other than that, I am also thankful to all technicians, patient and assistance to guide me how to do the work and using the machine in the laboratory. Special thanks for their great help in supplying materials and technical information. It is impossible for me to do all the lab work without guidance from all of them.

My utmost appreciation and thanks are given to all my friends, Salihin, Faisol, Arif, Azrem, Lokman, Haryanti and others for all the support throughout my studies. My friends have been my rock to whom I could always turn to comfort, understanding, and motivation. They made me see the silver lining in the clouds when all I could see was an abysmal black hole. Their friendship provided me the endurance to pass through the difficult stages in life.

Finally, my appreciation also goes to School of Materials Engineering and for giving me a space for superb facilities and Universiti Malaysia Perlis for sponsor my study. Lastly, thank you to all individuals who is contributes in this study. Without all of name stated above, it is impossible for me to complete my study.

- Alida Abdullah -

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURES

ASTM	American Society for Testing and Materials
CCB	Coconut Cement Board
CFB	Cement Fibre Board
DTA	Differential Thermal Analyzer
EDS	Energy Dispersion Spectroscopy
MOR	Modulus of Rupture
OPC	Ordinary Portland Cement
SEM	Scanning electron microscope
TG/DTA	Thermo Gravimetry/Differential Thermal Analyzer
TGA	Thermogravimetric Analysis
UTM	Universal Testing Machine

Pembangunan Komposit Simen Bertetulang dengan Gentian Kelapa

ABSTRAK

Penyelidikan ini telah dijalankan untuk membangunkan komposit simen dengan penambahan gentian kelapa dalam panel simen. Bahan-bahan mentah yang digunakan ialah simen Portland Biasa, gentian kelapa, pasir dan air. Pembangunan komposit simen dalam penyelidikan ini dilakukan dengan menggantikan gentian kelapa kepada sebahagian pasir berdasarkan nisbah simen kepada pasir. Dalam kajian ini, nisbah yang digunakan untuk merekabentuk campuran adalah 1:1:0, 1:0.97:0.03, 1:0.94:0.06, 1:0.91:0.09, 1:0.87:0.12 dan 1:0.84:0.15 (simen: pasir: gentian kelapa). Jumlah nisbah air per simen telah ditetapkan pada 0.55 untuk setiap nisbah campuran. Saiz sampel yang diuji adalah 160 mm x 40 mm x 40 mm untuk ujian mampatan, dan 100 mm x 100 mm x 40 mm bagi ujian ketumpatan, kandungan kelembapan dan penyerapan air. Sampel diawet di dalam air selama 7, 14, dan 28 hari. Keputusan menunjukkan bahawa komposit simen dengan 9 peratus berat gentian kelapa memberikan kekuatan lenturan dan kekuatan mampatan yang paling tinggi. Didapati bahawa dengan meningkatkan kandungan gentian kelapa, ketumpatan komposit simen telah menurun manakala peratus penyerapan air dan kandungan kelembapan telah meningkat. Kajian ini juga melaporkan kelakuan patah komposit selepas ujian lenturan. Ia menunjukkan penghubung retak yang bertindak mengukuhkan komposit.

Development of Composite Cement Reinforced with Coconut Fibre

ABSTRACT

This research was conducted to develop cement composite with the addition of coconut fibre in cement panel. The raw materials used were Ordinary Portland cement, coconut fibre, sand and water. The development of cement composites in this research were done by substituting coconut fibre to the portion of sand based on the ratio of cement to sand. In this study, the ratios used to design the mixture were 1:1:0, 1:0.97:0.03, 1:0.94:0.06, 1:0.91:0.09, 1:0.87:0.12 and 1:0.84:0.15 (cement: sand: coconut fibre). The amount of water per cement ratio was fixed at 0.55 for each mixture ratio. The sizes of sample tested were, 160 mm x 40 mm x 40 mm for compression test, and 100 mm x 100 mm x 40 mm for density, moisture content and water absorption tests. The samples were cured in water for 7, 14, and 28 days. The result shows that the cement composite with 9 wt. % of coconut fibre gives highest flexural and compressive strength. It was found that by increasing the content of coconut fibre, the density of cement composite was decreased while the water absorption and the moisture content percentages were increased. This study also reports the fracture behaviour of composites after flexural test. It revealed the crack bridging had strengthened the composite.

CHAPTER 1

INTRODUCTION

1.1 Background

A huge amount of agricultural wastes is abundantly available in Malaysia (Rozli et al., 2009). According to the United States Department of Agriculture (2011), 32000 metric ton of coconut oil was produced in the year of 2010 in Malaysia. These wastes are needed to be disposed properly especially for safety and environmental sustainability. They are mostly disposed by incineration or used as fuel, although their calorific value is much lower than that of coal. Utilisation of these agro-wastes, apart from solving the problem of their disposal would improve the agricultural economy considerably (Aggarwal, 1995).

There is a research activity in the utilisation of natural fibre as low cost construction materials especially in developing countries. In the recent years, there have been considerable efforts to develop natural fibre reinforced cementitious composites for affordable infrastructure (Penamora and Go, 1997; Asasutjarit et al., 2009). Among those agricultural wastes, coconut fibre or coir fibre has the potential to be used as reinforcement in the development of cement fibre composites. From the literature reviews and commercial product information, there is limited application of the coconut fibre except some product based on polymer composite (Savastano and Agopyah, 1999).

Coconut fibre is the most interesting fibre as it has the lowest thermal conductivity and bulk density. Some researchers have reported that the addition of coconut fibre reduced the thermal conductivity of the composite samples (Asasutjarit et al., 2007; Khedari et al., 2005). Asasutjarit and co-researchers studied the effect of chemical composition modification and surface modification of coconut fibres as reinforcement to the mechanical properties of cement composites. They observed that the mechanical properties of composites which is modulus of rupture, increased as a result of chemical composition modification and surface modification (Asasutjarit et al., 2009).

Asasutjarit and co-researchers also investigated the effect of fibre length, fibre pre-treatment and mixture ratio that affect the physical, mechanical and thermal properties of cement composites after 28 days of hydration. Their results indicated that the boiled and washed fibre improved mechanical properties of cement composites. In addition, the optimum fibre length was 1 to 6 cm fraction and the optimum (cement: fibre: water) mixture ratio by weight was 2: 1: 2. Thermal property of composites revealed that coconut fibre-based lightweight cement board has lower thermal conductivity (Asasutjarit et al., 2007).

A study from Khedari and co-researchers reported on the development of a new type of soil–cement block using coconut fibre. Various mixture ratios were considered. They concluded that the use of coconut fibre as an admixture can reduce the block thermal conductivity and weight (Khedari et al., 2005). The optimum volume ratio of soil: cement: sand to produce good properties is 5.75: 1.25: 2. The ratio of coconut fibre is 20 percent of cement corresponding to 0.8 kg/block. The compressive strength and thermal conductivity decreased when the quantity of fibre increased. It can be seen that, from the previous investigation, major works have been focused on the effects of fibre on the mechanical properties of cement composites.

1.2 Problem Statement

Malaysia has plenty of agricultural waste products such as coconut fibre, rice husk and oil palm frond fibre. If the waste cannot be disposed properly it will lead to social and environmental problem.

At present, there are many researches focus on natural fibres addition in construction materials field such as development of cement composites (Penamora, 1997; Khedari et al., 2005; Asasutjarit et al., 2009). Most of them focused on physical and mechanical properties of cement composites. None of them are focusing on fracture behaviour. This fracture behaviour study is important in order to relate the role of fibre in strengthening cement composite. In this work coconut fibre is added to substitute the portion of sand in the ratio of cement to sand. This proposed design mixture was aimed to reduce the use of sand in order to preserve our natural resources.

The selection of coconut fibre in this study is a good effort in order to reduce a bulk of coconut fibre waste in Malaysia. According to a survey that was conducted by Ministry of Agricultural Malaysia (Hisbany, 2005), there are about 156,000 hectares of coconut plantation in Peninsular Malaysia. There will be a huge amount of waste with these huge plantations. Recycling the waste material is one of the best methods with the intention of treating the agricultural waste.

1.3 Objectives of Study

The main purpose of the study is to develop cement composite reinforced with coconut fibre.

The specific aims of the study are:

1. To develop cement composite reinforced with coconut fibre as a construction materials.
2. To study the effect of coconut fibre addition on the physical and mechanical properties of cements composites.
3. To investigate the fracture behaviour of the composite cement after flexural test.
4. To study the potential application of coconut fibre replacing sand in composite cement.

1.4 Scope of Research

In this research, there are five steps have been done to produce a sample of cement composite. The first step is to prepare the raw materials which are coconut fibre, sand, cement and water. The second step is to weight all of the raw materials. As for this research, the work has focused on six different ratios of cement to sand.

These raw materials then were mixed together in a mechanical mixer to get a homogenous mixing of cement composite's sample. The fourth step is to transfer the uniform wet mix to an empty mould according to the mould's size to make composite. The size of mould is depending on the test that will be carried out for that composite.

The final step is to cure the composite in water for 7, 14 and 28 days. In this curing process, the composite get the initial strength. Once the samples were taken out from the curing tank, the testing for mechanical and physical properties of cement composite was done.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter summarizes the review of some other researches that have been done regarding fibre, natural fibres, coconut fibre and cement composites. Based on the literature review, the gathered information has been used as the guidelines to develop cement composite reinforced with coconut fibre.

2.2 Fibre

Fibre can be classified into two types which are natural fibre and synthetic fibre. This classification is shown in Figure 2.1.

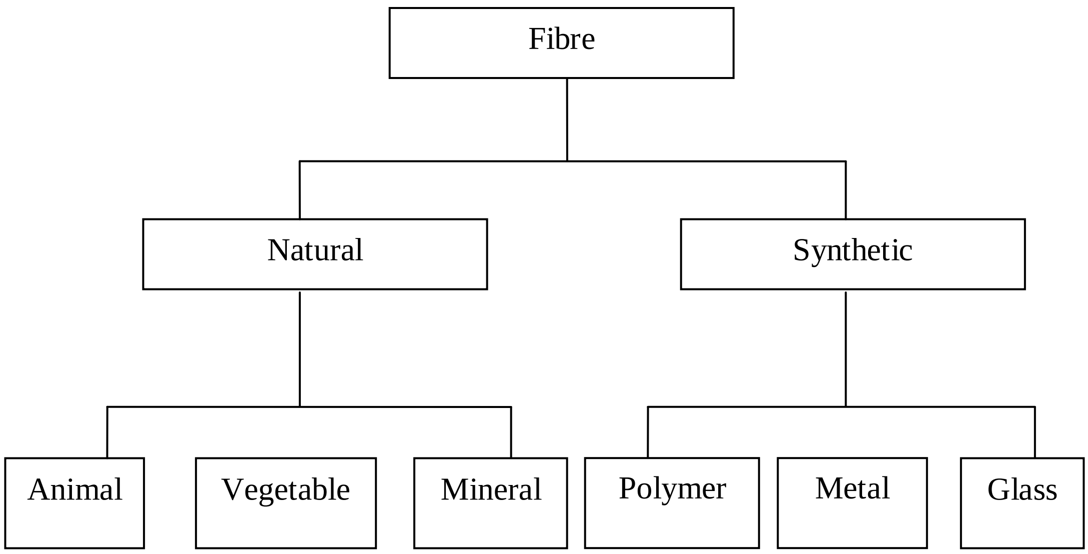

Figure 2.1: Classification of fibres based on natural and synthetic fibres (Chawla, 2005).

Mineral, vegetable and animal were classified as natural fibres. Vegetable and animal kingdom are polymeric in term of their chemical constitution while mineral is crystalline ceramics. Natural fibres are generally a mixture of different compound either chemical or physical. Whereas, polymer, metal and glass are classified as synthetic fibres.

Fibres that obtained from animals such as silk, wool, mohair and alpaca are composed of proteins. Mineral fibres are naturally occurring fibres such as asbestos. Glass fibres include glass wool and quartz while metal fibres include aluminium, brass, steel, etc. (Staiger and Tucker, 2008).

Vegetable fibres such as sisal, jute and coconut have been used as reinforcement of cementitious matrices in the form of short filament fibres (Toledo et al., 2000; Ramakrishna and Sundarajan, 2005). Short filament geometry composites presented a tension softening behaviour with low tensile strength, resulting in products which are more suitable for non-structural applications. Pulp fibres derived from wood, bamboo and sisal have also been used as reinforcement (Silva et al., 2004; Mohr et al., 2005; Silva et al., 2005; Roma et al., 2008).

2.3 Natural Fibre

There are six general types of natural fibres which are bast, leaf, seed, core, grass/reeds and other natural fibres group. The most common classification for natural fibres is by botanical type. Some plants yield more than one type of fibre. For example, agava, coconut, and oil palm have both fruit and stem fibres. Jute, flax, hemp and kenaf have both bast and core fibres (Rowell, 2008).

Table 2.1 shows a more complex list for six classifications types of natural fibres which shows that the coconut fibre (coir) is under the seed group. Type of seed fibre then classified into five groups which are fibres, pod, husk, fruit and hulls. In this classification, the coconut fibre is grouped under the husk group.

Table 2.1: Six general types of natural fibres (Rowell, 2008).

Bast	Leaf	Seed					Core	Grass/ reeds	Other
		Fibres	Pod	Husk	Fruit	Hulls	Kenaf		
Hemp	Pineapple	Cotton	Kapok	Coir	Oil	Rice	Jute	Wheat	Wood
Ramie	Sisal		Loofah		palm	Oat	Hemp	Oat	Roots
Flax	Agava		Milk			Wheat	Flax	Barley	Galmpi
Kenaf	Henequen		Weed			Rye		Rice	
Jute	Curaua							Bamboo	
Mesta	Banana							Bagasse	
Urena	Abaca							Corn	
Roselle	Palm							Rape	
	Cabuja							Rye	
	Albardine							Esparto	
	Raphia							Sabai	
								canary	
								Grass	

Since ancient times, natural fibres have been used to reinforce brittle materials. For example, thousands of years ago, Egyptians began using straw and horsehair to reinforce and improve the properties of mud bricks (Bentur and Mindess, 1990). In more recent times, large-scale commercial use of asbestos fibres in a cement paste matrix began with the invention of the Hatschek process in 1898. However primarily due to health hazards associated with asbestos fibres, alternative fibre types have been investigated and introduced throughout the 1960's and 1970's and have found that natural fibres are the most promising replacement. Some of the investigation and reports that using natural fibres as reinforcement are as follow:

Mansur and Aziz (1982) have studied the jute fibre reinforced cement composites. Different length of fibres were used as reinforcement which were randomly oriented and uniformly distributed in the matrix specimens with varying fibre contents (volume fraction) were tested in direct tension, flexure, axial compression and impact. From their study, the results of the investigation have shown the feasibility of using jute fibres in developing a low-cost construction material particularly for roofing, wall panels and other building boards in countries are ready available. Test results have indicated that a substantial increase in tensile, flexural and impact strength could be achieved by the inclusion of short jute fibres in cement based matrices. They also found that the flexural toughness of the composite could be improved significantly by using jute fibres.

Mathur (2006) has reported development of building materials from local resources with a particular attention on natural fibres based composites. The potential of sisal and jute fibres as reinforcements have been systematically investigated to overcome their well-defined problems of moisture absorption. The performance of polymer composites made from these natural fibres and unsaturated polyester/epoxy resin was evaluated in different humidity, hydrothermal and weathering conditions. Various composite products such as laminates/panels, doors, roofing sheets, shuttering and dough moulding compound have been prepared. The suitability to this products is assessed as an alternative material according to the existing of Indian standard specifications. From this study, Mathur found that natural fibre composite present big opportunities to play as alternative materials especially wood substitute and they have special relevance to developing countries like India in the view of their low cost, energy saving and applications as substitute materials.

Staiger and Tucker (2008) in their report have concluded that the specific tensile strengths of natural fibres are similar to those of glass fibre, although not competitive with carbon or aramid fibres. The mechanical properties of cellulose should be a good indication of the high potential of natural fibres in load-bearing applications.

In Asia, utilisation of bamboo fibres is widespread. For example, bamboo fibres have been used in a variety of panel compositions. The possibility of making three layer boards from the bamboo and wood waste has been studied in Taiwan (Chen et al., 1998). After the World War II, a building centre was created in Japan and Kyoto for the development of building materials using bamboo fibres (Iwai, 1983). A stress-skin panel-type product has been made by using polyurethane or polyester foam in the core and ply-bamboo in the faces (Wange, 1983). In Asia, other natural fibres are also used for applications such as particleboards made from bagasse and soybean stalks and hardboards made from Thai hardwood and coconut fibres (Kristnabamrung and Takamure, 1972).

In Saudi Arabia, manufacturers use bagasse fibres as an alternative in composites for building materials (Usmani, 1985). In Philippines, the focus of the research is on the using of coconut coir, banana, and pineapple fibres with wood wastes for particleboard productions (Pablo, 1989).

In the Middle East (Egypt), rice straw is the most important lignocellulosic material. Rice straw is used to produce fibreboards. In comparison to wood fibres, rice straw has low quality due to its high percentages of non-fibrous materials included in it. But, with care to rice straw fabrication, the properties of board can be increased considerably (Fadl and Rakha, 1990). In addition, in the Middle East, other agricultural fibres such as bagasse, hemp, cotton, and kenaf have been used to produce hardboards and have shown better properties compared to the rice straw composition boards (Fahmy and Fadl, 1974).

The interest in natural-fibre reinforced composites is growing rapidly owing to their great performance, significant processing advantages, bio-degradability, low cost and low relative density. In addition, natural fibres are important renewable resources in many countries and natural-fibre composites form a new class of materials, which have good potential as future substitutes for scarce wood, therefore providing a solution to environmental issues such as reduction of both synthetic and agricultural wastes. Natural fibres are increasingly used in automotive and packaging materials. In India, inorganic boards have been also developed. In addition, researchers have developed a variety of building materials utilising industrial and agricultural wastes that integrate cement and cementitious materials as binders. These combinations are utilised to make composition boards, flooring tiles, roof sheathing, and weatherproof coatings (Mohan, 1978).

However, using natural fibres in building materials has also some disadvantages such as low modulus elasticity, high moisture absorption, decomposition in alkaline environments or in biological attack, and variability in mechanical and physical properties (Swamy, 1990). Challenges still exist in the development of more suitable cost-effective fabrication techniques as well as composites having superior mechanical properties using natural fibres as reinforcement.

The experimentally determined mechanical properties for a range of different natural fibres are shown in Table 2.2. It shows the mechanical properties of natural fibres as compared to conventional reinforcing fibres. The mechanical properties vary considerably depending on the chemical and structural compositions, fibre type and growth conditions. The mechanical properties of plant fibres are much lower than those