Faculty of Engineering

THE EFFECT OF FIBRE CONTENT ON WATER ABSORPTION AND SORPTIVITY OF SAGO FIBRE REINFORCED CONCRETE

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KONG WEN YEE

A dissertation submitted in partial fulfillment
of the requirement for the degree of
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For my beloved family.

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ABSTRACT

Sago fibre reinforced concrete is a composite material that is made up of cement, fine aggregates, coarse aggregates, water and sago fibres. Sarawak is the main producer of sago starch in Malaysia and therefore it produces a lot of waste which consists of fibre from the manufacturing factories. Meanwhile, previous studies done by various researchers have shown that the use of fibres in concrete could affect the properties of concrete towards water absorption and sorptivity. However, the study on sago fibre reinforced concrete is still limited. Therefore, this research is important to investigate the effect of fibre content on the water absorption and sorptivity in sago fibre reinforced concrete to ensure its feasibility in actual practice. In this research, the sago fibre used is in 30mm length with fibre content of 0.5%, 1.0%, 1.5%, and 2.0% by concrete volume respectively. The results of these fibre contents are compared with the control sample (0% fibre content). Slump test is used to determine the workability of fresh concrete samples in this research. Meanwhile, there are three tests involved for the hardened concrete which are compressive strength test, water absorption test and sorptivity test. Generally, the slump value decreases as the fibre content increases. It also shows declination in compressive strength of sago fibre reinforced concrete with respect to the increment in fibre content. From results obtained from water absorption and sorptivity tests, it shows the performance of sago fibre reinforced concrete is slightly better than control sample.

ABSTRAK

Pengukuhan konkrit dengan gentian sagu merupakan bahan komposit yang dihasilkan dengan menggunakan simen, agregat halus, agregat kasar, air and gentian sagu. Sarawak merupakan pengeluaran utama sagu di Malaysia dan mengakibatkan penghasilan sisa-sisa sagu yang melampau dari pihak kilang. Sisa-sisa sagu tersebut kaya dengan gentian yang sesuai dijadikan sebagai bahan pengukuhan. Menurut kajian lepas, penggunaan gentian dalam konkrit akan menjejas ciri-ciri konkrit iaitu penyerapan air dan *sorptivity*. Oleh itu, penggunaan gentian sagu dalam pengukuhan konkrit boleh dijadikan sebagai kajian di bidang teknologi konkrit. Walaupun begitu, kajian tentang pengukuhan konkrit dengan gentian sagu amat terhad. Oleh itu, kajian ini penting untuk mengkaji kesan kandungan gentian atas sifat penyerapan air dan *sorptivity* dalam konkrit bertetulang gentian sagu untuk memastikan kemungkinan aplikasi dalam praktikal sebenar. Dalam kajian ini, panjang gentian yang digunakan adalah 30mm dengan kandungan 0.5%, 1.0%, 1.5% dan 2.0% berdasarkan isi padu konkrit masing-masing. Data yang diperolehi akan dibandingkan dengan konkrit terkawal. Ujian runtuhan juga dijalankan untuk mengenalpasti ciri-ciri konkrit segar. Ujian lain konkrit adalah ujian mampatan, penyerapan air dan *sorptivity*. Secara umumnya, keputusan ujian runtuhan merosot apabila kandugan gentian meningkat. Ujian mampatan juga menunjukkan senario yang merosot apabila kandungan gentian meningkat. Ujian penyerapan air dan *sorptivity* menunjukkan prestasi yang memuaskan berbanding dengan konkrit terkawal.

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A	Mass of specimen after immersion of water (kg)
a	Cross-sectional area (mm^2)
B	Mass of specimen after oven-dried (kg)
D_w	Increase in weight (g)
i	Sorptivity ($mm/min^{1/2}$)
m	Mass (kg)
V	Volume (m^3)
ρ	Density (kg/m^3)
ρ_w	Density of water (1000 kg/m^3)

LIST OF ABBREVIATIONS

ASTM	American Standard Test Method
BS	British Standard
FRC	Fibre Reinforced Concrete
SSD	Saturated Surface Dried

CHAPTER 1

INTRODUCTION

1.1 General

Plain concrete is defined as concrete without reinforcement bars and it is brittle materials. Generally, conventional concrete is widely used in construction industry Malaysia. Plain concrete is made up Portland Cement, water and aggregates. Plain concrete is excellent in compression strength but weak in tensile strength. Besides that, concrete is brittle product in the construction industry. Therefore, steel reinforcement bars are used in conventional concrete to overcome the weakness in plain concrete. In addition, restraining techniques are also implemented to improve tensile properties of concrete. Based on Mahadik et al., (2014), plain concrete will develop in numerous of micro cracks due to its plastic shrinkage, drying shrinkage and also changes in volume of concrete. Hence, these micro cracks are contributed to elastic deformation of concrete.

Fibre reinforced concrete had been introduced into academic and scientists researches in the early of 1960s (Zollo, 1996). Fibre reinforced concrete is defined as cementitious composite materials that contains Portland cement, aggregates, water with fibres as the supplementary materials (Rizzuti & Bencardino, 2014). Rizzuti and Bencardino (2014) also mentioned that addition of fibres into concrete mix helped to modify the cracking mechanisms in concrete. According to Elsaid et al., (2011), fibres which act as complementary reinforcement are capable to carry loads across the micro cracks. Hence micro cracks in concrete can be reduced by adding few amount of fibres during concrete mix. However, the mechanical behaviour of fibre reinforced concrete depends on the fibre amount, fibre geometry, fibre orientation, fibre dispersion and cementitious matrix mix design.

1.2 Research Background

In Sarawak, there are about 1.69 million hectares of peat soil that are distributed in Sibu, Mukah, Oya-Dalat, Pusa-Saratok, Igan and Balingan (Adeni et al., 2009). Peat soil is favourable to the growth of sago and the plantation of sago is usually handled by indigenous people in Sarawak which is Melanau. According to Chew et al., (1997), the present area that undergoes sago cultivation is approximately 19720 hectares which mainly located in Division of Sibu. Jong (1995, as cited in Chew et al., 1997) reported that production of sago in Sarawak can be achieved up to 37 tonnes of starch/hectare/year and about 44, 700 tonnes of sago are exported from Sarawak to Peninsular Malaysia, Hong Kong, Taiwan, Singapore and other countries by the year of 2007 (Adeni et al., 2009).

As the demand of sago starch increases drastically year by year hence the production sago is also increased dramatically. The rapid production of sago had generated abundant of sago pith waste which would lead to environment issues such as water pollution and destruction of ecosystem. Bujang et. al. (1996, as cited by Adeni et al., 2009) stated that there was approximately 7 tonnes of sago pitch waste from a single sago starch processing mill per day. The waste products were delivered into nearby streams or deposited in the factory compound. Therefore, environment issues had been raised into social and proper disposal method system should be implemented in order to protect the environment.

Woody ring of sago is usually becoming waste and fibres are embedded in the waste bark. The fibres that lies in the woody ring have potential used as fibre composite materials (Abral et al., 2012). Sunarti et al., (2012) stated that sago pith mainly contains 81.51 – 84.72 % of starch and 3.2 – 4.2 % of fibres. Tay et al., (2016) studied that generally natural fibres have good mechanical properties hence natural fibres are frequently selected as reinforcement composite. In their studies, thermal stability, mechanical and physical tests are conducted to determine sago particles' characteristics.

1.3 Problem Statement

Plain concrete is a brittle material with good compression strength but weak in tensile strength. Therefore, restraining techniques such as implementation of steel reinforcement bars are applied on plain concrete in order to improve its tensile strength. The application of sago fibres on concrete is not yet been investigated. Hence, effect of sago fibres

reinforced concrete due to fibre content is studied in this research. Besides that, water absorption and sorptivity test conducted to determine the effect of sago fibre content in concrete. Sago, which is also known as Metroxylon Sago are widely grow in Sarawak especially in Division of Sibu and Mukah. Based on Chew et al., (1997), the sago waste that produced by Sarawak is around 7 tonnes. Besides that, there has no proper sago waste management system then result of environmental pollution. Tay et al., (2016) mentioned that natural fibres usually used as reinforcement composite since they have good physical properties. In addition, sago is abundant in Sarawak, biodegradable waste and relatively sustainable. Therefore, sago fibre reinforced concrete had been proposed in research in order to study effect of compression strength, water absorption and sorptivity on concrete.

1.4 Research Significance

Sarawak is the main producer of sago since Sarawak had been recognized as the main exporter of sago di Malaysia. According to Adeni et al., (2009), there are about 44700 tonnes of sago had been exported to Peninsular Malaysia, Hong Kong, Taiwan, Singapore and other countries. However, the increases of sago production had created environmental problems such as water pollution, air pollution and soil pollution. The sago fibres and sago wastewater are discharged into river without proper treatment. Besides that, the sago barks are left in the landfill or burnt off had created land and soil pollution. Since Sarawak is the main production of sago, therefore sago fibres are selected used in fibre reinforced concrete researches. In addition, Tay et al., (2016) from mechanical engineering department conduct some tests on sago particleboard in order to determine thermal stability, mechanical and physical properties. Therefore, it is suggested to conduct the test on sago fibre reinforced concrete in order to obtain and investigate more in concrete technology field. The research on natural fibres reinforced concrete had started on 1960s (Zollo, 1996) however researches on sago fibres reinforced concrete are considered new. Since there has lacking of information on sago fibre reinforced concrete, therefore it can be studied as supplementary reinforcement in concrete.

1.5 Research Objectives

The main aim of this research is to investigate the effect of fibre content on the water absorption and sorptivity of sago fibre reinforced concrete. The objectives below are set in order to achieve the aim of study.

i. To obtain a suitable concrete mix proportion for the plain concrete as control sample with target strength of 30 MPa and slump of 80 to180 mm.
ii. To study the effects of different fibre content on the compressive strength of sago fibre reinforced concrete.
iii. To investigate the effects of different fibre content on the water absorption and sorptivity of sago fibre reinforced concrete.

1.6 Scope of Work

This research studies the effect of compression strength, water absorption and sorptivity on fibre reinforced concrete containing sago fibres. Slump test is conducted in order to measure its workability of fresh concrete. All the concrete samples are prepared with same mix proportions and fibres are added into the mix by 0%, 0.5%, 1.0%, 1.5% and 2.0%. Compressive strength test is carried out after the concrete samples undergo curing at age 3, 7, 28 and 56 days. Water absorption test is conducted after its curing and the data are collected after 30 minutes, 24 hours and 48 hours respectively. Apart from that, sorptivity test also conducted in this research. Data are recorded at 5, 10, 20, 30, 60, 120, 180 and 240 minutes after immersed in water.

1.7 Thesis Organization

Chapter 1 describes briefly on the introduction about plain concrete and fibre reinforced concrete. Besides that, problem statement, objectives of the research and scope of work also been described in the chapter 1.

Chapter 2 presents the previous studies that had been done by various researches. This included the reviews on the properties of various types of fibre reinforced concrete. Meanwhile, the effect of the fibre content in terms of water absorption and sorptivity FRC are also been discussed in this chapter.

Chapter 3 describes the materials and methodology that used in this research. The materials used throughout the research are determined are respect to their properties are

Portland Cement, aggregates, water and sago fibres. The standard procedures for testing are also discussed in this chapter

Chapter 4 discusses on result obtained from laboratory testing. Result are presented in tables and graphs. The discussion on comparison between the samples in terms of their properties based on their fibre content.

Chapter 5 provides the conclusions of this research and recommendations are given for the future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 General

Concrete is the materials that commonly used in constructions industry. Plain concrete is made up of Portland cement, aggregates and water. Plain concrete has brittle characteristics and also weak tensile strength. The weakness in tensile strength can be overcome by steel reinforcement bars or other restraining techniques. Fibre reinforced concrete is known as cementitious composite materials which made up of Portland cement, water, aggregates and fibres. Fibres are function as supplementary reinforcement in concrete. In the previous researches, there has several studies had been conducted in synthetic and natural fibres such as steel, glass, kenaf, coconut, basalt and sisal. However, there has lacking studies about sago fibre reinforced concrete hence more studies required in order to understand more about the characteristics of sago fibre reinforced concrete.

2.2 Fibre Reinforced Concrete

Fibre reinforced concrete is new construction materials that developed in construction industry after the extensive researches and development work. Fibre reinforced concrete is defined as cementing concrete reinforced mixture with randomly distributed fibres. Generally, fibres are categorized into synthetic fibre and natural fibres. Synthetic fibres are man-made fibres such as steel, glass and PET. Natural fibres are materials that produced by animals and plants which including sisal fibre, coconut fibres and kenaf fibres. Based on Vairagade and Kene (2012), fibres helps to transfer the load applied into micro cracks when they are bonded properly. Vairagade and Kene (2012) also stated that high volume fraction fibre composite materials able to show the significant performance in composite materials in tensile or flexural strength. The application of fibres in concrete

can increase flexural-tensile strength, shock resistance, fatigue resistance, ductility and crack arrest. Several tests such as compressive test, water absorption test and sorptivity test are conducted to determine the performance of fibre reinforced concrete.

2.2.1 General Behaviour of Fibre Reinforced Concrete

Generally, natural fibres had been investigated due to researcher's interest in order to replace synthetic fibre and more economical. However, performance of natural fibres applied on concrete are caused by some factors such as type of fibres, fibre content, orientation and distribution of fibres. Shetty (2005) mentioned that lower relative fibre matrix stiffness contributes efficient stress transfer. Fibres with low modulus such as nylon and polypropylene helped in the absorption of energy which give greater degree or toughness and resistance to impact. Meanwhile, high modulus of fibres such as steel, glass and carbon provide strength and stiffness to the composite. Shetty (2005) also stated that interfacial bond between the matrix and fibres are used to determine the effectiveness of stress transfer. It is important in order to improve the strength of the fibre composite.

Besides that, quantity of fibres is also one of the factors contributed to performance of fibre reinforced concrete. The strength of the fibre composite largely depends on the quantity of fibres used. The increment of quantity of fibre used, it will give different impact on composite strength. Shetty (2005) described that the higher percentage of fibre will cause segregation and harshness of concrete or mortar.

Other than that, orientation of fibre also contributed to performance of natural fibre composite (Pickering et al., 2015). Basically, it is hard to ensure that fibres aligned parallel with applied load especially natural fibres. It requires special techniques and designs. Basically, fibres that aligned parallel to applied load will give more tensile strength and toughness than randomly distributed or fibres which perpendicular to applied load.

Therefore, more studies are need in order to investigate the behaviour of fibre reinforced concrete. The use of fibre reinforced concrete gives the improvement in static and dynamic tensile strength, energy absorbing characteristics and better fatigue strength.

2.2.2 Synthetic Fibre Reinforced Concrete

Synthetic fibres are man-made fibres materials that specifically for concrete. Synthetic fibres are added into concrete during concrete mix operation. Synthetic fibres are benefit to concrete due to its resistance towards long term alkaline environment.

2.2.2.1 Steel Fibre Reinforced Concrete

The composite material of steel fibre reinforced concrete is made up of concrete, aggregates, water and steel fibres. Based on Amir and Ronaldo (2012), the application of steel fibres on concrete had been carried out since the early 1900s. Steel fibres are the most common fibres materials used in structural purposes (Jansson et al., 2008). However, there has no proper design method that suitable used for construction purposes therefore some engineer hesitates to apply steel fibres in their structural member in construction. The addition of steel fibres in concrete as complementary helps to improve some properties of concrete. The studies on steel fibres reinforced concrete (Amir & Ronaldo, 2012; Yoo et al., 2015; Shende et al., 2012; Vairagande & Kene, 2012; Shweta & Kavilkar, 2014) which conducted had shown the improvement in compressive strength properties for the cementitious materials.

Water absorption and sorptivity test are also conducted in previous study which was conducted by Tavade and Patil (2015). In the study, the steel fibre varies with 0.75%, 1.0% and 1.25% by volume of concrete. From the tests, the percentage of water absorbed by plain concrete is more than steel fibre reinforced concrete. It is observed that as the increases of fibre content, the water absorption of concrete decreases. Meanwhile, for the sorptivity test, it is observed that sorptivity values of steel fibre reinforced concrete is less than conventional concrete.

Based on Devi and Singh (2013), the aspect ratio of steel fibres contribute performance on slump result and compressive strength. As the aspect ratio increases, it leads to reduction in slump result and compressive strength.

2.2.2.2 Glass Fibre Reinforced Concrete

Concrete is well-known with excellent in compression but weak in tension. Based on study, the addition of glass fibres help to reduce cracking occurred in the concrete due to shrinkage (Deshmukh et al., 2012). Besides that, the application of fibres in concrete reduces the water bleeding occurred during casting. The glass fibres are added into conventional concrete as complementary reinforcement. Deshmukh et al., (2012) studied the effect of glass fibre in 0%, 0.03%, 0.06% and 1% in Grade 20 of plain concrete. According to the research conducted, the compressive strength of concrete had been increased as the percentages of fibre increased. The compressive strength had increased by 8.81% compared to conventional concrete as 0.03% of glass fibres been added. The compressive strength of 0.1% of glass fibres shows improvement drastically whereby the compressive strength had been improved by 23.44%.

2.2.2.3 PET Fibre Reinforced Concrete

Polyethylene terephthalate (PET) is one of waste materials which is obtained from the waste mineral water bottles. According to Nibudey et al., (2014), implementation of PET fibre can improves basic properties of concrete such as compressive strength, tensile resistance, impact resistance, permeability and flexural strength. Nibudey et. al., (2014) study the effect of compressive strength and sorptivity with fibre volume fractions of 0.0% to 3.0%. From the test conducted, the researchers observed that 1.0% of PET fibre reinforced concrete shows significant increases in compressive strength. It shows significant improvement in compressive strength from 0.0% to 1.0% volume fraction and reduction of compressive strength were observed after that. Besides that, sorptivity test also been conducted for PET fibre reinforced concrete. The sorptivity of PET fibre reinforced concrete decreased at 1% of volume fraction but it shows increment at 3% of volume fraction. Nibudey et al., (2014) also had conducted tests based on different aspect ratio which are 35 and 50. From the study, the higher aspect ratio provides higher result in compressive strength as compared to control concrete samples. However, sorptivity values shows reduction as compared to control concrete samples as aspect ratio is higher.

Besides that, there have researchers study regarding structural behaviour of fibre reinforced concrete by using PET fibres. Ogunfayo et al., (2015) studied the structural behaviour due to addition 0.5%, 1.0%, 1.5%, 2.0%, 2.5% and 3.0% volume of the total