COMPRESSIVE STRENGTH, SPLITTING TENSILE STRENGTH AND WATER ABSORPTION OF SAGO FIBRE REINFORCED CONCRETE

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Final Year Project Report ☑

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COMPRESSIVE STRENGTH, SPLITTING TENSILE STRENGTH AND WATER ABSORPTION OF SAGO FIBRE REINFORCED CONCRETE

TAN CHOON HONG

A dissertation submitted in partial fulfilment
of the requirement for the degree of
Bachelor of Engineering with Honours
(Civil Engineering)

For my beloved family, friends and lecturers.

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ABSTRACT

Sago fibre is one of the by-products of sago starch production in sago production plant that is usually disposed in landfill. Since the waste fibre generated from sago starch extraction is in a huge amount, it will contribute to environmental problems if not managed well. It had been shown that the application of natural fibre in fibre reinforced concrete is practicable. However, the application of sago fibre in fibre reinforced concrete is yet to be explored and studied. This research presents the strength development and water absorption of plain concrete and sago fibre reinforced concrete. 1.2% of sago fibre by volume is added to the plain concrete to produce the sago fibre reinforced concrete. Slump test was conducted to determine the workability of fresh concrete and the density of hardened concrete is determined in saturated condition. The strength development of concrete was identified from the compressive strength test and splitting tensile strength test. Furthermore, the water absorption characteristic of the concrete was also identified. The workability of fibre reinforced concrete in fresh state is lower than that of plain concrete as control. The fibre reinforced concrete also marked a higher compressive strength development over a curing age of 56 days. This is due to the crack arresting properties of the fibre incorporated in concrete matrix. The splitting tensile strength of fibre reinforced concrete is higher than that of plain concrete over a curing age of 28 days. This is due to the bridging effect of the sago fibre in the concrete matrix. The water absorption of fibre reinforced concrete is also higher than that of plain concrete over a curing age of 56 days.

ABSTRAK

Gentian sagu merupakan salah satu produk sampingan daripada penghasilan kanji sagu di loji pengeluaran sagu yang biasanya dilupuskan di tapak pembuangan sampah. Oleh sebab sisa gentian yang terhasil daripada pengekstrakan kanji sagu adalah dalam jumlah yang besar, ia akan menyumbang kepada masalah alam sekitar jika tidak diurus dengan baik. Kajian telah membuktikan bahawa penggunaan gentian semulajadi dalam konkrit bertetulang gentian adalah praktikal. Walau bagaimanapun, penggunaan gentian sagu dalam konkrit bertetulang gentian masih belum diterokai dan dikaji. Kajian ini membentangkan pembangunan kekuatan dan penyerapan air konkrit biasa dan konkrit bertetulang gentian sagu. 1.2% gentian sagu mengikut isi padu ditambahkan dalam konkrit biasa bagi menghasilkan konkrit bertetulang gentian sagu. Ujian 'slump' ini dilaksanakan untuk menentukan kebolehkerjaan konkrit segar dan ketumpatan konkrit keras ditentukan dalam keadaan tepu. Terhadap kekuatan konkrit telah dikenalpasti daripada ujian kekuatan mampatan dan ujian kekuatan tegangan membelah. Selain itu, ciri-ciri penyerapan air konkrit juga telah dikenalpasti. Kebolehkerjaan konkrit bertetulang gentian dalam keadaan segar adalah lebih rendah daripada konkrit biasa. Konkrit Bertetulang gentian juga menandakan pembangunan kekuatan mampatan yang lebih tinggi berbanding dengan konkrit biasa pada usia 56 hari. Ini disebabkan oleh sifat menangkap retak gentian yang diperbadankan di dalam matriks konkrit. Dengan kekuatan tegangan membelah konkrit bertetulang gentian adalah lebih tinggi berbanding dengan konkrit biasa pada usia 28 hari. Ini disebabkan oleh kesan penyambung sagu gentian dalam matriks konkrit. Penyerapan air konkrit bertetulang gentian juga lebih tinggi daripada konkrit biasa pada usia 56 hari.

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LIST OF ABBREVIATIONS

w/c	-	water by cement ratio
OPC	-	Ordinary Portland cement
FRC	-	Fibre reinforced concrete
SSD	-	Saturated surface dry

CHAPTER 1

INTRODUCTION

1.1 General Background

Concrete is a common material used in the construction industry due to its strength and durability. Plain concrete is excellent in compressive strength, but weak in tensile strength (Panzera et al, 2013; Jiang et al., 2014; Tschegg et al., 2015; Branston et al., 2016). The tensile strength of plain concrete is approximately one-tenth of its compressive strength (Tschegg et al., 2015). Fibre reinforced concrete is promoted to improve several properties of concrete in the fresh and hardened state (Panzera et al., 2013; Jiang et al., 2014).

The rising world population has caused demand for building infrastructure. This also increases waste generation, energy and material consumption by the construction industry. According to Melchert (2007), building construction also contributes immensely to environmental pollution, especially the emission of greenhouse gaseous (as cited in Onuaguluchi and Banthia, 2016). In order to improve the concept of sustainability in construction industry, the reuse of industrial by-products and renewable materials must be applied (Onuaguluchi and Banthia, 2016).

Researchers have found that fibre added into plain concrete to form fibre reinforced concrete can develop better cracking deformation capability, improve toughness, impact and tensile strength and also reduce cracks due to temperature and shrinkage (Panzera et al., 2013; Jiang et al., 2014). Sago bark fibre is an agricultural waste generated after sago pith is extracted for starch production. Sago fibre is proposed in this study because it is widely available in Sarawak.

1.2 Problem Statement

The amount of agricultural waste generated in Malaysia per year is very huge. The amount of agricultural waste generated in Malaysia is approximately 93,598,000 tonnes per year (Goh et al., 2010). Most of the waste is disposed in landfill (Goh et al., 2010). One of the common agricultural wastes found in Sarawak is from sago palm. According to Singhal et al. (2008), the sago palm pith can be processed to produce sago starch, leaflets for thatching and rachis for house building. The by-products of sago starch extraction are fibre and waste water. The fibre waste can be used for animal feed while refuse water can be used as fertilizer (Singhal et al., 2008). The trunk cortex, which cannot be used in any application will be disposed as solid agricultural waste.

The disposal of the trunk cortex as a waste is not a sustainable way to manage this material. The society is more concern about the reuse and recycle of this waste material to promote the sustainability in building construction. Fibre reinforced concrete (FRC) is introduced to the construction industry to improve the cracking deformation capability, toughness, impact and tensile strength and also reduces cracks due to temperature and shrinkage (Panzera et al., 2013; Jiang et al., 2014).

The typical types of fibre that can be used in concrete composite are steel fibre, synthetic fibre and natural fibre (Merta and Tschegg, 2013; Jiang et al., 2014). The steel fibre and synthetic fibre is not a sustainable and environmental-friendly material to be used in construction. Hence, a more sustainable and environmental-friendly material which is natural fibre is proposed. Since Sarawak produces a significant amount of sago per year, the wasted sago palm trunk cortex is also a huge amount. In Malaysia, according to the sago starch export data by the Department of Agriculture Sarawak, the estimated solid waste generated from sago production is 151,000 tonnes, while wastewater generated is 960,000 tonnes per year (Wan et al., 2016). Hence, sago palm trunk fibre is proposed to be the additional fibre to concrete composite.

1.3 Research significance

The world largest sago exporter is Sarawak which exports about 48,000 tonnes of sago products (Wan et al., 2016). Sago palm trunk fibre is a by-product of sago starch extraction. The starch is extracted from the sago palm pith which is the inner and softer part of the sago palm trunk (Singhal et al., 2008). From the large amount of sago being processed each year, the wasted fibre generated from the production process is also a significant amount.

According to studies done by researchers, fibre is incorporated into plain concrete to form fibre reinforced concrete in order to develop better cracking deformation capability, improve toughness, impact and tensile strength and also reduce cracks due to temperature and shrinkage (Panzera et al., 2013; Jiang et al., 2014). However, conventional fibre applied in fibre reinforced concrete is not an environmental friendly material. The production of steel fibre, glass fibre and synthetic fibre require relatively high energy for production. Natural fibre will be a more environmental-friendly material to be added to concrete mix.

Even though natural fibres have been shown to have the potential to be used as fibre reinforcement for fibre reinforced concrete, however, the application of sago fibre in fibre reinforced concrete is yet to be explored and studied by others. Hence, the properties of sago fibre reinforced concrete will be compared with plain concrete in this study to investigate the probability of sago fibre in fibre reinforced concrete. Since sago fibre is a waste product, the application of sago fibre in fibre reinforced concrete will help to reduce energy consumption in the production of artificial fibre and maintain the quality of the environment to promote the concept of sustainability.

1.4 Aim and Objectives

The main aim of present study is to compare the mechanical properties of plain concrete with sago fibre reinforced concrete with fixed fibre volume content.

In order to achieve the aim of the study, the objectives are established as shown below:

i. To determine the optimum concrete mix design proportion for normal concrete with Grade 30.
ii. To investigate the effects of sago fibre on the compressive strength, splitting tensile strength and water absorption of concrete.
iii. To compare the compressive strength, splitting tensile strength and water absorption of plain concrete and sago fibre reinforced concrete.

1.5 Scope of Study

This project is to investigate and compare the mechanical properties sago fibre reinforced concrete and plain concrete. There is no published research on fibre reinforced concrete with the addition of sago fibre. From a previous study, the fibre volume content for kenaf fibre reinforced concrete recommended is 1.2% (Elsaid et al., 2011). This fibre volume content is taken as a reference for sago fibre volume content.

The laboratory tests will be conducted for both fresh and hardened concrete. For fresh concrete, the workability is the main factor that alters the full compactness of concrete mix (Jackson and Dhir, 1996; Neville and Brooks, 2010). In order to achieve this, slump test will be conducted to determine the workability of concrete mix. The concrete specimens are cured in the curing tank using water. The ages of specimens are 3 days, 7 days, 28 days and 56 days. For hardened concrete, three types of test are conducted which are compression test, flexural test and splitting tensile test. A total of 48 cubes and 24 cylinders are needed for this study.

All data and results collected from the test done are analysed. The conclusion and recommendation of this study will be made after the data analysis.

1.6 Thesis Organization

This thesis consists of five chapters. In Chapter One, a brief introduction to the entire research project is provided. This chapter consists of the background of the study, problem statement, research significance, aim and objectives and also scope of study. Chapter Two is a literature review, which emphasized on the knowledge on concrete, previous studies by other researchers and also the research gap. Chapter Three is the methodology of the preparation of materials and the required methods to conduct the tests for this research study. Chapter Four presents the results and discussions from laboratory testing while Chapter Five presents the conclusion and recommendations for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 General

The important characteristics of hardened concrete are strength, deformation under load, durability, permeability and shrinkage (Jackson and Dhir, 1996). The most important characteristic is the strength which includes compressive strength, flexural strength and split tensile strength. Fibre reinforced concrete is introduced to overcome the low tensile strength and impact strength of plain concrete. This chapter focus on the theoretical study of fibre reinforced concrete. The addition of steel, glass and synthetic fibre in fibre reinforced concrete will increase the production cost of concrete. Hence, natural fibre such as sago fibre is proposed to be the substitute of synthetic fibre. Previous study on sago also discussed in this chapter.

2.2 Fibre Reinforced Concrete

Plain concrete is excellent in compressive strength, but weak in tensile strength (Panzera et al., 2013; Jiang et al., 2014; Tschegg et al., 2015; Branston et al., 2016). The tensile strength of plain concrete is approximately one-tenth of its compressive strength (Tschegg et al., 2015). Fibre is incorporated into plain concrete to form fibre reinforced concrete in order to develop better cracking deformation capability, improve toughness, impact and tensile strength and also reduce cracks due to temperature and shrinkage (Neville and Brooks, 2010; Panzera et al., 2013; Jiang et al., 2014).

The uniformly distributed fibre in the concrete matrix functioned as a crack preventer to limit the growth of faults in the concrete matrix into larger visible cracks under stress (Aziz et al., 1981; Gao et al., 1997). With the reduction of visible crack formation, the usable tensile strength of concrete is improved (Aziz et al., 1981).

The amount of fibre needed for fibre reinforced concrete is little which is 1% to 5% by volume normally (Neville and Brooks, 2010; Branston et al., 2016). The critical length of fibre is also very important for it to perform as reinforcement in concrete to avoid being pulled out of the concrete matrix and fail itself by tension (Neville and Brooks, 2010). Neville and Brooks (2010) suggested that the length of fibre larger than the maximum aggregate size. Maximum stress can be applied on the fibre will increase if the interfacial bond strength is higher (Neville and Brooks, 2010).

Water absorption of concrete is an important parameter to estimate the service life of concrete as a building material and to improve the quality of concrete (Martys and Ferraris, 1997; de Schutter and Audenaert, 2014). The rate of sorption can be related to the degree of saturation to generate capillary diffusivity which can be used for modelling by taking into consideration the environment exposure to estimate the moisture transport (Martys and Ferraris, 1997).

According to Kohoutkova and Broukalová (2013), the application of fibre reinforced concrete in small structural components that did not carry significant loads is very suitable. The typical types of fibre that can be used in concrete composite are natural fibre, synthetic fibre and polymer fibre (Neville and Brooks, 2010; Merta and Tschegg, 2013; Jiang et al., 2014).

Fibre reinforced concrete can be formed into sheets and boards which are light and suitable for walling, ceiling and roofing of low cost houses (Aziz et al., 1981). Fibre reinforced concrete can also be applied in areas where the impact energy need to be absorbed or area that possibly exposed to impact damage such as earthquake resistant construction, explosive resistance structures, airfield pavements, refractory lining, foundation of machineries and factory floors (Aziz et al., 1981; Shetty, 2005). Some applications of fibre reinforced concrete are beams for cellular foundation, roof panels, manhole covers, slabs, aprons, pavements, buried conduits and various types of shell structures (Aziz et al., 1981; Shetty, 2005).

According to Ali (2011), fibre reinforced concrete can be applied in slab, boards, wall panelling system and house construction. The corrugated slabs manufactured using fibre reinforced concrete has a similar thermal conductivity and sound absorption coefficient if compared with industrial asbestos board (Ali, 2011). The coconut fibre based lightweight cement board had been proved to have lower thermal conductivity than