DEVELOPMENT OF SYNTHETIC-COCONUT HYBRID FIBER REINFORCED MORTAR

DEBBIE NUR ALLYSA BINTI MATTIUS

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Bk18110148

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NAME : **DEBBIE NUR ALLYSA BINTI MATTIUS**

MATRIC NO : **BK18110148**

TITLE : **DEVELOPMENT OF SYNTHETIC-COCONUT HYBRID FIBER REINFORCED MORTAR**

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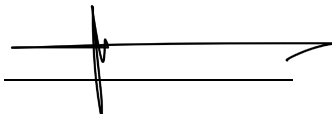

SINGLE SUPERVISION

SUPERVISOR

Dr. Sheikh Mohd Iqbal Sheikh Zainal Abidin

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ABSTRACT

A cementitious composite is any composite that contains Portland cement as its principal binder, and it can take the shape of concrete, mortar, grout, and other materials depending on its composition. Despite having numerous advantages, one of the disadvantages of mortar is it has low tensile strength. The purpose of this research is to determine the variation of mechanical properties which are compressive, tensile, and flexural strengths of synthetic-coconut hybrid fiber reinforced mortar with crumb rubber with different mix design. This research was conducted on mortar that incorporated rubber crumb aggregate as replacement for sand at 5%, 10% and 15%. Rubber crumb aggregate is generally obtained from recycled tyre. Many research shows adding rubber crumbs will reduce the strength of mortar. Thus, fibers will be adopted as the reinforcement for the rubberized mortar. Combination of different types of fiber proven to perform better than mortar with single fiber. In this research, synthetic fiber which is Forta Ferro Fiber (polypropylene) and natural fibers which are coconut fiber will be combined. With the addition of rubber crumb aggregate and fibers, the flowability could be negatively affected. Therefore, superplasticizer which is High Range Water Reducing Admixture (HRWRA) will be used to improve the flowability while maintaining mortar strength. In this research, a total of 351 specimens were tested which consist of 13 different design mix with 27 specimens each. For each mix design, the specimens undergo compressive strength test, flexural strength test and split tensile strength at 3 days, 7 days and 28 days of curing. Main findings of this research shows that addition of hybrid fiber improves the mechanical properties of rubberized mortar.

ABSTRAK

PEMBANGUNAN MORTAR BERDASARKAN FIBER HIBRID SINTETIK-KELAPA SEBAGAI BAHAN PENGUKUH

Komposit bersimen ialah sebarang komposit yang mengandungi simen Portland sebagai pengikat utamanya, dan ia boleh mengambil bentuk konkrit, mortar, grout dan bahan lain bergantung pada komposisinya. Walaupun mempunyai banyak kelebihan, salah satu kelemahan mortar ialah ia mempunyai kekuatan tegangan yang rendah. Tujuan kajian ini adalah untuk menentukan variasi sifat mekanikal iaitu kekuatan mampatan, tegangan dan lenturan mortar bertetulang gentian kelapa hibrid sintetik dengan getah remah dengan reka bentuk campuran yang berbeza. Kajian ini dijalankan ke atas mortar yang mengandungi agregat serbuk getah sebagai pengganti pasir pada kadar 5%, 10% dan 15%. Agregat serbuk getah biasanya diperoleh daripada tayar kitar semula. Banyak kajian menunjukkan penambahan serbuk getah akan mengurangkan kekuatan mortar. Oleh itu, gentian akan diterima pakai sebagai tetulang untuk mortar bergetah. Gabungan pelbagai jenis gentian terbukti berprestasi lebih baik daripada mortar dengan gentian tunggal. Dalam penyelidikan ini, gentian sintetik iaitu Gentian Forta Ferro (polipropilena) dan gentian asli iaitu gentian kelapa akan digabungkan. Dengan penambahan agregat serbuk getah dan gentian, kebolehaliran boleh terjejas secara negatif. Oleh itu, superplasticizer iaitu High Range Water Reducing Admixture (HRWRA) akan digunakan untuk meningkatkan kebolehaliran sambil mengekalkan kekuatan mortar. Dalam penyelidikan ini, sebanyak 351 spesimen telah diuji yang terdiri daripada 13 campuran reka bentuk berbeza dengan 27 spesimen setiap satu. Bagi setiap reka bentuk campuran, spesimen menjalani ujian kekuatan mampatan, ujian kekuatan lentur dan kekuatan tegangan pecahan pada 3 hari, 7 hari dan 28 hari pengawetan. Penemuan utama penyelidikan ini menunjukkan bahawa penambahan gentian hibrid meningkatkan sifat mekanikal mortar bergetah.

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FRM – Fiber Reinforced Mortar

CF – Coconut Fiber

RCA – Rubber Crumb Aggregate

HRWRA – High-Range Water Reducing Admixture

ASTM - American Society for Testing and Materials

PLC – Portland Limestone Cement

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CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter is made of the introduction of this research. It consists of six sections. The first section discussed on the research background. In the second section, the problem statements of this research were presented. For the third section, the research questions were stated. The fourth section presents the aims and objectives of this research. The fifth section discussed on the scope of research. Lastly, the sixth section presents the significant of research.

1.2 Research Background

A cementitious composite is any composite that contains Portland cement as its principal binder, and it can take the shape of concrete, mortar, grout, and other materials depending on its composition. This research mainly focuses on one of cementitious composites which is mortar. Mortar refers to a mixture of finely divided hydraulic cementitious material, fine aggregate, and water in either the unhardened or hardened state (ASTM C219). In civil engineering, mortar is used to bind various construction materials together, such as bricks, stone, tiles, or concrete blocks. The main difference between concrete and mortar is that mortar does not contain coarse

aggregate. The presence of coarse aggregates in fiber reinforced concrete reduces the fiber content of material and, as a result, the fibers' reinforcement effectiveness decreased. When fiber addition is considered, cements and mortars are more effective than concretes.

Fiber reinforced mortar also known as *fibronizzata* is mortar containing fibrous material which increases its mechanical properties. The concept of using fiber materials as reinforcement in building is not new. It has been employed as a form of reinforcement from the dawn of time. Horsehair was once used in mortar and straw was once used in mudbricks. Fiber began to be employed in the development of fiber reinforced concrete in the early 1900s. Early uses of plant and animal fibers in construction include straws in adobe and horse or goat hair in a binding mixture for masonry mortar and plaster (Erdogmus, 2015). Joseph Lambot patented the use of fibers in cementitious mixtures in 1847, which marked the beginning of the contemporary usage of fibers in cementitious mixtures (Naaman, 1985). The inclusion of fibers in the mortar mixture serves to counteract the hydraulic shrinkage that occurs during the hardening process of the mortar, preventing the creation of cracks and fissures on the plastered surface. Fiber reinforced mortar is simple to apply and does not necessitate the use of skilled workers.

In this research, rubber crumb aggregate (RCA) will be added in certain percentage in the development of fiber reinforced mortar. RCA generally produced from recycled rubber from disposed old tires by removing the steel and tire cable. The application of rubber crumb in construction can first be seen in the 2000s when it is used for artificial turf system. The use of rubber crumb aggregate in cementitious composite can enhance fracture toughness and energy absorption as well as promote sustainability as it reduces the need for primary aggregate.

1.3 Problem Statements

By nature, construction industry is the main contributor to the pollution due to the waste produced. This is mainly caused by the construction waste and carbon emission which is eight percent from the cement production (Robbie, 2017). One of the solutions suggested for this problem is to replace a certain percentage of the conventional material with waste materials. In this research, the effect of replacing a certain percentage of fine aggregate with RCA will be studied. RCA were obtained from recycled waste tires which is hard to disposed (Adesina, 2020). By researching and finding a useful way to reuse this waste, it will help to improve the environment as well as the country economy. Therefore, rubber crumb aggregate will be used in mortar development for this research.

There are many extensive studies done on the effects of the usage of waste materials and fiber reinforcement on the mechanical properties for concrete. However, there are still insufficient studies of this topic for mortar. Despite having numerous advantages, one of the disadvantages of mortar is it has low tensile strength. Hence, this research will aim on studying the effects of adopting hybrid fibers and rubber crumb aggregate in mortar development to its mechanical properties which are compressive strength, tensile strength, and flexural strength.

Various studies on different combination of fiber have shown positive impact on mechanical properties of cementitious composite. One of them is combination of coconut fiber and polypropylene fiber (Bijo MD and Sujatha Unnikrishnan, 2022). The mechanical characteristics of HyFRC with polypropylene and coconut fibres were investigated by Sarangi and Sinha. One percent was used as the overall fibre content, with different fibre proportions of 75 to 25, 50 to 50, and 25 to 75. HyFRC with 75% PP and 25% CF was discovered to have superior compressive strength and flexural strength. Though there are various studies on hybrid fiber in cementitious composite, there are limited research on synthetic fiber and coconut fiber in mortar. Another research with fiber mortar which incorporated tire crumb were made by Aznieta et al. found that adding fiber to rubberized mortar could improve its mechanical properties.

1.4 Research Questions

This research uses the result to address three research questions:

a. How does combining different types of fibers and developing a hybrid fiber reinforced mortar effect the mechanical properties of the mortar?

b. What is the percentage of fibers, rubber crumb and superplasticizer added that will give optimum result?

c. Does the conventional mortar experience failure? If yes, how to solve the problem and improve the mortar?

1.5 Aims and Objectives

The overall aim of this study is to determine the variation of compressive, tensile, and flexural strengths of synthetic-coconut hybrid fiber reinforced mortar with crumb rubber with different mix design.

The objectives of this research are as follows:

a. To observe the effect on mechanical properties of FRM after replacing 5%, 10%, and 15% of sand with RCA in hybrid fiber mortar.

b. To investigate the effect of hybrid fiber reinforced mortar by using two different types of fiber which are synthetic fiber which is FORTA Ferro fiber or polypropylene and natural fiber which is coconut fiber.

c. To investigate the effect of adding 0.4%, 0.6 and 3.2% of superplasticizer from cement weight in hybrid fiber mortar.

1.6 Scope of Research

This research mainly focuses on developing a synthetic-coconut hybrid fiber reinforced mortar with RCA. Different mix design will be developed throughout this research to study on the mortar properties which are compressive strength, flexure strength and tensile strength. The fibers combined will be FORTA Ferro fiber which is 0.6% from cement weight and coconut fiber which is also 0.6% from cement weight. The length of the fiber will be used for mixing is between 1.0cm to 3.0cm. For the mortar, the replacement of sand with RCA will be 0%, 5% and 15% from the wight of sand. The percentage of additive which is High-Range Water Reducing Admixture (HRWRA) is 0.4%, 0.6% and 3.2% from the weight of water. The target strength of the mortar is between 30MPa to 40MPa. For molding, the specimen will be in three different mold which are cube, prism, and cylinder. Size of the specimen are 50mm x 50mm x 50mm for cube, 40mm x 40mm x 160mm for prism and 100mm x 200mm for cylinder. There will be three specimens for each design. The mortar mix will undergo curing and tested at age of 3 days, 7 days, and 28 days.

1.7 Significant of Research

The finding of this research be beneficial to the society, considering how construction industry is vital in the world development. Mortar is one of the most commonly used materials as binder in construction. The drawback of mortar with low tensile strength shows the need of more effective solution on improving its mechanical properties. Thus, companies that apply the proposed approached developed from the result in their construction project will help to improve the quality of their project.

On the other hand, the finding of this research will also be significant to the environment and economy of the country. As the construction industry developing, there will be increase in the number of wastes. Hence, implementing the solution from this research helps to reduce the waste by making it useful in construction. For the researchers, the findings of this research may help in uncover critical area in construction materials that many researchers yet to explore.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter is made based on the literature review from previous researcher that is related to current research. This chapter consist of seven sections. The first section discussed on fiber reinforced mortar. In second section, combination of different types of fibers were reviewed. The third section were devoted to Forta Ferro fibers. For the fourth section, coconut fibers were discussed. The fifth section presented the types of fiber failure. The sixth section shows rubber crumb aggregate effects on mortar. Lastly, superplasticizer in mortar were reviewed in seventh section.

2.2 Fiber Reinforced Mortar

Concrete, mortar, and cement mixtures are brittle materials that are stronger in compression but weaker in flexure and tension. These brittle materials deform elastically without reinforcement, followed by macro-cracking, which results in fracture development (Erdogmus, 2015). On cementitious materials, fracture is a regular occurrence. It helps to engage and augment the system with extra tensile strength, which prevents brittle failure, by adding fiber reinforcement.

In construction, fiber reinforced mortar is mostly used as it is convenient and offers a lot of advantageous features. There may be additional criteria for aesthetics, compatibility, workability, and bond strength in masonry applications when FRM is

used at the mortar joints (Erdogmus, 2015) It has a positive economic impact because its increased durability, wear resistance, serviceability, increased overhaul life, and improved structural safety under seismic and fire loads. This is because the energy of deformation and destruction is frequently bigger in distributed fiber reinforcement than in discrete reinforcement, energy is dissipated in the volume of the structure or its component (Klyuev et al.,2018). As an example, fiber shotcrete is used in rock slope stabilization, tunnel lining, bridge repair and protection for steel structure (Hamid & Behzad, 2017). The most significant benefit of fiber inclusion is for post-cracking behaviors; crack management is one of most interesting uses in fiber reinforced concrete. The fibers can prevent wider crack widths, which could allow water and contaminants to penetrate the reinforcing steel and induce corrosion.

Fibers are crucial in the tensile behavior of concrete because they inhibit the creation of cracks and slow the spread of fissures. The most notable benefit of fibers in cementitious matrices is an improvement in post-cracking behavior, which is usually measured in terms of material toughness (Erdogmus,2015). The proportion and length of the fibers have a significant impact on the consistency of fresh mortar (Borinaga-Treviño et al.,2021). The length of building structures and buildings as a whole is influenced by the type of steel reinforcing fiber used and its shape (Klyuev et al.,2018). The proposition and initial strength of a cementitious matrix shall also be considered when adding fiber as the reinforcement.

Fiber originally categories into three which are metallic fibers like steel, mineral fibers such as glass fibers, and organic fibers which further categorized into two which is natural fiber such as CF and man-made fibers or synthetic fibers such as polypropene. Different type of fiber used gives different effect on the properties of mortar. The most common type of fiber used as reinforcement for cementitious composite is steel fiber. It was first used in concrete to control plastic and drying shrinkage. The ability of synthetic fiber reinforced concrete and glass fiber reinforced concrete to resist bridging stress transferred across a crack is exceptional, resulting in high compressive strength (Hedjazi & Castillo, 2020). Fibers have a significant impact on crack width reduction, particularly in beams with a low conventional reinforcement ratio (Głodkowska,2018).

Aside from mechanical properties, fiber usage in mortar also affects the physical properties of the mortar. The workability of polypropylene and glass fibers was found to be extremely low. This characteristic was discovered to play a significant

effect on porosity and bulk density (Simoes et al.,2018). Steel fibers have a higher density than the cementitious matrix, hence the mortar's specific density rises as the dosage rises (Simoes et al.,2018).

2.3 Forta Ferro Fibers

Synthetic fiber that will be used in this research is Forta Ferro fiber. Forta Ferro Fiber is made purely from polypropylene. It consists of a twisted bundle non-fibrillating monofilament and a fibrillating network fiber, resulting in a high-performance reinforcement system for cementitious composite. Forta Ferro fiber is commonly used in cementitious composite to reduce plastic and hardened concrete. Previous studies shows that this polypropylene-based fiber has both advantages and disadvantages in comparison to other fibers as reinforcement in cementitious composite.

When Forta Ferro fibers are added to high-strength concrete, they have a greater impact on the modulus of elasticity increase than steel fibers, with the highest modulus of elasticity improvements relative to plain concrete being 9.6 percent and 12.1 percent, respectively, at volume contents of 0.75 percent steel fibers and 0.65 percent Forta Ferro fibers (Hasan-Nattaj et al.,2017). The study also discovered that, when compared to concrete reinforced with monofilament polypropylene fibers, collated fibrillated fiber reinforced concrete is less flowable, has less passing ability, and has lower compressive and splitting tensile strength. (Sahar et al., 2021).

In comparison to steel fiber, Forta Ferro fiber cause a higher loss in concrete workability fibers in high-strength concretes containing the same volume percentages of the fibers individually (Hasan-Nattaj et al.,2017).

2.4 Coconut Fibers

Natural fibers are made primarily of renewable resources. One of the most significant advantages is that they are often inexpensive, easy to obtain, and environmentally benign, especially since regenerated natural fibers are agro-food leftovers or wastes (Roberto et al.,2019). In this research, natural fiber will be used to develop the fiber reinforced mortar which is coconut fiber. Coconut fiber is extracted from the outer shell of a coconut. The common name, scientific name and plant family of coconut fiber is Coir, Cocos nucifera and Aceraceae (Palm), respectively (Majid Ali, 2011). Coconut fiber is one of the natural fibers that is commonly used as a composite.

Coconut fibers are readily available at the test site, making it a viable option for use as a concrete reinforcing material. Marie-Therese has found that coconut fibers are the strongest natural fibers, with a strength of 21.51 MPa and it can withstand 4 to 6 times the tension of conventional fibers. There are few factors influence the properties of plant-based fiber such as shapes, chemical compositions, capacities for water absorption and mechanical properties (Laborel-Préneron et al., 2022) Depending on its composition, coir could reach a tensile strength up to 505 MPa (Pacheco-Torgal, 2011).

Adopting natural fiber in mortar improve the strength and durability of the mortar. When compared to control mix, mortar added with fiber execute better result in compressive strength, split tensile strength, flexural strength, water absorption and ultrasonic pulse velocity (Mathavan et al.,2020). In comparison to other fiber such as jute and kelp fiber, coconut fibers appear to boost the fracture energy of mortars due to its high ductility (Kesikidou et al.,2019). The compression strength test produces good results when using 0.6 percent coconut and 1.2 percent coconut with an aqueous water cement ratio of 0.40 (Syed et al.,2020). The tensile split strength increases by up to 5% when the fiber content is increased. A decrease in tensile stress is noted as fiber content increases after this amount (Syed et al.,2020).

Wang and Chouw investigated how coconut FRC responded to impact loading. lengths of 25, 50, and 75 mm The study employed 1.5 percent volume of coconut fibres. On the samples, an impact test using a single and repeated DWT was performed. In comparison to fibre with a 75 mm length, FRC with fibre lengths of 25 mm and 50 mm worked well. Thus, coconut fiber with length of 1cm to 3cm will be used for this research.