UNIVERSITI PUTRA MALAYSIA

DURABILITY PERFORMANCE OF RUBBERISED FIBRE MORTAR

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By

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High cost of building materials and reduction of healthy environmental conditions due to excessive use of natural aggregates had leads many researchers to find alternative replacement materials for construction. At the same time, abundance of recyclable non-biodegradable solids such as waste tyres and oil palm fruit fibre (OPFF) cause crucial environmental problems if not disposed well. Hence this research is carried out to make used of those waste materials as replacement of natural aggregates and as addition to enhance the durability performance of rubberised fibre mortar (RFM). RFM is a mix combination of treated crumb rubber (TRC) and OPFF in producing a 'greener' lightweight mortar. The RFM mix composition is made of 10 to 30% TCR as sand replacement and addition of 1% to 1.5% OPFF producing sixteen different mixes, in which all mixture are using water to cement ratio of 0.48. The mechanical properties of these 16 RFM mixes are well studied earlier; however none are reported on the durability aspects. Durability is influenced by temperature, humidity and curing methods. This study focuses on two types of water curing called ponding and wetting which are practical for brick/block production, which is the potential application of the mixtures. The specimens were cured by each curing method for 28 days before being subjected to compressive strength, chloride ion penetration resistance, water permeability under hydrostatic pressure, water absorption, Sodium Sulphate ingress and carbonation depth tests. These tests were carried out to evaluate the durability performance of the mixes. Based on the results obtained, the durability performance of RFM has significantly influenced by addition of OPFF and replacement of TCR. It was discovered that RFM mix containing 1.0% OPFF and 30% TCR for both curing methods can adequately sustain CO_2 penetration, moderate chloride ion penetration resistance and sulphate aggression. Medium permeability and moderate absorption characteristics were possible with RFM of 1% OPFF and 20% TRC for both curing methods. Density of RFM significantly decreased while structural lightweight concrete was achieved up to 30% TCR for both curing methods. There was insignificant effect of curing on sulphate and chloride ion penetration resistance of the RFM mixes. In conclusion it was found that RFM mix of 1.0% OPFF with any of 10% - 30% TCR replacements have potential applications in brick/block productions as it meets the durability requirements of lightweight materials.

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PRESTASI KETAHANAN MORTAR BERSERAT GETAH

Oleh

AHMAD MUSA MUKADDAS

September 2015

Pengerusi : Farah Nora Aznieta Binti Abd.Aziz, PhD
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Kos yang tinggi bagi bahan binaan dan pengurangan keadaan alam sekitar yang sihat kerana penggunaan agregat semula jadi yang berlebihan menyebabkan ramai penyelidik mencari bahan gantian alternatif bagi pembinaan. Pada masa yang sama, terdapat banyak bahan yang boleh dikitar semula dari bahan pepejal tidak terbiodegradasi seperti tayar terpakai dan serat buah kelapa sawit (OPFF) yang boleh menyebabkan masalah alam sekitar yang membimbangkan jika tidak diselenggara dengan teratur. Oleh itu kajian ini dijalankan untuk menggunakan bahan-bahan buangan tersebut sebagai pengganti agregat semulajadi dan sebagai tambahan untuk meningkatkan prestasi ketahanan mortar serat getah (RFM). RFM adalah gabungan campuran getah remah terawat (TRC) dan OPFF bagi menghasilkan mortar ringan 'hijau'. Komposisi campuran RFM diperbuat daripada 10 hingga 30% TCR sebagai pengganti pasir dan 1% hingga 1.5% OPFF sebagai bahan tambahan untuk menghasilkan enam belas campuran yang berbeza, di mana semua campuran menggunakan nisbah air kepada simen sebanyak 0.48. Sifat mekanikal 16 campuran RFM ini telah dikaji dengan baik, walau bagaimanapun tiada aspek ketahanan yang dilaporkan. Ketahanan dipengaruhi oleh suhu, kelembapan dan kaedah pengawetan. Kajian ini akan memberi tumpuan kepada dua jenis pengawetan air disebut kolam tradisi dan percikan. Spesimen-spesimen ini diawet oleh salah satu kaedah pengawetan selama 28 hari sebelum dikenakan ujian-ujian berikut; kekuatan mampatan, klorida ion rintangan penembusan, kebolehtelapan air di bawah tekanan hidrostatik, penyerapan air, kemasukan Sodium Sulfat dan ujian mendalam pengkarbonan. Ujian-ujian ini telah dijalankan untuk menilai prestasi ketahanan campuran. Berdasarkan keputusan yang diperolehi, prestasi ketahanan RFM dipengaruhi dengan ketara oleh penggabungan OPFF dan TCR. Adalah juga didapati RFM yang mengandungi 1.0% OPFF dan 30% TCR, untuk kedua-dua kaedah pengawetan dapat mengekang penembusan CO_2 secukupnya, mampu menghadapi rintangan penembusan ion klorida dan pencerobohan sulfat yang sederhana. Kebolehtelapan dan ciri-ciri penyerapan yang sederhana juga ditemui dari campuran RFM yang mengandungi 1% OPFF dan 20% TRC bagi kedua-dua kaedah pengawetan. Dari segi kesan kaedah pengawetan, ianya memberi kesan minimum ke atas campuran RFM. Dapatlah disimpulkan bahawa berdasarkan semua ujian ketahanan yang dijalankan, didapati bahawa RFM campuran 1.0% OPFF dengan 10% - 30% penggantian TCR berpotensi digunakan untuk aplikasi dalam pengeluaran bata/blok kerana ia memenuhi syarat-syarat ketahanan bahan ringan.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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This is to confirm that:

- The research conducted and the writing of this thesis was under our supervision;
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LIST OF ABBREVIATIONS

BE	Bitumen Emulsion
CR	Crumb Rubber
CRA	Coarse Rubber Aggregate
CRT	Concrete with Recycled Waste Tyre
C-S-H	Calcium Silicate Hydrate
DC	Direct Current
EFB	Empty Fruit Bunch
FA	Fine Aggregate
FCRA	Fine and Coarse Rubber Aggregates
FRA	Fine Rubber Aggregate
FRC	Fibre Reinforced Concrete
FTA	Fine Tyre Aggregate
GHA	Groundnut Husk Ash
ITZ	Interfacial Transition Zone
MCE	Methocel Cellulose Ethers
ML	Moisture Content
OPEFB	Oil Palm Empty Fruit Bunch
OPFF	Oil Palm Fruit Fibre
OPTF	Oil Palm Trunk Fibre
PPM	Parts Per Million
PSD	Particle Size Distribution
RCPT	Rapid Chloride Permeability Test
RFM	Rubberised Fibre Mortar
RH	Relative Humidity
RHA	Rice Husk Ash
SBR	Styrene-Butadiene Rubber
SEM	Scanning Electron Microscopy
SMT	Surface Modification Treatment
SP	Super Plasticiser
SSD	Saturated Surface Dry
TCR	Treated Crumb Rubber

TR	Tyre rubber
TRA	Tyre Rubber Aggregate
WA	Water Absorption
F0.5CR0	Mortar Samples Containing 0.5% OPFF
F0.5CR10	Mortar Samples Containing 0.5% OPFF and 10% TCR
F0.5CR20	Mortar Samples Containing 0.5% OPFF and 20% TCR
F0.5CR30	Mortar Samples Containing 0.5% OPFF and 30% TCR
F0CR0	Mortar Samples Containing neither OPFF nor TCR
F0CR10	Mortar Samples Containing 10% TCR
F0CR20	Mortar Samples Containing 20% TCR
F0CR30	Mortar Samples Containing 30% TCR
F1.0CR0	Mortar Samples Containing 1.0% OPFF
F1.0CR10	Mortar Samples Containing 1.0% OPFF and 10% TCR
F1.0CR20	Mortar Samples Containing 1.0% OPFF and 20% TCR
F1.0CR30	Mortar Samples Containing 1.0% OPFF and 30% TCR
F1.5CR0	Mortar Samples Containing 1.5% OPFF
F1.5CR10	Mortar Samples Containing 1.5% OPFF and 10% TCR
F1.5CR20	Mortar Samples Containing 1.5% OPFF and 20% TCR
F1.5CR30	Mortar Samples Containing 1.5% OPFF and 30% TCR

CHAPTER 1

INTRODUCTION

1.1 Research Background

Search for alternative sources of concrete building materials are mainly due to high cost of the conventional ones. Basically, there are two approaches for replacement of the alternative materials, either for cement or for aggregates. Cement replacements are carried out using sludge, rice husk ash (RHA) and groundnut husk ash (GHA) as reported by Tay & Yip (1989); Oyetola & Abdullahi (2006); Elinwa & Awari (2001); Ketkukah & Ndububa (2006).

On the other hand, aggregate replacements were either by using waste or agricultural by-products or solids. Coconut and palm oil shells are some of agriculture waste reported as adequate replacement for conventional coarse aggregate (Apata & Alhassan, 2012). Apart from that, sawdust, recycle aggregates, mining tiling waste and tyre waste are also reported as appropriate materials for aggregate replacements (Pierce & Blackwell, 2003; Ketkukah et al., 2004). Although, there was a general reduction in compressive strength over conventional concrete, the strength is adequate for medium load bearing structural elements. Waste is considered as one of the most crucial environmental problems of the world, particularly waste from scrap tyres which are non-biodegradable. Each year, about 8.2 million or approximately 57, 3911 tonnes of stockpile waste scrap tyre is generated in Malaysia with 60% unaccounted disposal method (Thiruvangodan, 2006). The unmanaged scrap tyre poses environmental and health associated risk through tyre stockpile fires and as a breeding ground for disease carrying mosquitoes, rats, mice and vermin (Siddique & Naik, 2004; Mohammed et al., 2012).

The use of rubber waste shredded tyres in concrete was studied in the past by many researchers in various forms such as crumb, chips, or particles and in the form of fibres. The potentialities of utilising waste crumb tyres in various mechanical properties of mortar and concrete shows that the compressive strength, density, and modulus of elasticity were decreasing as the percentage of waste crumb tyre replacement was increased. On the same note, the initial water absorption capacity was decreasing but later it increased in line with the addition of percentage of crumb tyres replacement, with no significant change in slump height during the process. The abrasion resistance, noise and thermal insulation were also increased as the percentages of replacement were increasing. Hence, the study finally recommended the use of waste crumb tyres for non-structural Portland cement concrete, such as floor rips, partitions, back stone concrete, concrete blocks, and other non-structural uses (Shtayeh, 2007).

Natural fibres are another waste materials that have potential to enhance the properties of concrete. Fibres are usually used in concrete to control plastic and drying shrinkage cracking. They also lower the permeability of concrete and thus reduce bleeding of water. Some types of fibres produce greater impact, abrasion and shatter resistance in concrete (Balaguru & Shah, 1992). Some examples of natural fibres are sisal, coconut, jute, bamboo, palm, industrial hemp, banana leaves and wood fibres with the view to produce a sustainable 'green' concrete material. These fibres have always been considered promising as reinforcement of cement based matrices because of their availability, low cost and low energy consumption.

In Malaysia, about 4 million hectres of land is used for oil palm plantation yielding about 19 million tons of palm oil per year. The waste from this plantation industry give significant impact to the environment if not treated or disposed well. Therefore, the waste products derived from the oil palm such as its leaves, trunks and empty fruit bunches need to be recycled and use in other industries. One of the waste product is natural fibre called oil palm fruit fibre (OPFF) that has a potential to be used in concrete to reduce the shrinkage in concrete. The OPFF had been tested and it proves to improve mechanical properties of concrete and mortar matrix when added as an additive in concrete (Ismail & Hashim, 2008; Aziz et al., 2014).

Apart from various studies on the mechanical properties of concrete using these alternative waste products, durability studies are very limited. The deterioration of concrete and or mortar can occur in various forms. If adequate precautionary measures are not exercised in their protection from adverse effects that could be as a result of exposure from natural or artificial conditions, deterioration due to cracking is as a result of several physical, chemical and electrochemical processes which could lead to eventful failure of concrete elements, particularly if the raw materials used in the concrete are not adequately studied, understood and controlled.

1.2 Problem Statement

Uses of crumb rubber in concrete as replacement materials for aggregates are well reported in many journals, however apart from works by Bida (2014) on the mechanical properties of mortar with crumb rubber as sand replacement and OPFF as addition, no studies have reported on the durability of this mix composition of mortar. Hence this study will focus on the durability of the same mortar mixture as Bida (2014).

Durability of concrete or mortar is defined as an ability of concrete to resist weathering action, chemical attact and abrasion while maintaining its designed properties without deterioration for a long period of years. The durability of concrete are depending on factors such as cement content, compaction, curing method, cover thickness and the important factor is the permeability of the concrete itself. Since work by Bida (2014) is the main reference of this research, the cement content and compaction effect on durability are not further studied in this research and the same mortar mix compositions with addition and replacement percentages of OPFF and crumb rubber are followed. However only the durability of OPFF and cement treated crumb rubber mortar mixes are further studied because the mechanical properties of those are better than mortar made of OPFF and untreated crumb rubber.

As mentioned in the introduction, the potential use of this mixture is as nonstructural construction building product which specifically planned for block or brick productions and curing method is one of the factors influencing the durability of mortar or concrete, hence two potential curing methods which are practical for brick or block production were studied, namely ponding and wetting curing methods.

Apart from curing methods, the mix composition resistant to weathering action, chemical attack, abrasion and other degradation processes are the other importance durability properties that must be quantified before the mixture is safe and economical for general use. To understand these aspects, the carbonation resistance, sulphate resistance, chloride ion penetration resistance, water permeability and water absorption of this mortar mixture compositions that must be addressed.

Therefore this research will focused on the durability performance of treated crumb rubber and OPFF mortar by penetrability tests including absorption, diffusion, and permeability. Mix design proportion by Bida (2014) is followed to confirm the strength achievement as it is not the focus of this study. Success of this study gives complete durability performance of treated crumb rubber and OPFF mortar which from here onwards will be addressed as "Rubberised Fibre Mortar" (RFM). Output of this research when combine with the mechanical performance reported by Bida (2014) will provide the complete properties of RFM that are ready to be used as greener mixture for brick and block productions.

1.3 Research Objectives

The aim of this research is to determine the effect of different curing methods on the durability properties of the Rubberised Fibre Mortar (RFM), thus the following specific objectives are outlines:

i. To determine the effect of curing methods on density and compressive strength of the RFM samples in relation to its structural morphology.

ii. To examine the effect of curing methods, crumb rubber replacements and OPFF additions on water absorption, permeability and the durability performance (carbonation resistance, sulphate resistance and chloride ion penetration resistance) of the RFM samples in relation to its morphology.

iii. To examine the morphology of the RFM samples subjected to two different curing methods due to carbonation and sulphate attack.

1.4 Scope and Limitation of Study

This research is limited to the laboratory investigation for the determination of durability performance of samples produced in accordance with the standard method of civil engineering laboratory practice using RFM. The laboratory performance requirements investigated includes compressive strength, chloride ion penetration resistance, water permeability test of concrete under hydrostatic pressure of 500 ± 50 KPa, water absorption, accelerated carbonation resistance and sulphate resistance. The microstructure of the matrix mix was also examined using scanning electron microscopy (SEM). Fibre content (30-50 mm length) by weight of cement of 0.5% 1.0% and 1.5% was used as well as treated crumb rubber content (150 µm to 4.75 mm sizes) of 10%, 20%, and 30%. A mix ratio of 1:2.75 and a constant water cement ratio of 0.48 maintained at a minimum target strength of 17 MPa. The investigation does not include field effect of the durability performance. Chemical treatment was not performed on any of the materials (crumb rubber and oil palm fruit fibre) with the view of achieving green mortar mix for sustainability.

1.5 Significance of Research

Determining the effect of the durability performance of the research material is not only to help in sustainable green construction, it is to add to ascertaining that RFM does no harm user and the environment once incorporated into the building structure. The success of this work removes large chunk of non-biodegradable and biodegradable (crumb rubber and OPFF) resulting in a cleaner, safer and healthier construction material.

1.6 Thesis Outline

In this section, the layout of the thesis including contents of each chapter is highlighted.

The background of the research study elucidating the need for alternative sourcing of greener building construction material, statement of the research problem, aim and objectives of the research, also scope and limitations of the study are presented in chapter one.

In chapter two, literature review on the performance of crumb rubber concrete and OPFF mortar including their applications is deliberated upon with particular reference to some properties of crumb rubber concrete.

Chapter three thoroughly highlights the methodology and experimental works conducted, including detailed procedure for the treatment of crumb rubber, curing methods, and experimental methods used in the determination of durability properties of the RFM samples produced.

In Chapter four, the results of the experimental studies are presented and discussed in terms of effects of curing method, rubber crumb replacements and OPFF additions to the durability properties of RFM accordingly.

Finally in Chapter five, the conclusions derived from chapter four are stated and deliberated upon including given necessary recommendation as regards the viability of greener construction with the material in relation to its durability performance were presented.

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