THE INFLUENCE OF ROOF TILE WASTE AS FINE AGGREGATES ON THE PROPERTIES AND MICROSTRUCTURE OF GREEN CONCRETE

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Submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Hons.)

By

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Saya yang menjalankan amanah,

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DECLARATION

I hereby, declared this report entitled "The Influence of Roof Tile Waste as Fine Aggregates on The Properties and Microstructure of Green Concrete" is the result of my own research except as cited in references

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Date : 22/06/2024

APPROVAL

This report is submitted to the Faculty of Industrial and Manufacturing Technology and Engineering of Universiti TeknikalMalaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow

....

(Profesor Madya Dr. Jariah Binti Mohamad Juoi)

ABSTRACT

Roof tile waste (RTW) constitutes a huge part of construction waste generated at sites and is mostly disposed of in landfills. This study analyses the characteristics of different kinds of RTW as fine aggregates in green concrete, the effect of different types of roof tile wastes on physical and mechanical properties, and the influences on the microstructure of green concrete. This study assesses some of the physical properties of green concrete containing 50 wt% unglazed (URTW) and 20 wt% glazed (GRTW) fine aggregates with the following techniques: particle size analyses (PSA), scanning electron microscopy (SEM), Brunauer-Emmett-Teller analyses (BET), X-ray fluorescence analyses (XRF), and X-ray diffraction (XRD). Green concrete GRTW accounts for the highest compressive strength at 31.2 N/mm², with the lowest water absorption rate of 4.15% and a density of 2231 kg/m³. Green concrete URTW had a density of 2295 kg/m³, an absorption rate of 5.7% by water, and a compressive strength of 26.9 N/mm². In contrast, the control concrete had the lowest density, at 2164 kg/m³, with the largest rate of water absorption at 6.43% and the lowest compressive strength at 24.1 N/mm². The results indicate that the addition of RTW aggregates, particularly GRTW, to green concrete gives it high mechanical strength, lower water absorption, and a refined microstructure in comparison with traditional sand.

ABSTRAK

Sisa jubin bumbung (RTW) merupakan sebahagian besar daripada sisa yang dihasilkan di tapak pembinaan dan kebanyakannya dibuang ke tapak pelupusan sampah. Dalam kajian ini, penganalisisan ciri-ciri pelbagai jenis RTW sebagai agregat halus dalam konkrit hijau, kesan perbezaan jenis sisa jubin bumbung pada sifat fizikal dan mekanikal, serta pengaruhnya pada struktur mikro konkrit hijau. Dalam kajian ini, penilaian beberapa sifat fizikal konkrit hijau yang mengandungi 50 wt% jubin bumbung tidak berkaca (URTW) dan 20 wt% jubin bumbung berkaca (GRTW), sebagai agregat halus menggunakan teknik berikut: analisis saiz zarah (PSA), mikroskop elektron pengimbas (SEM), analisis Brunauer-Emmett-Teller (BET), analisis pancaran sinar-X (XRF), dan pembelauan sinar-X (XRD). Konkrit hijau GRTW menunjukkan kekuatan mampatan tertinggi pada 31.2 N/mm^2, dengan kadar penyerapan air terendah iaitu 4.15% dan ketumpatan 2231 kg/m^3. Konkrit hijau URTW mempunyai ketumpatan 2295 kg/m^3, kadar penyerapan air sebanyak 5.7%, dan kekuatan mampatan sebanyak 26.9 N/mm^2. Sebaliknya, konkrit kawalan mempunyai ketumpatan terendah pada 2164 kg/m^3, dengan kadar penyerapan air terbesar sebanyak 6.43% dan kekuatan mampatan terendah sebanyak 24.1 N/mm^2. Keputusan ini menunjukkan bahawa penambahan agregat RTW, terutamanya GRTW, kepada konkrit hijau memberikan kekuatan mekanikal yang tinggi, penyerapan air yang lebih rendah, dan struktur mikro yang lebih halus berbanding dengan pasir tradisional.

DEDICATION

In the Name of Allah, the Most Gracious, the Most Merciful. First and foremost, I would like to thank and praise Allah the Almighty, my Creator, my Sustainer, for everything I received since the beginning of my life. I would like to extend my appreciation to the Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform. This report is dedicated to my beloved family - mama, papa, adik, yaya, and baby. Throughout my academic path, their constant support, inspiration, and compassion have been vital. It is because of their unwavering love and faith in me that I have had the courage and drive to overcome any obstacles and follow my ambitions. I would also like to express my sincere gratitude to my supervisor, Profesor Madya Dr. Jariah Binti Mohamad Juoi, for the invaluable guidance she has provided me in completing this study. To my close friends, my classmates, and the precious friends I made during my manufacturing engineering journey - you were always there for me, through the late nights, the tears, and the laughter. Whether we were staying up together, singing in the car, or working side-by-side in the lab or in the class, your constant support and companionship made this achievement possible. I sincerely appreciate having you in my life, you're my diamonds that I will treasure. Lastly, I want to thank myself. Even when I doubted and felt down, I persevered and made it here. I'm so proud of you athirah, for not giving up. To show you all how much I care for and appreciate you, I have dedicated this to you.

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LIST OF ABBREVIATIONS

RTW	-	Roof Tile Waste
CO_2	-	Carbon Dioxide
URTW	-	Unglazed Roof Tile Waste
GRTW	-	Glazed Roof Tile Waste
SEM	-	Scanning Electron Microscopy
BET	-	Brunauer-Emmett-Teller
XRD	-	X-ray Diffraction
XRF	-	X-ray fluorescence
SCC	-	Self-Compacting Concrete
CAZ	-	Curing Affected Zone
WGP	-	Waste Glass Powder
GGBS	-	Granulated Blast Furnace Slag
GRAC	-	Geopolymer Recycled Aggregate Concrete
RCA	-	Recycled Concrete Aggregate
C-S-H	-	Calcium Silicate Hydrated
CH	-	Calcium Hydroxide
Por	-	Portlandite
Ett	-	Ettringite
W/C	-	Water/Cement Ratio
UHPC	-	Ultra High-Performance Concrete
ITZ	-	Interfacial Transition Zones

WRP	-	Waste Rubber Powder
FTKIP	-	Faculty of Industrial and Manufacturing Technology and Engineering
PSA	-	Particle Size Analyses
PCC	-	Portland Composite Cement
BJH	-	Barrett-Joyner-Halenda
SiO_2	-	Silicon Dioxide
Al_2O_3	-	Aluminium Oxide
C-A-S-H	-	Calcium Aluminate Silicate Hydrates
K_2O	-	Potassium Oxide
Fe_2O_3	-	Ferric Oxide
ICDD	-	International Centre for Diffraction Data
ASR	-	Alkali Silica Reaction

LIST OF SYMBOLS

Wt%	-	Weight percentage
°C	-	Celsius
g/cm^3	-	Gram per cubic centimetre
mm	-	Millimeter
N/mm^2	-	Newtons per millimeter squared
MPa	-	Megapascals
mm^3	-	Cubic millimetre
kg	-	Kilogram
µm	-	Microns
kPa	-	Kilopascal
ρ	-	Density
v	-	Volume
kN	-	Kilo Newton
g	-	Grams
m^2/g	-	Square meter per grams
cm^3/g	-	Cubic centimetre per gram
Å	-	Angstrom
°	-	Angle
a.u	-	Arbitrary Units

CHAPTER 1
INTRODUCTION

The first chapter presents the background of the study, the problem statement, the objectives, and the scope of the study. The background of the study elaborates on the influence of roof tile waste as fine aggregates on the properties and microstructure of green concrete. The problem statement describes the problems faced in current study based on review of previous findings reported in the literature. The objectives represent this research's main goal, while the scope of the study shows the focus and limitations of this research.

1.1 Background of Study

The common use of roof tiles in construction, particularly in Malaysia due to urban expansion, has led to an increased demand for roof tile houses. However, it has resulted in a proportional increase in roof tile waste (RTW). Therefore, this study aims to analyze the characteristics of different types of roof tile waste as fine aggregates in green concrete. As the construction industry seeks sustainable practices, understanding the different types of roof tile waste of these recycled materials on concrete performance is crucial for advancing eco-friendly construction methods.

Roof tile waste (RTW) refers to discarded materials obtained from roof tiles that have the potential to be recycled and used in a variety of applications. According to Mulyono et al. (2014), the increased demand for roof tile houses has resulted in an increase in the volume of roof tile trash, underlining the importance of sustainable management and reuse of these materials. In response to this environmental concern, researchers have investigated the use of RTW in building materials like eco-friendly concrete, emphasizing its potential as a resource for sustainable building methods.

The construction industry significantly contributes to resource depletion and environmental degradation due to its large carbon and material footprint. Buildings account for approximately 40% of total global CO_2 emissions, according to (Sangmesh et al., 2023), and construction materials account for around 15% of emissions. Green concrete aims to advance this evolution by exploring ways to reuse construction waste streams like recycled roof tiles in concrete mixes, which can help reduce waste and emissions from traditional concrete production. As the sector accounts for a substantial portion of global impacts, transitioning to greener building approaches is imperative to achieve emissions targets (Labaran et al., 2022).

This research focuses on exploring the influence of the physical and mechanical properties of green concrete. Working with roof tile waste can be challenging due to its uneven behavior and difficulty in machining. It requires careful consideration of water content to achieve the right balance for strong concrete without causing it to take too long to set (Achak et al., 2023). The primary objective is to investigate the effect of different types of roof tile waste on the physical and mechanical properties of green concrete. Farihah (2022) studied that the use of different types of roof tile waste in green concrete significantly impacts its physical and mechanical properties. Unglazed fired roof tile waste (URTW) has been shown to enhance the compressive strength of concrete, achieving strengths above the target mean strength of M25 concrete, particularly at a 50wt% replacement level, although it reduces workability at higher percentages while glazed roof tile waste (GRTW) improves the mechanical performance of concrete at a 20wt% replacement level, increasing workability and compressive strength.

Additionally, the research aims to evaluate the influence of different types of roof tile waste on the microstructure of green concrete. Porous ceramic roof-tile waste aggregate (PCA) serves as an effective internal curing material, promoting hydration and improving microhardness around the aggregate, which enhances compressive strength and reduces autogenous shrinkage. (Shigeta et al., 2018). It involves studies that utilize various imaging and analytical techniques, such as scanning electron microscopy (SEM) to assess changes in microstructural features. This comprehensive analysis involves conducting various tests utilising URTW and GRTW in the lab.

1.2 Problem Statement

Roof tile waste (RTW) constitutes a significant portion of construction waste, often ending up in landfills and causing environmental harm. In order to help solve this issue, the purpose of this study is to analyze the properties of several RTW types that are used as fine aggregates in green concrete. Particle size distribution, surface area, porosity, and composition of RTW are the main areas of focus for this study. Understanding that RTW is a suitable, sustainable replacement for natural sand in concrete mixtures requires an understanding of these characteristics.

The study also seeks to fill the gap in comprehensive studies regarding the way that control samples with 50wt% URTW and 20wt% GRTW interact with the cement matrix. The characteristics, properties, and overall performance of green concrete are significantly influenced by this interaction. The study's goal is to determine how different RTW types influence green concrete's physical and mechanical characteristics by analyzing these interactions. This involves analyzing elements including water absorption, density, and compressive strength.

Lastly, the research evaluates how different RTW types influence the microstructure of green concrete. Analyzing the microstructural elements, such as pore structure and hydration product development, provides an understanding of how effectively RTW performs as time passes in green concrete. By achieving these objectives, this research aims to help in the development of environmentally friendly building materials that can reduce the impact of construction waste on the environment while promoting the recycling of remaining building waste.

1.3 Objectives

The objectives of this research are:

i. To analyse the characteristic of different type roof tile waste as fine aggregates in green concrete.
ii. To analyse the effect of different type roof tile waste on the physical and mechanical properties of green concrete.
iii. To evaluate the influence different type roof tile waste on the microstructure of green concrete.

1.4 Scope

• Recycled roof tile waste (RTW) served as the primary raw material, replacing fine aggregates in concrete. A grinding machine and a planetary milling ball machine were utilized to achieve a fine aggregate from RTW. By using 50wt% unglazed roof tile waste (URTW) and 20wt% glazed roof tile waste (GRTW).

• Sieve analysis (gradation test) determined the adequacy of ceramic RTW particle size and grading for use in concrete mixing. Slump tests assessed concrete workability, while water absorption tests evaluated durability, incorporating additional RTW.

• Brunauer-Emmett-Teller analysis (BET) is used to analyse particle size distribution, surface area, pore size, and pore volume. The characterization of RTW is being conducted using scanning electron microscopy (SEM), X-ray diffraction (XRD), and X-ray fluorescence (XRF). The characterization of green concrete is being conducted to analyse the physical properties of density, water absorption, and compressive strength.

CHAPTER 2

LITERATURE REVIEW

The chapter summarizes the current finding related to this research. It concentrate on a reviewing, green concrete, role of fine aggregates, physical properties of porous recycled roof tile waste fine aggregates, hydration process in concrete, curing of concrete, influence of curing on the hydration reaction process, curing duration influences concrete strength and porosity-microstructure relationship, significance in concrete mix design, influence of aggregate properties on hydration and concrete performance, structural and mechanical attributes previous studies on recycled roof tile waste in concrete

2.1 Green Concrete

Green concrete is a more sustainable and eco-friendlier alternative to conventional concrete. It is made using waste materials such as ceramic waste, fly ash, and recycled aggregates. The properties of green concrete vary depending on the specific materials used. Adding ceramic waste as a partial substitute for natural coarse aggregates in self-compacting concrete (SCC) can decrease efficiency but increase compressive strength and resistance against segregation (Tafheem et al., 2011; Achak et al., 2023).

Green concrete offers the potential to significantly reduce the climate impact of conventional concrete by using alternative binder materials. In Datta et al. (2019) experimental study investigating the replacement of fine aggregate with scrap metal and