# INVESTIGATING THE MECHANICAL PERFORMANCE OF THE NEW GREEN CONCRETE PRODUCT

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**BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY (PROCESS AND TECHNOLOGY) WITH HONOURS**

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# INVESTIGATING THE MECHANICAL PERFORMANCE OF THE NEW GREEN CONCRETE PRODUCT

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**INVESTIGATING THE MECHANICAL PERFORMANCE OF THE NEW GREEN CONCRETE PRODUCT**

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**A thesis submitted**
**in fulfillment of the requirements for the degree of**
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**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2022**

**DECLARATION**

I declare that this thesis entitled " Investigating The Mechanical Performance Of The New Green Concrete Product " is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

| | | |
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## APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology (Process & Technology) with Honours.

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Date : 14 January 2022

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**DEDICATION**

Alhamdulillah

Praise to Allah for the strength, guidance and knowledge that was given by Allah for me to complete this study.

&

To my beloved parents and families for every support that was given to me.

&

To my supervisor, Profesor Madya Ts. Dr. Zulkifli bin Mohd Rosli and PM Dr Jariah Binti Mohd Juoi for their guidance and advices in completing this research.

&

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**ABSTRACT**

In this work, recycled roof tiles waste (GRTW) is studied to replace the fine aggregates used in a cement mixture. This is an innovative effort to produce green concrete. The produced green concrete is intended for construction purposes such as buildings, car porch, drainage, paving and landscaping. The objectives of this project are; to convert the rooftile waste into fine aggregate according to British Standard (BS), to substitute the glazed fired rooftile waste (GRTW) as fine aggregate in the concrete mixture with various percentage, to compare the mechanical performance of new green concrete product containing GRTW with conventional concrete in accordance with British Standard (BS). A total of 12 concrete specimens, 100mm x 100mm x 100 mm each, were tested. Three concrete specimens were kept as control specimens, 9 specimens were contained GRTW as fine aggregate with various proportions (10%, 20% and 50%). Eventually, all specimens were tested for workability which is slump test, water absorption test and compressive strength by using compression testing. It was found that strength gradually increases with the 20% and 50 % in replacement percentage of GRTW compared to British Standard and decreased with 10% of replacement of GRTW. Hence, substitution of 20% of GRTW had been proven to have better mechanical performance compared to control specimen in term of slump test, water absorption test and compression test and can replace sand as fine aggregate in concrete.

# *ABSTRAK*

Dalam kerja ini, sisa jubin bumbung kitar semula (GRTW) dikaji untuk menggantikan agregat halus yang digunakan dalam campuran simen. Ini merupakan satu usaha inovatif untuk menghasilkan konkrit hijau. Konkrit hijau yang dihasilkan bertujuan untuk tujuan pembinaan seperti bangunan, anjung kereta, saliran, penurapan dan landskap. Objektif projek ini adalah; untuk menukar sisa bumbung menjadi agregat halus mengikut Piawaian British untuk menggantikan sisa bumbung berlapis api (GRTW) sebagai agregat halus dalam konkrit campuran dengan pelbagai peratusan, untuk membandingkan prestasi mekanikal produk konkrit hijau baharu yang mengandungi GRTW dengan konkrit konvensional mengikut Piawaian British. Sebanyak 12 spesimen konkrit, 100mm x 100mm x 100 mm masing-masing, diuji. Tiga spesimen konkrit disimpan sebagai spesimen kawalan, 9 spesimen telah terkandung GRTW sebagai agregat halus dengan pelbagai perkadaran (10%, 20% dan 50%). Akhirnya, semua spesimen diuji untuk kebolehkerjaan iaitu ujian kemerotan, ujian serapan air dan kekuatan mampatan dengan menggunakan mesin ujian mampatan. Didapati bahawa kekuatan secara beransur-ansur meningkat dengan 20%dan 50 % dalam peratusan penggantian GRTW berbanding Piawaian British dan menurun dengan 10% penggantian GRTW. Oleh itu, penggantian 20% GRTW telah terbukti mempunyai prestasi mekanikal yang lebih baik berbanding specimen kawalan dari segi ujian slump, ujian serapan air dan ujian mampatan dari segi ujian kejatuhan, dan boleh menggantikan pasir sebagai agregat halus dalam konkrit.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Today, concrete is commonly used as building material due to its high compressive strength and durability. Depending on the nature of the work, the fine aggregate, the coarse aggregate, and the water are combined in specific proportions to produce plain concrete (Anjali 2015)

Looking forward into the technologies, the use of recycled materials in concrete production has grown in popularity. Recycling ceramic rooftiles waste as aggregate in concrete will help to alleviate industrial waste disposal issues while also preserving natural aggregate supplies (Medina 2013). According to Fengli et. al. (Fengli 2012), it is possible to use recycled ceramic rooftiles aggregate with a diameter of less than 9.5 mm in concrete as a partial substitute for natural aggregate. Since ordinary concrete has a higher apparent density than recycled ceramic rooftiles concrete, this can help to minimise the self-weight of structure. Since the ultra-fine sand has a high mud content, the splitting tensile strength of recycled ceramic rooftiles is weak under similar workability conditions when the replacement rate is less than 20%. Furthermore, when the replacement rate exceeds 40%, the compressive and fracturing tensile strengths of the concrete exceed those of the reference concrete. The use of 100% recycled rooftiles as fine aggregate increases both splitting tensile strength and compressive strength significant.



Torgal. et. al. (Torgal 2011) studied the chemical and physical characteristics of crushed ceramic rooftile waste from landfills. Furthermore, ceramic powder was used as a partial replacement for cement in concrete mixes, while fine and coarse ceramic aggregates were used as a 100 percent replacement for fine and coarse natural aggregates. They discovered that mixing ceramic waste into concrete improves compressive power. In another study, Al Bakri et. Al (Al Bakri A. Mohd Mustafa 2008), in concrete mixes with various w/c ratios; 0.4, 0.5, and 0.7, different forms of recycled ceramic wastes were used as partial replacements for coarse aggregate. The compressive strength of all concrete mixes containing ceramic aggregates was found to be higher than that of conventional concrete.

Halicka et al. (Halicka 2019), used ceramic sanitary ware waste as coarse aggregate in concrete mixes. The porosity of the ceramic particles' structure was revealed by scanning electron microscopy. Ceramic aggregates also have a low crushing ratio and a high water absorption, as discovered by studying their properties. Ceramic sanitary ware waste aggregate can be used to make high-performance and abrasion-resistant concrete, according to the researchers. In another study, Medina et al (Medina 2013) used ceramic sanitary ware waste as a partial substitute of gravel with replacement levels 20% and 25%. They discovered that mixing ceramic aggregate with natural gravel increased porosity slightly. As the replacement percentage increased, both compressive and tensile splitting power increased. In comparison to reference concrete, recycled ceramic aggregate concrete has a lower slump, lower density, higher water absorption, higher sorpitivity, and higher porosity.

## 1.2 Problem Statement

River sand is the most common material used in building construction for fine aggregates. It is used in construction to provide strength and other properties to construction materials, resulting in a solid and rigid structure. Work on the building, river sand and gravel are widely used in the preparation of concrete for use in building construction ( Torgal 2011). Abdul Ghani Hamzah (Abdul 2015) complained that sand dredging activities used in their village are causing erosion of the riverbanks. The erosion of the banks of the Padang Terap River occurred very quickly as a result of the activity. Besides that, The chairman of the state Health, Environment, Cooperatives and Consumerism Committee, S Veerapan (Verapan 2019) said his party had received complaints from public who informed that the river had become murky, affecting the surrounding farmers.

As sand dredging activities is dangerous, waste material can be used as a substitute for river sand as well as for fine aggregates. According to Davoud et al (Davoud 2015), the environmental advantages of using waste material as a replacement for river sand can be investigated in two ways. One is the removal of a part of the river sand from concrete and the other is the use of waste material that is useless in concrete. Due to the volume of river sand consumption around the world, a lot of waste can be used as a replacement for concrete. One of it is by replacing river sand with rooftiles waste as fine aggregate.

## 1.3 Research Objective

The main aim of this research is to Investigate the mechanical performance of the new green concrete product by comparing with the British Standard. Specifically, the objectives are as follows:



a) To convert the glazed fired rooftile waste (GRTW) into fine aggregate according to British Standard.

b) To substitute the glazed fired rooftile waste (GRTW) as fine aggregate in the concrete mixture with various percentage.

c) To compare the mechanical performance of new green concrete product containing GRTW with conventional concrete in accordance with British Standard.

## 1.4 Scope of Research

The scope of this research are as follows:

- Analyzing the mechanical performance of new green concrete product in term of workability, water absorption and compressive strength.
- The concrete grade of 25N/mm$^2$ at day 28 with 5% of proportion defective is used for concrete mix design ratio by referring to BRE Method.
- The compression test is done to get the value of compressive strength accordance to BS EN 12390-3:2019.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

Paul O. Awoyera (Paul O. Awoyera 2016) stated most buildings employ ceramic items as part of the basic construction materials. Wall tiles, floor tiles, sanitary ware, home ceramics, and technical ceramics are all examples of manufactured ceramics. They are mostly made from a variety of materials that contain a high concentration of clay minerals (Medina 2013). Despite the ornamental benefits of ceramics, their waste, among other things, causes a lot of pollution in the environment (Paul O. Awoyera 2016). As a note D.O. Omele (D.O. Omole 2011) reported solid wastes have a terrible impact on the Nigerian population.

According to (F. Pacheco-Torgal 2010), ceramic waste can be divided into two groups based on the source of its raw materials. The fired ceramic waste was divided into categories based on the manufacturing process as shown in Figure 1, which was distinguished by the use of red or white ceramic pastes. White paste, on the other hand, is used much more frequently and in much larger quantities.

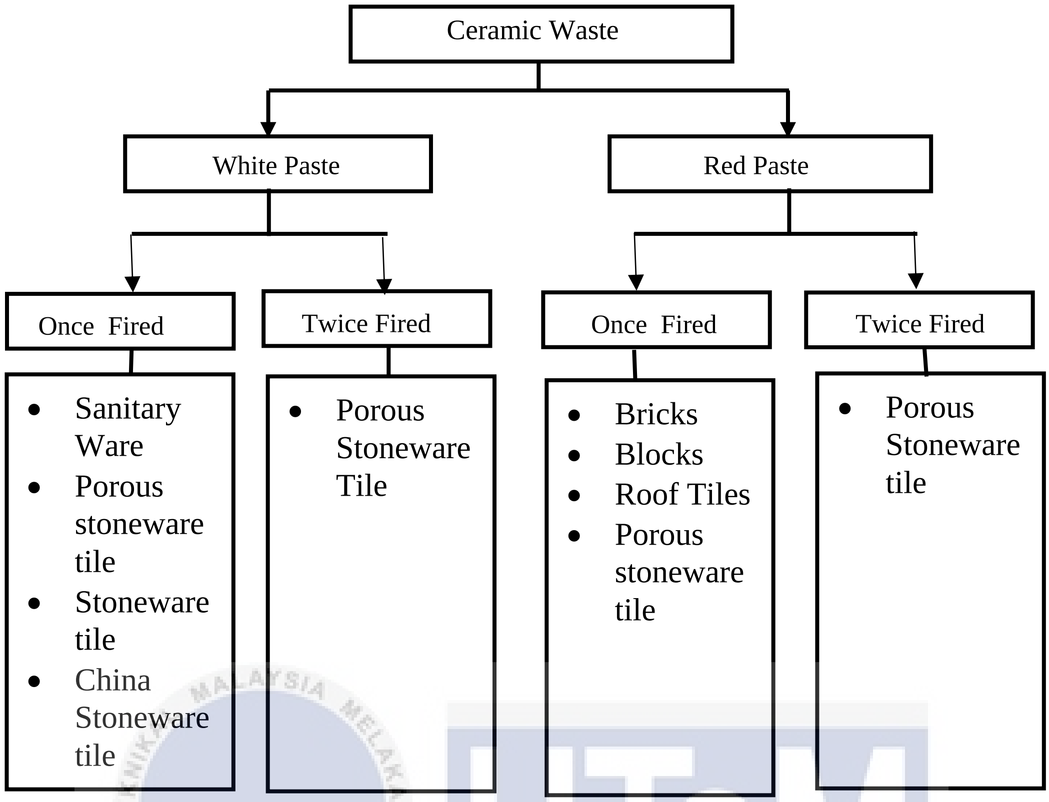


Figure 2.1 Classification of fired ceramic waste by type and production process (F. Pacheco-Torgal 2010)

Meanwhile, investigations have indicated that roughly 30% of the material used in ceramic manufacture is wasted, and it is currently not being used to its full potential (Medina 2013). This emphasises the importance of pursuing novel approaches to repurposing ceramic waste. In the manufacturing of concrete, aggregates account for roughly 70% of the overall ingredients. The cost is rising as a result of increased demand from both rural and urban areas. Ceramics have been highlighted by a number of researchers as having the potential to replace natural aggregates (P. M. R.M Senthamarai 2005) (M. Suzaki 2009).

According to research by Senthamarai (P. D. R.M Senthamarai 2011), ceramic wastes are a good material that might be used to replace traditional aggregates in concrete. Recently, the impact of ceramic tile waste on the structural qualities of laterite concrete was investigated. As a result, the current research looks into the mechanical properties of concrete built with ceramic rooftile debris and floor from building and demolition sites as a partial replacement for natural aggregates.

### 2.1.1 Ceramic Waste Properties

Ceramic wastes have unique characteristics that can help in other areas of recycling. Devanathan et. al (R. Devanathan 2011) studied ceramic waste formations is to see if they were ideal for providing a stable geological structure that may operate as a barrier to retain nuclear wastes (radionuclides) for long periods of time. Toxic radioisotopes with extremely long half-lives, such as plutonium 239 (239Pu), with a half-life of roughly 24 200 years, were the main source of concern. Radioisotopes (radionuclides) from material like 239Pu must be disposed of in a safe environment so that they do not leak into groundwater for long periods of time. The study concluded that ceramic waste had the potential to give such stability due to its degrading capacity, albeit more research is needed to validate this. This is mostly owing to the challenges of modelling and investigating the behaviour of ceramic waste forms over lengthy periods of time. As a result of the research, ceramic wastes have the potential to be used in nuclear waste management (R. Devanathan 2011).



The Recycling Component Project of the National Waste Management Strategy Implementation (NWMSI) in South Africa aims to establish a viable and practical way to increasing and extending recycling (O. Zimbili 2014). The strategy includes provisions for the investigation and possible pilot implementation of an industrial waste exchange project as a tool for decreasing waste through reuse, reduction, and recycling. Ceramic material has the potential to be utilised in the manufacturing of concrete in this light (D.O. Omole 2011). Concrete is used as the primary structural material in many construction projects. Aggregates, which are plentiful in most places, make up around 75% of the volume of concrete (Tam 2003). However, in most areas when a substantial supply of concrete is required, the natural environment is sacrificed for economic reasons. Due to a surge in environmental awareness, there has been a lot of research into incorporating wastes, particularly C&D wastes, into the concrete manufacturing process (P. M. R.M Senthamarai 2005).

Table 2.1 Composition of Construction and Demolition Wastes (A. Juan 2012)

| MATERIALS | COMPOSITION (%) |
|---|---|
| STONY FRATION | 75 |
| Bricks, wall tiles and other ceramic materials | 54 |
| Concrete | 12 |
| Stone | 5 |
| Sand, gravel and other aggregates | 4 |
| Wood | 4 |
| NON STONY FRACTION | 25 |
| Wood | 4 |
| Glass | 0.5 |
| Plastic | 1.5 |
| Metals | 2.5 |
| Asphalt | 5 |
| Plaster | 0.2 |
| Rubbish | 7 |
| Paper | 0.3 |
| Others | 4 |



### 2.1.2 The Ceramic Industry

Studied showed that ceramics is a broad phrase that refers to all ceramic products. Wall tiles, floor tiles, sanitary ware, home ceramics, and technical ceramics are all examples of manufactured ceramics. In essence, ceramic is a phrase that refers to inorganic materials (with some organic content) that are formed up of non-metallic compounds and are fired to make them permanent (O. Zimbili 2014). Clay, the most common material used in the production of most ceramics, is not a pozzolanic substance. This is due to the fact that it lacks silicate characteristics, which might allow calcium hydroxide to develop when mixed with water in the manufacture of concrete (A. Juan 2012). The activation of clay to become pozzolanic begins during the dehydration process, which begins when heating clay from around 500-degree celcius, and the separation of amorphous and very active aluminium oxide, according to research conducted on the possibility of waste clay materials being used as pozzolanic additions. The temperature necessary to obtain maximum aluminium oxide concentrations varies depending on the type of minerals present in the clay. (Medina 2013). Clay is heated to relatively high temperatures during the production of ceramics, the exact temperature varying depending on the type of ceramic being made. The current research by Pacheco et. al. (F. Pacheco-Torgal 2010) is focused on ceramic wall tile wastes, which are reject tiles that have gone through the entire firing process. The ceramic wall tiles are fired at a temperature of roughly 1150 degrees celcius. As a result, it is natural to conclude that wastes from the ceramic industry (ceramic waste) have properties that make them acceptable for use as pozzolanic materials, and hence for use in the production of concrete (P. D. R.M Senthamarai 2011).

## 2.2 Introduction to Concrete

Concrete is the most extensively used construction material because of its superior mechanical and durability features. According to Ahmad et. al (Ahmad 2004), every year, nearly one tonne of concrete is produced for every person in the planet, totaling about ten billion tonnes. Buildings, bridges, dams, and other concrete constructions have