UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INVESTIGATION OF MECHANICAL AND PHYSICAL PROPERTIES OF CONCRETE BRICK MADE OF WASTE MATERIALS

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DECLARATION

I declare that this research "Investigation of Mechanical and Physical Properties of Concrete Brick Made of Waste Materials" 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.

Signature : 

Name : Tinish A/L Shanmugam

Date : 11 January 2023

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 Mechanical Engineering Technology with Honours.

Signature : 

Supervisor Name : Dr. Fadhilah binti Shikh Anuar

Date : 11 January 2023

DEDICATION

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ABSTRACT

The construction industry has expanded because of rapid urbanisation and economic development. As a result, the demand for brick as a building material has increased in tandem with the expansion of the construction industry all over the world. Building developers and engineers are entitled to consider the surrounding environment when they are constructing buildings and should support sustainable development in their works. Thus, the production and use of bricks and aggregates that are friendlier to the environment would be significant. According to past research, recycled materials can be used to replace part of the usual mixed components in brick products, resulting in a more sustainable building material. Waste oyster shell, eggshell, and plastic are three common waste items that can be recycled. The objective of this research is to create a new generation of sustainable bricks from waste material and investigate their physical and mechanical properties. This study will also evaluate the new generation brick's reliability as a construction material as compared to the traditional burnt clay brick and concrete brick The brick sample produced in this study is based on ASTM standards with the addition of various composition of waste material treated into fine (300 µm) and coarse (4.7 mm) aggregates. The proportion is ranging from 30% to 90%, with various cement-water ratio. Individually, the samples are tested for compressive strength, water absorption, and the presence of efflorescence. The compressive strength and water absorption decreases as the percentage of waste aggregates increases. Only seven samples meet the minimum requirements in terms of compressive strength and thirteen samples in terms for water absorption that can be used for construction purposes. As for samples tested for efflorescence, six samples are classified as heavy efflorescence and one sample with severe flaking where it will damage building structure. Samples made with only plastic aggregates exhibited highest efflorescence in this research. No samples produced better results compared to commercial bricks in terms of efflorescence and water absorption. However, sample with 30% eggshell (S30-E) exhibited higher compressive strength (17.6 N/mm²) with a difference of 71.2% for concrete brick (10.28 N/mm²) and 62.2% for clay brick (10.85 N/mm²). In nutshell, using oyster shell, eggshell and plastic is a reliable source of aggregates to be used in concrete.

ABSTRAK

Industri pembinaan telah berkembang kerana pembandaran yang pesat dan pembangunan ekonomi. Akibatnya, permintaan terhadap batu bata sebagai bahan binaan telah meningkat seiring dengan perkembangan industri pembinaan di seluruh dunia. Pemaju dan jurutera bangunan berhak untuk mempertimbangkan persekitaran sekitar semasa mereka membina bangunan dan harus menyokong pembangunan mampan dalam kerja mereka. Oleh itu, pengeluaran dan penggunaan batu bata dan agregat yang lebih mesra alam sekitar adalah penting. Menurut penyelidikan lepas, bahan kitar semula boleh digunakan untuk menggantikan sebahagian daripada komponen campuran biasa dalam produk bata, menghasilkan bahan binaan yang lebih mampan. Sisa kulit tiram, kulit telur dan plastik ialah tiga barangan buangan biasa yang boleh dikitar semula dan digunakan semula dalam banyak aplikasi. Objektif penyelidikan ini adalah untuk mencipta generasi baharu bata lestari daripada bahan buangan dan menyiasat sifat fizikal dan mekanikalnya. Kajian ini juga akan menilai kebolehpercayaan bata generasi baharu sebagai bahan binaan berbanding bata tanah liat bakar tradisional dan bata konkrit Sampel bata yang dihasilkan dalam kajian ini adalah berdasarkan piawaian ASTM. dengan penambahan pelbagai komposisi bahan buangan yang dirawat kepada agregat halus (300 µm) dan kasar (4.7 mm). Perkadaran adalah antara 30% hingga 90%, dengan nisbah simen-air. Secara individu, sampel diuji untuk kekuatan mampatan, penyerapan air, dan kehadiran efflorescence. Hanya tujuh sampel memenuhi keperluan minimum dari segi kekuatan mampatan dan tiga belas sampel dari segi penyerapan air yang boleh digunakan untuk tujuan pembinaan. Bagi sampel yang diuji untuk kemekaran, enam sampel diklasifikasikan sebagai kehadiran efflorescence berat dan satu sampel dengan pengelupasan yang teruk di mana ia akan merosakkan struktur bangunan. Sampel yang dibuat dengan hanya agregat plastik menunjukkan kecemerlangan tertinggi dalam penyelidikan ini. Tiada sampel menghasilkan keputusan yang lebih baik berbanding dengan bata komersial dari kehadiran efflorescence dan penyerapan air. Walau bagaimanapun, sampel dengan 30% kulit telur (S30-E) mempamerkan kekuatan mampatan yang lebih tinggi (17.6 N/mm²) dengan perbezaan 71.2% untuk bata konkrit (10.28 N/mm²) dan 62.2% untuk bata tanah liat (10.85 N/mm²). Secara ringkasnya, menggunakan kulit tiram, kulit telur dan plastik adalah sumber agregat yang boleh untuk digunakan dalam konkrit.

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°C	-	Degree Celcius
%	-	Percentage
µm	-	Micrometer
Mm	-	Milimeter
G	-	Gram
Kg	-	Kilogram
M	-	Meter
N	-	Newton
>	-	More Than
<	-	Less Than
A	-	Area
ASTM	-	American Society For Testing And Materials
F	-	Force
FTKMP	-	Faculty Of Mechanical And Manufacturing Engineering Technology
UteM	-	Universiti Teknikal Malaysia Melaka
WOS	-	Waste Oyster Shell

CHAPTER 1

INTRODUCTION

This chapter represents the background of this study, problem statement, general and specific objectives, and scope of study.

1.1 Background of Study

The construction business has grown because of the rapid urbanisation and economic development that has taken place. Because of that, the need for brick has risen in tandem with the growth of the construction industry where brick is widely used as building material around the globe because of its low cost, consistency, long life, and ability to withstand extreme weather conditions (Almeida et al., 2019).The construction industries has used roughly billion tonnes of concrete and bricks (4.4 billion) every year, and it is expected to expand more than 5.5 billion tonnes by 2050 as impoverished countries modernise fast according to Hilburg, (2019). As a result, engineers must consider environmental effects while constructing structures to move further on the road of sustainable development. A major contribution to the achievement of sustainable development would be the creation and use of more environmentally friendly cements and concretes.

Recently, it has been discovered that waste oyster shell (WOS) could be used to replace natural sand and aggerate in cement-based construction products outsourced from oyster farming which is a profitable business (Silva et al., 2019). Interestingly, China has surpassed the United States as the world's biggest producer producing 300 million tonnes per year of oyster

shells where previously were producing 218 million tonnes annually (Liao et al., 2021; Ramakrishna et al., 2018). However due to the limitation of technological and economic processing to make use the WOS, many have been thrown away in public waterways or open landfills, causing in serious environmental hazards for both humans and the environment (Khan et al., 2018).

Aside from WOS, research have shown that it is possible to use recycled materials to replace some of the traditional mixture components in brick products and produce a more sustainable building material. One common material that can be recycled and have the possibility of use in brick applications is eggshell waste (Geeta & Saleem, 2021). The eggshell waste falls within the category of food waste, which, if subjected to adequate scrutiny, they could be suitable alternative material for construction(Raji et al., 2019).

Other than WOS and eggshell waste, shredded plastic may also be utilised to make coarse aggregates, giving a sustainable solution to plastic waste (Raut et al., 2020). That makes these by product earth fill instead of recycling it where the building sector will benefit if it is used to prepare aggregates for brick. Realizing the need of converting waste into valuable material for product development to create a cleaner environment, researchers are continuing to investigate the possibilities of these materials for product development. Some researchers have looked at the possibility of using these by product for a specific use in the construction industry (Eziefula et al., 2018; Mo et al., 2018; Monneron-Gyurits et al., 2018; Silva et al., 2019; Wei et al., 2018).

1.2 Problem Statement

Nowadays the planet is feeling the brunt of these unabated activities, which include biodiversity loss, soil pollution, surface, and groundwater contamination because of chemical reactions. Increased quarrying will exacerbate an already irreversible environmental situation (Ong & Kassim, 2019). Most operation of quarrying is due to demand of cement, aggregate and limestone. Thus, introducing sustainable and eco-friendly alternatives to cement, aggregate, and sand production is crucial if to considerably reduce carbon and other greenhouse gas emissions (He et al., 2019).

Aside from that waste oyster shell (WOS), which is one of the agricultural by-products, is causing environmental difficulties as the oyster output continues to grow at an alarming rate year after year (Ruslan et al., 2021). Oyster shell is a by-product of oyster production that accounts for around 90% of the entire oyster mass, resulting in a significant amount of waste creation (Yoon et al., 2018). WOS is formed in dumpsites and dumped on the land or thrown into the sea, causing major pollution. These wastes take a long time to decompose, leading to an increase in dumping places, soil, and water pollution. The waste's strong stench might attract bugs when buried in the soil. When oyster shell trash is dumped in water, it pollutes and poisons aquatic life (Silva et al., 2019). Additionally, the decomposition of microbiological substance of oyster shell has the potential to cause serious health risks, such as dengue and other diseases (Lin et al., 2020).

Aside from that, the environment sustainability can be achieved by substituting limestone powder to cement in brick which will result in cost savings and energy savings, as well as a reduction in carbon dioxide emissions (Bonavetti et al., 2003). However, since limestone is a

natural mineral resource, mining and extended usage may cause environmental and sustainable development issues. Lime manufacturing uses a lot of energy and water. Identifying similar waste materials such as eggshells and utilizing it in brick production could be a good option.

Another solution to reduce usage of raw material for brick is by using plastic. Plastics has been an unsolved problem since it was created regarding its decomposition. Large amounts of plastic waste, as well as its low biodegradability, have a harmful impact on the environment. All types of plastic used by humans in daily life eventually disintegrate into waste; several tonnes of these plastic wastes need huge areas of land for storage and cannot be fully recycled at once. Instead of recycling it endlessly, if it is used to prepare aggregates for brick, it will benefit the construction sector. Most of brick in construction industry collapses due to aggregate crushing failure (Khandelwal, 2019).

1.3 Research Objective

The specific objectives of this study are listed as follows:

1. To produce a new sustainable generation of brick by using waste products.
2. Investigate the physical and mechanical properties of the new generation brick.
3. To compare the reliability as construction material of the new generation brick with conventional burnt clay brick and concrete brick.

1.4 Scope of Research

This research covers the scope for manufacturing a sustainable brick made from by products which is oyster shell, eggshell, and plastic. The main material in this study will be oyster shell with different ratios and combination of different waste. The eggshell will act as limestone powder as binder while the plastic will be shredded to substitute sand. Furthermore, the curing and drying process is an important parameter for this study. The samples after the curing process will be tested at labs to study the physical and mechanical properties together to few commercial bricks.

1.5 Thesis Organisation

This research begins with an explanation of the project's background in Chapter 1 and continues with a thorough analysis of similar work and research in Chapter 2 under the title of literature review. The methodology of this study is outlined in Chapter 3, which is followed by a full explanation of the findings and analysis in Chapter 4. Finally, Chapter 5 brings the research to a conclusion.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Brick is utilised extensively in the construction of many buildings around the globe. Consequently, it has been appropriately referred to as the backbone of a nation's infrastructure development. The engineering community has taken an interest in sustainable construction, and numerous standards have been developed to evaluate the environmental impact of new construction projects (Raji et al., 2019). It has been demonstrated through research that recycled materials can be used to replace some of the typical mixing components in concrete products and provide a more sustainable building material (Tiong et al., 2020). Oyster shell, eggshell, and plastic are three potential recyclable materials that have the tendency to be utilized in brick applications.

In this chapter, the literature review is carried out in a systematic and comparative way. It includes a few different types of brick and aggregate that are available on the commercial market, as well as the new possibilities of waste materials for this investigation. Aside from that, the advantages and disadvantages of using each type of material in this research are discussed, followed by the accepted industry standard for the, which serves as a framework for the recommendations made in this research. Finally, the type of experiments that is necessary to determine the applicability of this newly developed brick in real-world settings is also discussed.

2.2 Type of Bricks and Aggregate

Bricks are a fixed size rectangular block. Clay or cement are the primary ingredient in bricks. In most cases, they are used for most of the building tasks. Bricks are the suitable material as a substitution for stone most of the time when stone block cannot be procured. Classification of bricks are made based on the practice as shown in Table 2.1 and raw materials used to produce the brick for different purposes as illustrated in Table 2.2.

Table 2.1: Classification of Brick Based on Practice (Hossain, 2020)

Classification	Description
First class	The size is standard. These bricks are uniformly yellow or red in colour. It is evenly burned, has a consistent texture, and a uniform shape. The absorption capacity is less than 10 % of the total dry weight, and the crushing strength is 280kg/cm² (mean), whereas it is 245 kg/cm² (minimum). It is absent of efflorescence. When struck with a similar brick or with a hammer, it creates a metallic sound. On the surface of a brick, every expression made with a fingernail will be resisted if one attempts it with a thumbnail. It lacks stones, gravel, and organic stuff. The surface and edges of the bricks are sharp, square, straight, and smooth. They possess all the characteristics of quality bricks. These bricks are often used for permanent construction.

Second class	These bricks are ground and shaped before being fired in kilns. The surface of these bricks is uneven, and their shape is irregular. There are fine hair fractures present in these bricks, and their edges may not be uniformly sharp. These bricks are typically utilised in locations where a coat of plaster will be applied to brickwork. The size is standard, and the colour is yellow or red and uniform. It is sufficiently burned and a small overburn is acceptable. It has a regular form and negligible efflorescence. Greater than 15 % but less than 20 % is the absorption capability of this gred. Mean crushing strength is 175 kg/cm2, with a minimum of 154 kg/cm^2. When struck with a similar brick or with a hammer, it creates a metallic sound. On the surface of a brick, every expression made with a fingernail will be resisted if one attempts it with a thumbnail. It is used for the construction of one-story structures and temporary sheds with a lifespan of no more than 15 years.
Third class	These bricks are burned in clamps. These bricks are soft, and their surfaces are rough, with uneven and twisted edges. These bricks produce a repetitive sound when struck together. They are useful for small, temporary structures and in areas with light rainfall. The size and shape are irregular. The colour is a gentle, mild shade of red. It is under heated and a small overheat is acceptable. It possesses significant efflorescence. The texture is inconsistent.

	The capacity to absorb is greater than 20 %. Mean crushing strength is 140kg/cm2, with a minimum of 105kg/cm². When struck by another brick of the same type or by a hammer, it creates a dull or blunt sound. It leaves a fingernail appearance when one attempts to perform something with the thumbnail.

Table 2.2: Classification of Brick Based on Raw Material (Athaworld Sdn.Bhd, 2020)

Type of Brick	Description
 (a) Clay Bricks	Clay bricks are made by pressing the clay into molds, then dried and heated in a kiln. When used in walls, these bricks require plastering or rendering. Clay brick typically created by Malaysian brick provider has a grey surface instead of a reddish hue.
 (b) Engineering Brick	Engineering brick is a dense and sturdy brick that is created at high temperatures for low water penetration, absorption, and porosity. It is utilised for damp-proofing courses with exceptional acid resistance. This sort of engineering brick is typically not sold by brick suppliers in Malaysia due to its higher cost.