PERFORMANCE OF COMPOSITE SAND CEMENT BRICK CONTAINING RECYCLED CONCRETE AGGREGATE AND WASTE POLYETHYLENE TEREPTHALATE

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I dedicate this study to my beloved family and friends, who were always with me through ups and downs along this great journey to complete this study. A special loving couple I dedicate too, which is my parents, En. Azmi Bin Mohamed and Pn. Zainon Binti Mat Saat, always support and giving encouragement for successful this thesis with excellent.

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ABSTRACT

The reuse and recycling of waste materials from construction and demolition waste is one of the new concepts for brick manufacturing production. Construction and demolition debris refers to waste materials that result from the construction, renovation and demolition of buildings. Bricks are an important material for developing areas where manufacturers find it difficult to locate adequate sources due to the shortage of natural aggregate supply. Construction waste can be recycled to replace naturals resource or other competitive materials. This study aims to establish the sustainable properties for composite bricks using Recycle Concrete Aggregate (RCA) and Polyethylene Terephthalate (PET) waste bottles as sand aggregate replacement. RCA was obtained from crushed laboratory concrete cubes while PET bottles were collected around UTHM and Parit Raja areas. The objectives of this study are to determine the optimum cement-sand ratio (1:5, 1:6 and 1:7) for composite brick through density, compressive strength and water absorption tests, to investigate the mechanical properties and durability of composite sand cement bricks through shrinkage and carbonation tests, and to identify the optimum percentages of RCA and PET as sand aggregate replacement in composite bricks. For this study, the brick specimens were prepared using 25%, 50% and 75% of RCA and 1.0%, 1.5%, 2.0% and 2.5% of PET by volume of natural sand with a water-cement ratio of 0.6. The size of the RCA used measured less than 5 mm. Moreover, the size of the sieved waste PET granules was between 0.1 to 5 mm which made it physically similar to the size of fine aggregates. The bricks were cast in moulds measuring 215 mm in length, 103 mm in width, and 65 mm in depth. Three types of sand-cement ratios were used, namely 1:5, 1:6 and 1:7. The first stage of the study was the determination of the best sand-cement ratio through density, water absorption and compressive strength tests. The next stage was the determination of the optimum percentages of RCA and PET according to the shrinkage and carbonation tests. The overall results revealed that the best cement-sand ratio was 1:6. The density test indicates that the average density of composite bricks is lower compared to that of control bricks. The cement-sand ratio of 1:6 was the optimum value for all sample bricks. In addition, the percentage of water absorption for composite bricks was found to be satisfactory. It can be concluded that the optimal replacement of RCA and PET was R25P1 with a cement-sand ratio of 1:6 as it achieved the lowest values during the drying shrinkage and carbonation tests.

ABSTRAK

Penggunaan semula dan kitar semula bahan buangan daripada sisa pembinaan dan sisa perobohan adalah salah satu konsep baru di dalam pembuatan batu-bata. Runtuhan pembinaan dan perobohan adalah bahan sisa yang dihasilkan dari pembinaan, pengubahsuaian, perobohan atau mana-mana struktur bangunan. Bata ialah sejenis bahan yang penting di dalam bidang pembinaan di mana pembuatan bata didapati agak sukar untuk mencari sumber yang mencukupi kerana kekurangan bekalan agregat semulajadi. Mengguna semula dan mengitar semula bahan buangan boleh menggantikan sumber semula jadi atau bahan kompetitif lain di dalam pasaran baru. Kajian ini bertujuan untuk menubuhkan ciri-ciri lestari bagi bata komposit dengan menggunakan sisa agregat konkrit (RCA) dan Polietilena Terephthalate (PET) sebagai agregat pasir. RCA diperoleh daripada cubit konkrit yang telah dihancurkan di makmal dan PET dikumpulkan dari sekitar kawasan UTHM dan Parit Raja. Objektif utama kajian ini adalah untuk menentukan nisbah simen pasir optimum (1:5, 1:6 dan 1:7) daripada bata komposit melalui ujian ketumpatan, ujian mampatan dan ujian penyerapan air, bagi menyiasat sifat-sifat mekanikal dan ketahanan bata komposit oleh ujian pengecutan dan ujian pengkarbonan dan untuk mengenal pasti penggantian optimum RCA dan PET sebagai bahan pasir di dalam bata komposit. Berdasarkan kajian ini, penyediaan spesimen bata bagi RCA adalah 25%, 50% dan 75% dengan nisbah PET terdiri daripada 1.0%, 1.5%, 2.0% dan 2.5% berbanding jumlah pasir semulajadi dengan nisbah air simen 0.6. Saiz RCA yang digunakan adalah kurang daripada 5 mm. Selain itu, saiz sisa-sisa PET yang telah dihancurkan adalah di antara 0.1 hingga 5 mm yang menjadikan ia secara fizikal sama dengan saiz agregat halus. Batu-bata itu dibentuk dengan ukuran acuan panjang 215 mm, lebar 103 mm, dan kedalaman 65 mm. Nisbah tiga simen pasir digunakan 1: 5, 1: 6 dan 1: 7 untuk bata komposit. Peringkat pertama ialah penentuan nisbah simen pasir yang terbaik melalui ujian ketumpatan, ujian penyerapan air dan ujian kekuatan mampatan. Tahap seterusnya ialah penentuan RCA dan PET yang optimum mengikut ujian pengecutan dan pengkarbonan. Hasil keseluruhannya menunjukkan nisbah simen pasir yang terbaik dari 1: 6 adalah berpotensi digunakan untuk penghasilan bata komposit. Selain itu, peratusan penyerapan air bata komposit didapati memuaskan. Sepanjang kajian ini, hasil yang diperolehi daripada ujian pengecutan dan ujian pengkarbonan ialah peratusan optimum RCA dan PET di dalam bata komposit telah dapat ditentukan. Ini dapat disimpulkan bahawa, perolehan penggantian terbaik RCA dan PET adalah R25P1 pada nisbah simen pasir 1:6 yang menunjukkan nilai ujian pengecutan dan ujian pengkarbonan adalah yang paling rendah.

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LIST OF SYMBOLS AND ABBREVIATIONS

C&D	-	Construction and demolition
$Ca(OH)_2$	-	Calcium hydroxide
CB	-	Crushed brick
CC	-	Crushed concrete
CDW	-	Construction and demolition waste
CIDB	-	Construction Industry Development Board
CO_2	-	Carbon dioxide
FNA	-	Fine natural aggregates
FRA	-	Fine recycled concrete aggregates
GBFS	-	Granulated blast furnace slag
H_2O	-	Water
HDPE	-	High-density polyethylene
IRS	-	Initial rate of suction
LDPE	-	Low-density polyethylene
NA	-	Natural aggregate
NAC	-	Natural aggregate concrete
OD	-	Oven dried
PBW	-	Plastics bag wastes
PET	-	Polyethylene terephthalate
RC	-	Recycled concrete
RG	-	Recycle glass
RCA	-	Recycled concrete aggregates
SEM	-	Scanning Electron Microscopy
SSD	-	Saturated surface dried
W/A	-	Water absorption

WPLA	-	Waste PET lightweight aggregates
WPLAC	-	Waste PET lightweight aggregates concrete

CHAPTER 1

INTRODUCTION

1.1 Background of study

The demand for construction materials has been growing in Malaysia. It is becoming increase to manage and treat the solid waste generated by industry and municipal waste. A huge quantity of construction and demolition (C&D) wastes has become a severe social and environmental problem. In order to pursue an excellent approach for sustainable issue in construction industry, researchers and companies focus on using the wastes as a new construction material. The reuse and recycling of solid waste can help to conserve natural materials and to reduce the cost of waste treatment prior to disposal (Silva et al., 2014). The recycling of wastes in construction industry and building materials will lead to greener and sustainable environment (Sadek et al., 2012).

The increasing of population of people leads the growth of the construction in Malaysia to fulfil their living needs. Brick is one of the most common masonry units as a building material in the civil engineering sector. It has the largest range of products with its unlimited assortment of patterns, texture and colors. In order to the production of brick, many attempts have been made to incorporate wastes (Abdul Kadir et al., 2011). The production process of brick manufacturing has major emphasis on the use of post-consumer wastes and industrial by-products (Syakir et al., 2013).

Nowadays, composite bricks are a type of the important material that is commonly used in low and medium cost housing development and other commercial for the construction industry. Brick is easy and inexpensive product to produce but currently, the demand of brick is high especially in developing areas where manufactures find it difficult to locate adequate sources due to shortage of natural aggregate supply. Moreover, reuse and recycling of waste materials from construction and demolition waste is one of the new concepts for brick manufacturing production. It is widely available and extremely cheap resource which is used Recycled Concrete Aggregate (RCA) as main material to replace natural aggregate in the production of cement and sand bricks (Ismail & Yaacob, 2010).

Construction materials are increasingly judged by their ecological characteristics. RCA is the most used construction material in structural application. Towards the sustainability of the construction industry, the use of Recycled Aggregates (RA) as the best way to manage construction and demolition waste (Matias et al., 2013). Recycling aggregates is an alternative from using the natural aggregates which are an environmental damage result when using the natural aggregates. Cutting the hills and crushing the rocks is producing a lot of pollution and environmental problems. Development of the built environment is predicted to destroy natural habitats and wildlife on over 70% of the earth's surface by 2032 (Bohari et al., 2015).

On the other hand, plastic consumption of package products has caused a large amount of solid waste all over the world. Plastics have been used in very large and useful application in packaging, automotive, industrial application, water desalination, food preservation and other uses. Plastic waste cannot be dumped in landfills because of its bulk and slow degradation rate. Plastic materials showing the potential product due to the user friendly fabricate, long life, light weight and low cost characteristics. Recycling plastic to produce new products such as concrete seems to be one of the best solutions to dispose waste plastics because of its ecological advantages and being very economical (Saikia & de Brito, 2014).

Polyethylene Terephthalate (PET) is used on the largest scale in water bottles manufacturing that represents one of the most common forms of plastic in solid waste. The last is obtained in huge quantity from plastic bottles utilized as containers of beverages and mineral water (Foti, 2013). PET is one of the polymer wastes which does not create a direct hazard to the environment, but due to its high resistance to the atmospheric and biological agents, it is seen as a noxious material. These polymer wastes are almost non-degraded in the natural environment even after a long period of exposure. Moreover, recycled PET waste as aggregate in masonry mortar or concrete would be a good solution to this environmental hazard (Rahman & Chowdhury et al., 2013).

In order to tolerate an issue to locate adequate sources of natural sand supply, RCA and PET are selected as natural replacements in brick production. This idea was in line with current environmental issues as launched by the Construction Industry Development Board (CIDB). Therefore, this study aims to discover material such as RCA and PET materials that can potentially serve as substitute for natural sand in brick making as way to produce eco-friendly and sustainable building materials. Additionally, this study intends to conserve resources and promote sustainability building design in construction industry.

1.2 Problem statement

In civil engineering construction industry, the most basic building material of houses is the conventional brick. Conventional brick is one of the main components which manufacturing from natural resources such as sand and cement. There is an issue in producing brick especially in developing areas where manufacturers find it difficult to locate adequate sources of natural aggregate supply. As the price of sand increased, it affected the price of cement and sand bricks (Kubissa et al., 2015). Thus, intervention into looking for the alternative should be emphasized to solve the inadequate sources of natural aggregate supply (Kartini et al., 2012).

The production of larger quantity of concrete causes serious problems in construction industry. It increases consumption of natural aggregates as the largest concrete component and creates enormous amount of waste material from construction and demolition activities. Demolition of old and deteriorated buildings is frequently phenomena today (Mirjana et al., 2010). In this way, a huge amount of waste concrete aggregate disposal is created and causes human environmental pollution.

Nowadays, PET products are largely utilized and therefore they contribute to increase in solid waste volume. One of the PET products is PET bottles. PET bottles have been remained abandoned, considerable amount of them are dumped on the roadside, bank of river, which block the flow of water in the drain and leads to environmental problems.

Moreover, the government will be able to find solutions for the problem regarding the disposal in landfills of these waste materials and save the environment. This improper treatment would decrease landfill capacity and contribute to environmental issues in the long term. It somehow gives negative impact to environment and human itself. To overcome this problem, using RCA and PET in production of brick might lead to preserve the natural aggregate sources in landfill and save the environment from increase of demolition in construction waste. Through experimental method, this study is conducted to evaluate the physical and properties of brick containing RCA and PET as partial sand replacement materials.

1.3 Objectives

This study aims to promote sustainable materials in production of brick using waste materials as partial sand replacement. In order to achieve the above goals, the following objectives are outlined as follows:

1. To determine the sand cement ratio (1:5, 1:6 and 1:7) of composite brick by density, compressive and water absorption tests.
2. To investigate the durability properties of composite brick by shrinkage and carbonation tests.
3. To identify the optimum replacement of RCA and PET as sand materials in composite brick.

1.4 Scope of work and limitations

This study aims to clarify the potential use of RCA and PET to substitute partially the usage of sand in the production of sand cement brick. This study consists of field activities and laboratory works. Field activities involve collecting waste drinking bottles and concrete aggregate around Universiti Tun Hussein Onn Malaysia (UTHM). The drinking bottle wastes that have be use is mineral water bottle and concrete aggregate is obtained from the waste normal concrete block Grade 30-35 during compressive strength at the laboratory.

Laboratory works involve determining the physical, mechanical, and durability properties of sand cement brick specimens which contain RCA and PET. The size of specimen is 213 mm in length, 103 mm in width and 63 mm in depth. The total specimens in this study are 729 bricks involving compressive strength, water absorption, density, shrinkage and carbonation tests. The ratio of 1:5, 1:6 and 1:7 are going to be use as mix design ratio of sand cement brick and water cement ratio is fix at 0.6. The replacement volume of fine aggregate consists of RCA with 25%, 50% and 75% while PET with 1.0%, 1.5%, 2.0% and 2.5%.

1.5 Significance of study

The recycling of wastes in concrete is becoming evermore popular and it can lead to many environmental benefits. Normally, natural aggregate is used in producing sand cement brick, but nowadays manufacturing itself finds it is difficult to obtain the sources due to the shortage of supply. In this study, a new alternative concept to reduce this problem is to utilize the RCA and PET waste in manufacturing of construction materials such as brick. The production of brick involves recycling of materials from construction and demolition waste. RCA and PET are widely available and extremely cheap resource. In this study, this waste is used as the main material to replace natural source in the production of composite brick (Ismail & Yaacob, 2010).

The use of RCA will conserve natural resources and help in maintaining a clean environment. The RCA is also an aggregate produced from recycling process of waste concrete from demolition and construction waste (CDW). As known, the workability of RCA is lower than the natural aggregate concrete. Thus, with a recent advancement of technology for processing the waste concrete it is possible to produce recycle aggregate as similar quantity as the natural aggregate (Kumar et al., 2015).

Naturally, the use of waste materials as an aggregate in manufacturing building materials will reduce the pressure on the exploitation of natural resources. Thus, plastic waste (PET) is used as substitute for conventional materials. This has been used for improving mechanical properties of mortars and concrete (Benosman, 2012). Therefore, the possible application is to utilize waste PET fiber as replacement of fine aggregate in concrete. Hence, it is very eco-friendly, non-hazardous as it easily gets dispersed in concrete mix. Furthermore, using PET waste may also lead to reduce the consumption of natural aggregate resources in construction industry.

1.6 Thesis structure

The structure of this study consists of five parts. The thesis of this study is divided into five chapters as stated below.

The first chapter outlines the introduction of the background, problem statement, objective, scope and the significance of the study.

The second chapter discusses the detail information and literature review of this study. In this section, the review from the previous study from some researchers through the materials RCA and PET have been explained in construction materials such as concrete, brick and cement mortar. The detailed information is describing and highlighting the findings obtained from previous studies.

Chapter three discusses the work sequence, material preparation, mix design, specimen preparation, laboratory testing and standard used are discussed in detail in the third chapter

Chapter four presents the evaluation, analysis and discussed in detail. The data obtained throughout the experiments were analyzed and interpreted.

Chapter five in this study concludes the whole work conducted in order to meet the objectives.

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