THE POTENTIAL OF PORCELAIN WASTE AS SAND REPLACEMENT TO PRODUCE HIGH STRENGTH CONCRETE

MOHAMMED JAMAL JASIM

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Universiti Tun Hussein Onn Malaysia

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DEDICATION

This thesis is especially dedicated to my parents especially my beloved mother and father for support, prayer, encouragement and unconditional love, May God almighty reward you to my beloved wife, daughter and my brothers.

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ABSTRACT

Presently, green environment has been the biggest challenge in building and construction industries. An alternative in promotion to green environment is an effective and efficient recycling system by reusing solid waste materials like porcelain waste (PW). Recently, due to high demand in the construction industries, consumption of sand has increased which lead to series of problems such as natural sand depletion and its negative impact on the environment. This research is to investigate the possibility of using porcelain waste as sand replacement in the concrete production. Three different samples of concrete have been casted (cubes, cylinders and beams), with different sizes, the water cement ratio adopted is 0.5 and 0.37 when superplasticizer was added with mix proportion of concrete 1:1.5:3. The sand was replaced with porcelain waste at 10 %, 20 %, 30 %, 40 % and 50 %. Laboratory investigation were focused on examining the mechanical properties and thermal properties of the porcelain waste concrete (PWC). This involved compressive strength, splitting tensile strength, flexural strength and thermal conductivity, specific heat capacity, thermal diffusivity. The physical properties examined are porosity, water absorption and density. The chemical composition of PW material was completed by using X-ray fluorescence (XRF) technique. The distribution of porcelain waste particles inside the concrete were examined using optical microscope. Furthermore, mineralogical configuration of PWC were determined using X-ray diffraction (XRD) technique. At 50 % replacement the compressive strength of concrete at 60 days was 56.5 MPa and 75.2 MPa for 0.5 and 0.37 w/c ratio respectively, which shows an improvement of 17.2 % and 29.2 % over the concrete with natural sand. Similarly, specific heat capacity and porosity for concrete at 60 days was shows an improvement of 29.3 %, 28.6 % and 62.8 %, 36 % for 0.5 and 0.37 w/c ratio respectively. Therefore, 50 % sand replacement with PW resulted in concrete with excellent performance and it has the quality to be used as partial replacement of sand.

ABSTRAK

Persekitaran hijau merupakan cabaran terbesar dalam industri pembinaan dan bangunan di dunia sekarang. Sebagai alternatif untuk mempromosikan persekitaran hijau adalah sistem kitar semula yang berkesan dan efisien dengan menggunakan semula bahan buangan pepejal seperti sisa porselin (PW). Disebabkan oleh permintaan yang tinggi dalam industri pembinaan sekarang ini, penggunaan pasir telah meningkat yang menyebabkan punca masalah seperti pengurangan pasir semula jadi dan ia memberi kesan negatif terhadap alam sekitar.Penyelidikan ini adalah untuk mengkaji kebolehgunaan sisa porselin sebagai pengganti pasir dalam penghasilan konkrit. Tiga sampel konkrit yang berbeza telah dibuat (kubus, silinder dan blok), dengan ukuran yang berbeza, nisbah air dan simen yang digunakan adalah 0.5 dan 0.37 apabila *superplasticizer* ditambahkan dengan bahagian campuran konkrit 1: 1.5: 3. Pasir diganti dengan sisa porselin pada komposisi 10%, 20%, 30%, 40% dan 50%. Penyelidikan makmal difokuskan pada pengujian sifat mekanik dan sifat termal bagi konkrit sisa porselin (PWC). Ini melibatkan kekuatan mampatan, kekuatan tegangan perpecahan, kekuatan lenturan dan kekonduksian terma, kapasiti haba tertentu, penyebaran haba. Sifat fizikal yang diuji adalah keliangan, penyerapan air dan ketumpatan. Komposisi kimia bahan PW ditentukan dengan menggunakan teknik pendarfluor sinar-X (XRF). Penyebaran partikel sisa porselin di dalam konkrit ditentukan menggunakan mikroskop optik. Selanjutnya, konfigurasi mineralogi PWC ditentukan menggunakan teknik pembelauan sinar-X (XRD). Pada penggantian 50%, kekuatan mampatan konkrit pada 60 hari adalah 56.5 MPa dan 75.2 MPa masing-masing untuk nisbah 0.5 dan 0.37 w/c, yang menunjukkan peningkatan 17.2% dan 29.2% berbanding konkrit dengan pasir semula jadi. Begitu juga, kapasiti haba dan keliangan tertentu untuk konkrit pada 60 hari menunjukkan peningkatan masing-masing 29.3%, 28.6% dan 62.8%, 36% untuk 0.5 dan 0.37 w/c. Oleh itu, penggantian pasir 50% dengan PW menghasilkan konkrit dengan prestasi yang sangat baik dan ia mempunyai kualiti untuk digunakan sebagai penggantian separa pasir.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	-	Percentage
ε	-	Dielectric permittivity
P	-	Porosity
π	-	Pi
τ	-	Relaxation time
ε'	-	Dielectric constant
ε''	-	Dielectric loss
D	-	density
ε_o	-	Dielectric permittivity of free space
=	-	Equal to
≤	-	Less than
°	-	Degree
°C	-	Degree celsius
A	-	Area
CaO	-	Calcium oxide
SiO_2	-	Silicon oxide
Fe_3O_4	-	Magnetite nanoparticles
f_{cf}	-	Flexural strength
f_{ct}	-	Tensile strength
cm	-	Centimeter
f_{cu}	-	Compressive strength
S	-	Specific heat capacity
Cu	-	Copper
D	-	Diameter
EDX	-	Elemental dispersive x-ray
R^2	-	The coefficient of determination
FTIR	-	Fourier transforms infra-red

g	-	Gram
h	-	Hour
Hz	-	Hertz
Al_2O_3	-	Aluminum oxide
Fe_2O_3	-	Ferric oxide
kg	-	kilogram
m	-	Meter
SO_3	-	Sulfur oxide
M''	-	Imaginary electric modulus
M'	-	Real electric modulus
SP	-	Superplasticizer
RT	-	Room temperature
MgO	-	Magnesium oxide
W/C	-	Water-cement ratio
W.A	-	Water absorption
t	-	Thickness
XRD	-	X- Ray diffraction
β	-	Beta
θ	-	Theta
µ	-	Micro
D	-	Conductivity
W_d	-	Dry specimen with the mass
W_s	-	Sample mass with water
σ_{gb}	-	Grain boundary conductivity
W_i	-	Sample immersed in water
lit	-	Liter
PW	-	Porcelain waste
CWA	-	Ceramic waste aggregate

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Malaysia, as envisaged by the year 2020, to move from the developing country towards achieving a developed nation status. To realize this vision, many of the activities and industrial development are of significant importance such as construction sector. Meanwhile, socio-economic development is being actively planned and carried out. Thus, the construction sector is considered to be one of the most vital industries to sustain the overall economic growth of Malaysia by providing the necessary physical infrastructure needed to support the economic development plan. The industry also plays a significant role in creating housing for the annually growing Malaysian population. According to the plan of the solid waste generation is about 48 million tons per annum of which 25% are from the construction industry, the construction sector is predicted to boom and grow rapidly in the coming years, considering the present construction scenario in Malaysia (Kumar & Samadder, 2017). The rapid growth of this sector, in conjunction with economic growth, consequently indirectly requires a considerably high amount of production and consumption of construction minerals, such as rock materials (aggregate) and sand.

However, one of the most challenging issues at stake, affecting the natural concrete aggregate production is the environmental problem that is currently rising as the production increases. The consumption of natural aggregate concrete as the largest component material is a key concern because it comprises 70 to 80 % of the total volume (Neville, 2011). According to Yaprak *et al.*, (2011). More than 10 billion tons of concrete were produced annually worldwide (Yaprak *et al.*, 2011). The massive use of natural aggregate which will destroy the ecological balance of the environment due to the high demand of aggregate for the production of concrete due to increasing population growth, which lead to increase the consumption of natural resoures such as sand (Zheng *et al.*, 2020).

Sand is generally used as fine aggregate in concrete and usually produced from mining exploration. Sand mining has been recently improving due to the urgent need for the new technology in building (Xiao *et al.*, 2017). It is thus clear that the processes of prospecting, extracting, and transporting have great potential for disrupting the natural environment. Several factors have been identified as physical impacts of sand mining, which include reduction of water quality and destabilization of the stream bed and banks. Sand mining can also disrupt sediment supply and channel form, which can result in a deepening of the channel as well as sedimentation of habitats downstream (Ashraf *et al.*, 2011). Thus instability of channel and sedimentation from stream mining also can damage public infrastructure (bridges, pipelines, and utility lines). This process can also destroy riverine vegetation, cause erosion, pollute water sources, and reduce the diversity of animals supported by these woodlands habitats (Byrnes & Hiland, 1995). In view of that, there is an urgent need to find alternative replacements for river sand as fine aggregate in concrete by exploring the use of industrial waste in the making of concrete.

Researchers have recently directed their goals towards the utilization of construction wastes (Xuan *et al.*, 2018). These wastes are being reused in buildings and construction industries, which include ceramics, glass, insulating materials, nails, roofs, rubble, wood, iron, and so on. Furthermore, it was revealed that these wastes are able to use successfully play a vital role for sand replacement (Contreras *et al.*, 2016).

Currently, achieving a sustainable environment and eco-friendly community through effective recycling of waste materials in the construction industries are the fundamental issue worldwide. The utilization of certain categories of waste and by-products of industries in construction and as building materials for the production of concrete seems to provide adequate solutions to these issues. Many researches have been proven that waste materials from industries such as foundry sand, copper tailings, recycled concrete, fly ash, and ceramic waste can be utilized in the production of sustainable concretes (Umara *et al.*, 2016). However, the increasing amount of industrial wastes being produced due to the rapid increase in industrialization worldwide has dwindled the space for landfills. This problem of a landfill and other economic and environmental issues clamour for more usage of industrial waste materials through extensive research and utilization in concrete to produce a green and eco-friendly environment.

Concrete is the most popular building material in the world. However, the production of cement has diminished the limestone reserve in the world and requires a great consumption of energy (Scrivener *et al.*, 2018). Sand has been the most popular choice for the fine aggregate component of concrete in the past, but overuse of the material has led to environmental concerns, the depleting of securable sand deposits, and a concomitant price increase in the material (Muhammad *et al.*, 2015). Therefore, it is desirable to obtain cheap, environmentally friendly substitutes for sand that are preferably by-products.

The main constituents of concrete are coarse aggregate, fine aggregate, cement, and water. Despite that, Portland cement particles occupy only 10% to 15% of the concrete mixture total volume; it is a critical material structure that, after reacting with water, combines and binds other constituents together (Mashaly *et al.*, 2015). The combustion of fossil fuel and cement manufacture techniques considered the main producers of CO_2 that drive climate change. The cement industry contributes to around 5-8 % of the annual global greenhouse gas emissions to the atmosphere (Najim *et al.*, 2015). The concrete production has been looking for techniques that might effectively decrease the elevated energy and negative environmental impacts of cement making that may lead to a greener environment.

Due to the growing interest in sustainable development, the adaption of appropriate policies and proper methods to save the environment across all industries, including construction, attracted the attention of researchers all over the world (Pachauri, 2016). The continued growth of societies and human developments increased the reliance on natural and non-renewable resources to encounter consumer's demand (Bretschger & Smulders, 2012). This ends with the continual increase of industrial wastes, which constitutes one of the major worldwide environmental challenges (Kim & Jeong, 2017). Porcelain waste can be fully recycled within its usual manufacturing process (Zimmer & Bragança, 2019). However, this is easy task because the waste should be available large quantity in the landfill. The waste management technique decreases the consumption of raw resources, and the required energy, in addition, helps in saving the exhausted landfills (Nabavi *et al.*, 2017).

Therefore, the porcelain wastes are generated as a waste during the process of dressing and polishing. It is estimated that 15 % to 30 % waste are produced of total raw material used, and although a portion of this waste may be utilized on-site, such as for excavation pit refill, The disposals of these waste materials acquire large land areas and remain scattered all around, spoiling the aesthetic of the entire region (Keerthiraman, 2016).

Therefore, according to previous research work, the only solution to deal with large amounts of ceramic waste is to reuse it as the most viable application in the concrete industry. Besides, to promote recycling, demolition contractors should be given incentives to establish hot material concrete. The thermal performance of concrete considered one of the attentions of our research. The study identifies the performance of recycling porcelain waste as a partial substitute as sand to improved the performance of concrete and to developed good mechanical and thermal properties of concrete.

1.2 Problem statement

The amount of solid wastes (derived from Construction & Demolition and Mining & quarrying activities) in Europe is estimated to be more than 1,500 million tonnes (Qing *et al.*, 2010). Similarly, construction projects are increasing annually. Thus, the production of natural resources has been depleted (Venables, 2016). Waste from construction industries has become a global issue faced by researchers and practitioners around the world. Moreover, this directly affects the construction industry due to cost, time, productivity, and sustainability aspects (Nagapan *et al.*, 2012).

Lura *et al.* (2014) reported that the disposal of solid waste prompt researchers to embark on environmental awareness that greatly contributed to reducing the waste and suggestion a proper way of using it. Similarly, due to the increase in costs of landfills and distance of the designated landfills from the construction industries, waste utilization has become an alternative to waste disposal minimization. The high demand for concrete were also involve the growing demand for fine aggregates. This problem has led to the search for a good solution to recycle waste and reduce disposed waste and find a way toward the sustainability of natural resources. This is because the waste materials produced by various industries are very important to the sustainable development of various ceramic industries. Thus, wastes from the demolition of buildings have been reported to have potential applications as a fine sand replacement, which may save the natural resources and reduces the space of landfill disposal (Lura & Pietro, 2014).

Waste from construction industries also been increasing due to the increasing demands and urbanization, thus the need for large areas and minimize the capacity of landfilling to support the construction waste. The demand for houses and major infrastructure keeps the amount of construction waste getting increased. Therefore, the only alternative to solve this menace is waste utilization (Bahoria *et al.*, 2013).

Pacheco & Jalali (2010), Porcelain is consists of feldspar, quartz, and kaolin, and its wastes can be recycled as an economical, environmentally friendly alternative to building materials and used as building materials in today's world due to its properties. In addition, landfills have become overcrowded, and waste disposal costs are high, even though several efforts have been made to minimize the amount of material that ended up in landfills. In order to reduce the overuse of natural sand in building material for the construction industries, the researchers have put forward to recycle the porcelain waste and replace it with natural sand to reduce the waste disposed of the landfill. The benefits of this recycling are economically advantageous because of the lower cost of waste removal and pollution reduction (Senthamarai & Manoharan, 2005).

Coelho & Brito (2013) studied the concrete is a composite material composed of aggregate materials that embedded in a hard matrix of cement or binder that fills up the void between the aggregate particles and hold them together, hile aggregates are inert granular materials such as sand, gravel, or crushed stone. Aggregates supposed to be clean, hard, and strong particles that free from absorbed chemicals or coatings of clay or other fine materials that could deteriorate the concrete. All these granular materials came from natural resources, which have significant influences on environmental sustainability. Florini & Sovacool (2009), the issue of environmental sustainability has been facing challenges as a result of the increasing demand for concrete products. Therefore, to ensure sustainability in construction industries, alternative ingredient materials, predominantly the aggregates, need to be sourced for; hence the use of porcelain waste has the potential of solving this problem.

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