Analyses of Cement Composites with the Addition of Quarry Dust as Partial Sand Replacement Materials

by

Madzura binti Mohamad
(1230410755)

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DECLARATION OF THESIS

Author's full name : MADZURA BT MOHAMAD

Date of birth : 08 SEPTEMBER 1979

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
BS	British Standard
MS	Malaysian Standard
SEM	Scanning electron microscope
XRF	X-ray fluorescence
XRD	X-ray diffraction
MOR	modulus of rupture
OPC	ordinary Portland cement
ITZ	interfacial transition zone
ASR	alkali silica reaction
UTM	universal testing machine
wt.%	weight percent
C-S-H	calcium silicate hydrate
w/c	water cement ratio

LIST OF SYMBOLS

θ	Theta
ρ	rho
O	omicron
ω	omega
Δ	Delta

Analisis Komposit Simen dengan Penambahan Debu Kuari Sebagai Bahan Pengganti Pasir Separa

ABSTRAK

Pembangunan komposit simen telah diperkenalkan sejak beberapa dekad untuk memenuhi keperluan di dalam sektor pembinaan dan telah menjadi salah satu pengeluar utama bahan buangan dan pengurangan sumber, terutamanya pasir sungai. Debu kuari telah menjadi bahan alternatif di dalam komposit simen untuk mengurangkan penggunaan pasir sungai dan pemulihan ekologi dalam usaha untuk mempromosikan pembangunan yang mapan di dalam industri pembinaan. Oleh itu, kajian ini dijalankan untuk mengkaji kesan-kesan debu kuari sebagai bahan gantian separa bagi pasir untuk menentukan nilai optimum debu kuari di dalam komposit simen. Sehubungan dengan itu, komposit simen dikategorikan kepada dua bahagian. Bahagian yang pertama ialah kajian perkadaran yang mengkaji kesan debu kuari terhadap sifat-sifat fizikal dan mekanikal, profil retak, patah dan morfologi permukaan komposit simen di bawah beban tekanan. Dalam kajian ini, pembangunan komposit simen dijalankan dengan menggantikan debu kuari dengan sebahagian pasir sungai mengikut kepada pelbagai peratusan pada nisbah air simen berkadar tetap (0.45). Komposit simen dihasilkan daripada campuran simen Portland biasa (OPC), pasir sungai, debu kuari dan air. Lima nisbah campuran yang berlainan iaitu 1: 1.00: 0.00, 1: 0.90: 0.10, 1: 0.875: 0.125, 1: 0.850: 0.150 dan 1: 0.825: 0.175 (simen: pasir sungai: debu kuari) disediakan dengan merujuk kepada piawaian yang berkaitan. Komposit simen diawet di dalam air selama 7 dan 28 hari, dan diuji untuk menentukan sifat-sifat mekanikal seperti kekuatan mampatan dan modulus pecah, sifat-sifat fizikal seperti ketumpatan, penyerapan air dan kandungan lembapan. Bahagian yang kedua pula adalah kajian ketahanlasakan, yang telah dijalankan untuk memantau perubahan panjang komposit simen apabila terdedah kepada serangan sulfat dengan penambahan debu kuari pada 12.5 dan 17.5 peratus berat. Tempoh kajian untuk menentukan sifat-sifat ketahanlasakan adalah 15 minggu. Berdasarkan pemantauan, penambahan debu kuari di dalam komposit simen menunjukkan peningkatan pada sifat-sifat kekuatan, berbanding dengan komposit simen tanpa penambahan debu kuari (1: 1.00: 0.00). Namun begitu, sifat-sifat kekuatan komposit simen menunjukkan hala pengurangan apabila debu kuari meningkat, manakala penyerapan air dan kandungan lembapan telah meningkat apabila kandungan debu kuari semakin digunakan sebagai bahan pengganti di dalam komposit simen. Dapatan kajian menunjukkan bahawa komposit simen dengan nisbah bancuhan 1: 0.875: 0.125 (12.5 peratus berat debu kuari) pada 28 hari memberikan nilai optimum pada kekuatan mampatan (56.04 MPa), modulus pecah (16.34 MPa), ketumpatan (2192 kg/m^3), penyerapan air (3.09%) dan kandungan lembapan (0.74%). Profil keretakan dan morfologi permukaan komposit simen juga berada dalam keadaan yang baik. Disamping itu, komposit simen tidak menunjukkan sebarang perubahan panjang dan kemerosotan permukaan yang ketara selepas direndam di dalam larutan sodium sulfat. Sebagai kesimpulan, debu kuari boleh digunakan sebagai bahan ganti separa kepada pasir sungai pada peratusan tertentu (12.5 wt.%) dan didapati dapat memperbaiki sifat-sifat fizikal, mekanikal dan ketahanlasakan komposit simen.

Analyses of Cement Composites with the Addition of Quarry Dust as Partial Sand Replacement Materials

ABSTRACT

The development of cement composites has been proposed for many decades to fulfil the requirements in the construction sector and became one of the major producers of waste and source depletion, especially river sand. Quarry dust became an alternative material in cement composites to reduce the consumption of river sand and ecology rehabilitation in order to promote sustainable development of the construction industry. Therefore, this research was conducted to study the effects of quarry dust as partial sand replacement material on physical, mechanical and durability properties of the cement composites. In relation to this, the cement composites were categorised into two main sections. First section is the proportioning study that investigates the effect of quarry dust on the physical and mechanical properties, crack profile, fracture and surface morphology of cement composites under pressure load. In this study, the fabrication of cement composites was carried out by substituting quarry dust with a portion of river sand according to the various percentages at constant water cement ratio (0.45). The cement composites were produced from a mixture of ordinary Portland cement (OPC), river sand, quarry dust and water. Five different ratios of 1: 1.00: 0.00, 1: 0.90: 0.10, 1: 0.875: 0.125, 1: 0.850: 0.150 and 1: 0.825: 0.175 (cement: river sand: quarry dust) were prepared according to the related standards. The cement composites were cured in water for 7 and 28 days, and tested to determine the mechanical properties such as compressive strength and modulus of rupture, physical properties such as density, water absorption and moisture content. The other section is the durability study, which was conducted to observe the length change of cement composites when subjected to sulphate attack with the addition of 12.5 wt.% and 17.5 wt.% of the quarry dust. The period to determine the durability properties was 15 weeks. Based on the observations, the addition of quarry dust in the cement composites showed improvement in strength properties, compared to cement composites without the addition of quarry dust (1: 1.00: 0.00). However, the strength properties of cement composites showed a reduction trend when quarry dust increases, while the water absorption and moisture content increased when the content of quarry dust was increasingly used as a substitute in the cement composites. The findings showed that the ratio of 1: 0.875: 0.125 (12.5 wt.% of quarry dust) at 28 days obtained the optimal value of compressive strength (56.04 MPa), modulus of rupture (16.34 MPa), density (2192 kg/m^3), water absorption (3.09%) and moisture content (0.74%). The crack profile and surface morphology of the cement composites also in good condition. Besides that, the cement composites with the addition of 12.5 wt.% of quarry dust did not show any major changes in length and surface deterioration after being immersed in the solution of sodium sulphate. As a conclusion, quarry dust can be used as a partial substitute for river sand at certain percentage (12.5 wt.%) and was found can improved the physical, mechanical and durability properties of the cement composites.

CHAPTER 1

INTRODUCTION

1.1 Research background

Malaysia is generally perceived as one of the successful countries and have achieved modern economic growth in various sectors. In modernisation process, the economic sector grows rapidly to fulfil the living requirements, including the construction industry. Subsequently, there are many materials and goods that have been produced. In respect of that, the mining industry is operated extensively to produce construction materials for many construction applications (Safiuddin et al., 2010), which are essential for the development of modern countries, including Malaysia. This has led to major solid wastes or residues that need proper management.

One output of the quarry industry is the production of quarry dust that has been used in large scale for various construction activities including road construction and manufacturing of building materials such as bricks, lightweight concrete, tile blocks and so on. Quarry dust has been adopted as a building material in the industrially advanced countries of the west for the past three decades (Abhijeet, 2014). Besides that, the use of quarry dust in construction gives the benefits to economic and environmental aspect for the quarry industry, which can reduce the disposal cost and the lifespan of primary rock sources could be extended (Florida Department of Transportation, 2002).

In recent years, tremendous efforts were taken in concrete technology to investigate the consumption of by-products and waste materials (Raman et al., 2005). Unfortunately, only a handful of researchers have investigated the development and characterisation of cement composites by using quarry dust. Therefore, it is important to study and promote a new product in construction applications based on quarry dust. Successful utilisation of quarry dust will reduce the environmental load, waste management and concrete production cost (Raman et al., 2005), besides improving the properties of cement composites.

The aim of this research is to fabricate and characterise the cement composites with the addition of quarry dust as partial replacement to river sand, subsequently study the effects on the strength and durability of cement composites.

1.2 Problem statement

Nowadays, the growth of population, modern urbanisation and the improvement in living standards has donated to the increase of waste materials resulting from the manufacturing, mining, domestic and agricultural activities. These wastes have become environmental burden and require disposal management in Malaysia, so recycling the wastes to be used as construction materials is increasingly important (Safiuddin et al., 2010).

In the construction industry, the productions of concrete, bricks, hollow and solid blocks, pavement blocks, tiles and others are generally from natural resources, such as river sand. Excessive and continuous dredging of river sand tends to contribute to ecological disruption and environmental destruction. Erosion has changed vegetative properties leading to soil infertility for the agricultural activity, as well as the survival of flora and fauna, and the alteration of river ecosystem that can attribute to flood (Sakthivel et al., 2013).

Besides that, the production of coarse aggregates especially at the crushing and screening processes generate the dust in large quantities. Consequently, various toxic substances such as carbon monoxide, oxides of sulphur, oxides of nitrogen and suspended particulate matters are invariably emitted into the atmosphere during the manufacturing process of construction materials (Safiuddin et al., 2010). The emission of this substance can contaminate air, water and soil which can influence the standard of human health.

In order to safeguard the environment, many efforts are taken to recycle or reuse different types of waste such as agro waste, industrial waste, mining or mineral waste, hazardous and non-hazardous waste (Pappu et al., 2007) by utilising them as construction materials (Safiuddin et al., 2010). According to Kralj (2011), the government contribution is necessary in attaining the sustainable construction, which give the benefits to the environmental aspects and economical dynamics of society. For instance, environmental issues becomes the major concern in Hong Kong since the waste material produced annually by local construction activities increased more than 75 percent (Poon et al., 2013). Thus, many extensive researches and development work have been taken to explore waste alternatives and to conserve natural resources towards achieving sustainable construction industry.

In this research, the utilisation of quarry dust as sand replacement material in cement composites is to produce the construction material that can bring about strength improvement and can solve the environmental problems. Based on the previous study, the consumption of quarry dust in desirable because it is a useful by-product material, reducing the utilisation of river sand and improve the strength of concrete (Chaturanga et al., 2008). Furthermore, quarry dust is known to increase the strength and gives additional benefit, and has been proposed by many researchers as an alternative to the river sand (Chandana et al., 2013). In 2009, Hameed & Sekar revealed that the compressive strengths and durability resistance to sulphate attack was enhanced when utilising quarry dust compared to the traditional concrete.

Consequently, many researchers around the world utilised quarry dust as a partial replacement for sand (Celik & Marar, 1996; Lohani et al., 2012; Manguriu et al., 2013; Kannan et al., 2014; Mohammad et al., 2015) or cement (Abukersh & Fairfield, 2011; Soman & Abubaker, 2014; Kartini et al., 2014; Kumar & Krishna, 2014) in concrete production and a lot of results were published, but very limited in the concept of cement composite. Therefore, this study was conducted to identify the effects of quarry dust as a partial substitute for river sand in terms of physical, mechanical and durability properties of cement composite. Previous studies on the use of quarry dust in concrete can be used as a benchmark or guidelines in the perspective of cement composites.

1.3 Objectives of research

The main purpose of this research is to fabricate cement composites with the utilisation of quarry dust and the specific objectives are listed as the followings:

1. To study the raw material characterisations of cement composites.
2. To study the effects of quarry dust as partial sand replacement material on the physical, mechanical and durability properties of cement composites.

3. To analyse the crack profile, fracture and surface morphology of cement composites with the addition of quarry dust.

1.4 Scope of research

The research can be divided into three phases, namely proportioning, characterisation and durability studies. The materials used in the experiment were cement, water, river sand and quarry dust. The samples were prepared depending on the respective test and curing for 7 and 28 days by following the related standards. The suitable weight percent of quarry dust was obtained from proportioning study according to the results of physical and mechanical properties of cement composites.

According to the results, the characterisations of the samples were determined by studying the crack profile, fracture and surface morphology of cement composites. Finally, in the durability study, the samples were prepared and immersed into the solution of sodium sulphate to investigate the effects of quarry dust on cement composites due to sulphate attack.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The chapter is to review the related literatures from many researchers about the utilisation of by-product materials in the concrete and cement composites. The findings and the gathered information form the basis for the investigation on the effects of quarry dust as a partial sand replacement in the development of cement composites.

2.2 Sustainable construction from general viewpoint

The construction sector plays an important role in generating economic development and provides job opportunities for many people. Besides that, construction industry is a major resource of waste, and responsible for around half of the total carbon dioxide (CO_2) emissions (Zuhairi et al., 2011) and depletion of natural resources such as natural sand. The environmental imbalance has made the people to focus on the implementation of eco-friendly construction materials and new technologies, which human and nature can live in harmony (Sakthivel et al., 2013). In order to achieve the goal, one way is to go 'green' or create the sustainability in the construction industry.

Basically, sustainable construction refers to the construction process that is responsible to environment and uses resources efficiently starting from planning, designing, construction, operation, maintenance, renovation and demolition. According to Nazirah (2009), sustainability has focused on the consumption of energy and raw materials, and method to decrease the impacts on the environment in the technical issues such as materials, building components and construction technologies. In this regard, renewable energy resources appear to be one of most effective solutions, whether to replace the consumption of cement or natural aggregates.

2.3 The important of sand replacement in sustainable construction

Generally known, river sand is one of the important material in cement composites which is affecting the strength of cement composites. The utilisation of river sand must be free from any impurities such as salts, clay or other foreign materials that will affect the adhesion factor between cement and water. In the same way, it offers surface area for film of cementing material to adhere and spread, which avoids the shrinkage and cracking of cement composites (Tasnia et al., 2013).

Besides that, the strength of cement composites is mainly affected by the function of fine aggregates or sand (Sharmin et al., 2006). According to Lohani et al. (2012), fine aggregates are usually sand from the river. River sand that is normally included as fines aggregates in cement composites, is smaller than 4.75 mm but larger than 75 µm (Mehta & Monteiro, 2006).

Lately, the demand for river sand is very high due to its strength properties to satisfy the infrastructure growth. For an example, India has been facing the shortage of river sand that are causing serious threat to environment and the society (Lakhan et al., 2013). Unfortunately, the excessive and continuous excavation of river sand has contributed to deteriorating the environmental ecology such as failure of river banks, disturbs the aquatic life and become a high demand in the construction industry.