POZZOLANIC ACTIVITY OF RICE HUSK AND ITS APPLICATION IN THE PRODUCTION OF LIGHTWEIGHT MORTAR

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ABSTRACT

The properties of lightweight mortar using rice husk (RH) can benefit from pozzolanic reaction and from organic fibre reinforcement. The use of RH as a partial replacement to cement is economical, besides creating a better environment. The study investigates the pozzolanic activity of rice husk and its effect on the strength and physicochemical properties of lightweight mortar (LWM) containing RH. The pozzolanic activity of RH was determined via conductivity measurement. In this study, RH was used as a cement replacement at 10% (w/w) and 20% (w/w). The strength development of LWM was monitored at 3, 7, 14, 28, 56 and 90 curing age. Physicochemical composition of RH and LWM were studied by field emission scanning electron microscopy (FESEM) coupled with energy dispersive X-ray (EDX), X-ray diffraction (XRD), single point BET and thermogravimetry analysis (TGA). The studies showed that RH contains 96% silica (SiO_2). XRD analysis confirmed the presence of amorphous silica. Conductivity studies indicated that the RH exhibit pozzolanic activity as reflected by a decrease in conductivity. The decrease is attributed to the interaction between $Ca(OH)_2$ and the SiO_2 in RH. The amorphous silica contained in RH can react with $Ca(OH)_2$ to form a type of C-S-H gel. FESEM analysis showed a smooth internal surface and irregular morphology at external surface of the RH. The morphology of the LWM samples showed the development of portlandite, C-S-H gel and enttrigite indicating the occurence of cement hydration. EDX microanalysis gave higher silica content at the external surface than the internal surface which may promote a pozzolanic action. XRD and TGA showed that $Ca(OH)_2$ increased with time for LWM without RH, indicating cement hydration. The strength development of the LWM showed increasing strength at 3, 7, 14 and 28 days, but the strength of conventional LWM is almost constant after 28 days. Eventhough the mortar containing RH showed lower strength than the conventional LWM, but it showed an increasing strength after 28 days due to cement hydration, pozzolanic reaction and possibly fibre reinforcement.

ABSTRAK

Sifat kimia fizik mortar ringan dapat dimanfaatkan dengan menggunakan sekam padi melalui tindak balas pozzolanik dan penguatan fibernya. Penggunaan sekam padi sebagai bahan ganti kepada simen adalah menjimatkan disamping sifatnya yang mesra alam. Kajian dijalankan untuk menyelidik aktiviti pozzolanik bagi sekam padi dan kesannya ke atas kekuatan dan sifat kimia fizik mortar ringan yang mengandungi sekam padi. Kesan pozzolanik sekam padi ditentukan melalui pengukuran konduktiviti. Sebanyak 10% dan 20% sekam digantikan kepada simen di dalam kajian ini. Perkembangan kekuatan mortar diperhatikan setiap 3, 7, 14, 28, 56 dan 90 hari pengawetan. Komposisi fizik kimia sekam padi dan mortar dikaji dengan Mikroskop Medan Pancaran Imbasan Elektron (FESEM) digandingkan dengan Tenaga Sebaran Sinar-X (EDX), Pembelauan Sinar-X (XRD), luas permukaan BET dan Analisis Termogravimetri (TGA). Keputusan menunjukkan sekam padi mengandungi 96% silika (SiO_2) dan XRD mengesahkan kehadiran silika amorfus. Kajian konduktiviti menunjukkan sekam padi mempunyai aktiviti pozzolanik dengan melihat penurunan nilai konduktivitinya. Ini menunjukkan tindak balas antara $Ca(OH)_2$ dengan silika amorfus, SiO_2 di dalam sekam padi membentuk sejenis gel C-S-H. Analisis FESEM menunjukkan permukaan yang rata pada bahagian dalam sekam, manakala kasar di permukaan luar. Morfologi mortar menunjukkan perkembangan portlandite, gel C-S-H dan ettringite yang menggambarkan berlakunya penghidratan simen. Mikroanalisis EDX memberikan kandungan silika yang tinggi di permukaan luar sekam berbanding di permukaan dalam, di mana keadaan ini menyokong lagi aktiviti pozzolanik. XRD dan TGA menunjukkan kuantiti $Ca(OH)_2$ meningkat dengan masa untuk mortar tanpa sekam padi, menunjukkan penghidratan cement. Perkembangan kekuatan mortar menunjukkan peningkatan pada 3, 7, 14 dan 28 hari, tetapi kekuatan untuk mortar biasa didapati hampir malar selepas 28 hari. Walaupun mortar yang mengandungi sekam padi menunjukkan kekuatan yang lemah berbanding mortar biasa, tetapi ia menunjukkan peningkatan kekuatan selepas 28 hari, menunjukkan berlakunya penghidratan simen, tindak balas pozzolanik dan penguatan fiber.

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LIST OF SYMBOL AND ABBREVIATIONS

BET	Brunauer, Emmett and Teller
Ca	Calcium
$Ca(OH)_2$	Calcium hydroxide
$CaCO_3$	Calcium carbonate/calcite
C_2S	Dicalcium silicate
C_3S	Tricalcium silicate
C_3A	Tricalcium aluminate
$CaSO_4$	Calcium sulphate
C-S-H	Calcium silicate hydrate
CH	Portlandite
CO_2	Carbon dioxide
DTA	Differential thermal analysis
H_2O	Water
N_2	Nitrogen
N/mm^2	Newton/metre^2
OH^-	Hydroxyl ion
OPC	Ordinary Portland Cement
RH	Rice husk
RHA	Rice husk ash
FESEM	Field emission scanning electron microscope
SiO_2	Silicone dioxide
TGA	Thermogravimetry analysis
w/c	Water-to-cement (binder) ratio
XRD	X-ray diffraction

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CHAPTER I

INTRODUCTION

1.1 General Introduction

The agroindustries inevitably produce large amount of agrowaste. One of the agrowaste product is rice husk. The main use of rice husk is as fuel for the rice paddy milling process. Rice husk is a by-product of rice mill. In biomass power plant, rice husk is burnt as a fuel to produce steam for electricity generation in order to support energy conservation. After burning, a by-product in ash form is produced (Tangchirapat *et al.,* 2007). The use of this fuel generates a huge volume of ash (Rodriguez, 2006).

Rice husk ash (RHA) obtained by burning rice husk (RH) under controlled temperature has been used in many countries as a low cost concrete admixture due to its pozzolanic activity and its role as a filler. The use of RHA in concrete however, requires the RHA to be burnt at certain temperature which can contribute to air pollution.

Rice husk is a fibrous, abrasive and tough agriculture by-product. It is essentially composed of 30% cellulose, 20% lignin, 18% pentosans, 20% ash, consisting of mainly silica, and other organics and impurities (James and Rao, 1980). Because of the tough, woody, abrasive nature of the hulls, their low nutritive properties, resistance to weathering, great bulk, and high ash content, the use or disposal of rice husk has frequently proved difficult. Due to the growing concern with environmental pollution and an increasing interest in conservation of energy and resources, the traditional disposal of rice husk is no longer available in the society today. Every country, especially the developing country has to overcome this problem and how to use or dispose this low-value by-product within the framework of its economic structure. Experimental studies had shown the properties and application of rice husk ash are dependent on their preparation. The sensitivity of the ash products to the treating condition is the primary reason that obstructs the widespread use of this material.

Pozzolanic additive is a substance contains materials that can react with $Ca(OH)_2$ at room temperature in the presence of water. This reaction will form a stable compound and show the characteristic of cement (Lea, 1970). The common pozzolanic additives that have been used are silica ash, rice husk ash and fly ash. These pozzolana are waste from steel industry, agriculture and electrical generator.

The pozzolanic effects of rice husk ash have been reported by several researchers. Jaubherthie *et al.* (2000) has shown that the amorphous silica is found in the rice husk, thus explaining its presence in the ash. This gives rise to the pozzolanic effect in RH which has a beneficial effect on the durability. The use of rice husk in the production of light-weight concrete benefits from its pozzolanic effect, and improvement in the tensile strength of the material due to the fibrous nature of rice husk (Fisher *et al*., 2001).

Two main uses of RHA are in the steel industry and as pozzolan in industry, masonry and plastering. However, the economical aspects for the bulk production of rice husk ash could not be considered. Along with bulk production, utilisation of the fuel value of rice husk can further improve the affordability of RHA pozzolana (Yogananda and Jagadish, 1988). Besides, uses of RHA include being used as a raw material for the synthesis of zeolite (Hamdan, *et al.*, 1997).

1.2 Natural Fibre-Cement Composites

Fibre-reinforced cement-based materials have found increasing applications in residential housing construction. Currently, fibre-cement composite products can be largely found in non-structural housing components, including siding and roofing materials.

While Portland cement concrete is the most widely used manufactured material (Mehta and Monterio, 1993), plain concrete, mortars, and cement pastes are brittle, possess low tensile strength, and exhibit low tensile strains prior to failure. These shortcomings have been traditionally overcomed by embedding within the cement-based material some other material with greater tensile strength.

Among the different types of fibres used in cement-based composites, natural fibres offer distinct advantages such as availability, renewability, low cost, and current manufacturing technologies. One promising and often-used natural fibre is rice husk. Studies by Mac Vicar *et al.,* 1999 reported that wood pulp fibre-cement composites offer numerous advantages when compared to both non-fibre-reinforced cement materials as well as other fibre-reinforced cement-based materials. Fibre-cement composites exhibit improved toughness, ductility, flexural capacity, and crack resistance as compared to non-fibre-reinforced cement-based materials. Pulp fibre is a unique reinforcing material as it is non-hazardous, renewable, and readily available at relatively low cost compared to other commercially available fibres.

1.3 Problem Statement

Based on the previous researches, rice husk ash (RHA) obtained by burning rice husk (RH) under controlled temperature could be used as a cement replacement in producing a lightweight mortar due to the high amount of amorphous silica (Zhang *et al.*, 1996; Tangchirapat, *et al.*, 2007 and Rodriguez, 2006). However, the burning of rice husk to produce RHA will further contribute to the existing air pollution. Hence, the use of rice husk rather than RHA is not only more economical but does not contribute to the environmental pollution.

The use of rice husk can benefit from pozzolanic reaction and organic fibre reinforcement. This study attempts to investigate the suitability of Malaysian rice husk in the production of lightweight mortar. The significance of this study is the possibility of using RH as cement replacement material.

1.4 Objectives of the Research

The objectives of this study are to investigate the pozzolanic activity of rice husk, to identify the origin of silica in rice husk and its application in the production of lightweight mortar.

1.5 Scope of the Research

a) To study the pozzolanic activity of RH via conductivity measurement
b) To study the chemical and physical characteristic of rice husk using FESEM/EDX
c) To produce lightweight mortar using cement, sand and RH
d) To determine compressive and flexural strength of lightweight mortar
e) To study the extent of hydration reaction of cement and pozzolanic reaction in the lightweight mortar at 3, 7, 14, 28 and 90 days curing ages using TGA and XRD analysis
f) To determine the surface area of lightweight mortar by using BET nitrogen adsorption

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