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การใช้เถ้าทิ้งจากผลผลิตเกษตรกรรมในงานคอนกรีต
Use of Waste Ash from Agricultural by-Products in Concrete Work

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บทคัดย่อ

งานวิจัยนี้เป็นการศึกษากำลังอัดและความพรุนของมอร์ต้าร์ทำจากส่วนผสมของปูนซีเมนต์ปอร์ตแลนด์ประเภทที่ I (OPC) ทราย (Sand) และเถ้าแกลบบดละเอียด (RHA) หรือเถ้าปาล์มน้ำมันบดละเอียด (POA) ส่วนผสมมอร์ต้าร์แทนที่ปูนซีเมนต์ปอร์ตแลนด์ด้วย RHA และ POA ในอัตราส่วนร้อยละ 0-40 โดยน้ำหนัก สัดส่วนผสมน้ำต่อวัสดุประสานใช้เท่ากับ 0.5 ควบคุมค่าการไหลแผ่เท่ากับร้อยละ 110 ± 5 ด้วยสารลดน้ำพิเศษ (SP) วิเคราะห์วัสดุ RHA และ POA ด้วย X-ray diffraction (XRD) และภาพถ่ายกำลังสูงหรือ scanning electron microscopy (SEM) จากนั้นนำมอร์ต้าร์ไปทดสอบเพื่อหาการรับกำลังอัดและหาความพรุน การวิเคราะห์ด้วย XRD ยืนยันว่า RHA และ POA มีองค์ประกอบหลักทางเคมีเป็นซิลิกา การใช้ RHA และ POA ซึ่งเป็นเถ้าทิ้งให้ค่ากำลังอัดที่สูง การใช้ RHA และ POA ในอัตราส่วนร้อยละ 20 ความพรุนลดลง แต่ความพรุนเพิ่มขึ้นเมื่อแทนที่ในอัตราส่วนร้อยละ 40 RHA และ POA มีศักยภาพในการใช้เป็นวัสดุปอซโซลานได้ดีสำหรับงานคอนกรีต

Abstract

This paper presents a study on the strength and porosity of mortars made with binary blends of ordinary Portland cement type I (OPC) sand and ground rice husk ash (RHA) or ground palm oil fuel ash (POA). The mortar mixtures were made with Portland cement Type I containing 0-40% RHA and POA. The water to binder ratio was kept constant at 0.5 and the flow of mortar was maintained at 110 ± 5% with the aid of superplasticizer (SP). X-ray diffraction (XRD) and scanning electron microscopy (SEM) were used on materials. Compressive strength and porosity of the mortar were determined. The XRD pattern confirmed that POA and RHA were mainly amorphous silica. The use of RHA and POA produced waste ash with relatively high strength. The porosity of mortar containing RHA and POA decreased with the low replacement level of up to 20% of pozzolanic but increased with the 40% replacement level. RHA and POA have a high potential to be used as a good pozzolanic material in concrete work.

คำสำคัญ : เถ้าปาล์มน้ำมัน เถ้าแกลบ เถ้าทิ้ง กำลังอัด

Key words : Palm oil fuel ash, Rice husk ash, Waste ash, Strength

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1. Introduction

In Thailand and many parts of the world, a large amount of rice husk could be obtained as an agricultural by-product. By burning the rice husks under the controlled temperature and atmosphere, a highly reactive rice husk ash is obtained. The properly burnt and ground rice husk ash is also suitable for use as a pozzolanic material [1].

Palm oil fuel ash is one promising pozzolan and is available in many parts of the world. It is a by-product obtained from a small power plant, which uses the palm fiber, shells and empty fruit bunches as a fuel and burnt at 800-1000 °C [2]. The main chemical composition of palm oil fuel ash is silica which is a main ingredient of pozzolanic material [1].

The landfill of palm oil fuel ash is the problem of all power plants because this waste ash is not used in any work. Therefore, the objective of this research is to utilize the palm oil fuel ash and rice husk ash as a pozzolanic material in blended Portland cement in order to reduce negative environmental effects and landfill area required to dispose of waste ash.

In this work, ordinary Portland cement, ground palm oil fuel ash and ground rice husk ash were used as base materials for studying the ternary blended cement. The knowledge in terms of strength would be beneficial to the understanding of the mechanisms as well as for future applications of these materials.

2. Materials and methods

2.1 Materials

Ordinary Portland cement (OPC) type I, palm oil fuel ash from a thermal power plant from the south of Thailand, local rice husk, river sand with specific gravity of 2.63 and fineness modulus of 2.82, and type-F superplasticizer (SP) were the materials used in this study. Ground palm oil fuel ash (POA) and ground rice husk ash (RHA) were obtained using ball mill grinding until the percentage retained on a sieve No. 325 was 1-3%.

2.2 Mix proportions and curing

OPC was partially replaced with 20% and 40% of single pozzolan viz., POA and RHA of difference portion of RHA and POA. Sand-to-binder ratio of 2.75 by weight and water to binder ratio (W/B) of 0.5 were used. SP was incorporated in order to obtain mortar mixes with similar flow of 110 ± 5%. The cast specimens were covered with polyurethane sheet and damped cloth and placed in a 23 ± 2 °C chamber. They were demoulded at the age of 1 day and cured in water at 23 ± 2 °C until the test.

2.3 Compressive strength

The 50 × 50 × 50 mm cube was used for the compressive strength test of mortar. They were tested at the age of 7, 28 and 90 days. The test was done in accordance with the ASTM C109 [3]. The reported results were the averages of three samples. The mix proportions of mortar are given in Table 1.

2.4 Porosity tests

The ϕ 100 × 200 mm cylinders were prepared in accordance with ASTM C39 [4]. They were tested at the age of 7, 28 and 90 days. After being cured in water, they were cut into 50 mm in thick slices with the 50 mm ends discarded. They were dried at 100 ± 5 °C until constant weight were achieved and were then placed in desiccators under vacumm for 3 hours. The set-up was finally filled with de-aired, distilled water to measure the porosity of the mortar. The porosity was calculated using Equation (1).

$$p(\%) = \frac{(Wa - Wd)}{(Wa - Ww)} \times 100 \qquad (1)$$

Where *p* (%) is vacuum saturated porosity (%), *Wa* is the weight of specimen in the air at saturated condition (g), *Wd* is the dry weight of the specimen after 24 hours in oven at 100 ± 5 °C (g), and *Ww* is the weight of the specimen in water (g). This method was used to measure the porosity of the cement-based materials successfully [1].

Table 1 Mortar mix proportions

Mix No.	Symbol	OPC	POA	RHA	SP (%)
1	OPC	100	-	-	1.9
2	20POA	80	20	-	0.4
3	20RHA	80	-	20	2.2
4	40POA	60	40	-	0.1
5	40RHA	60	-	40	3.7

3. Results and discussions

3.1 Characteristics of OPC, POA and RHA

The fineness characteristics of Portland cement and pozzolanic materials are given in Table 2. The Blaine fineness of OPC was 3,600 cm^2/g. The finenesses of the RHA and POA were 11,200 and 11,800 cm^2/g, respectively. The specific gravities of the OPC, RHA and POA were 3.14, 2.23 and 2.25, respectively. The mean particle sizes of these were as follows: POA 7.9 µm, RHA 10.0 µm and OPC 15 µm (Fig. 1). The chemical constituents are given in Table 3. The main chemical composition of POA was 63.6% SiO_2, 7.6% CaO and 6.9% K_2O. The high CaO and K_2O were most likely from lime and fertilizer. The loss on ignition (LOI) was 9.6% which was not too high, indicating a reasonable burning temperature and time. The sum of SiO_2, Al_2O_3 and Fe_2O_3 was 66.6% which was slightly less than 70% as required for natural pozzolan according to ASTM C618 [5]. RHA, on the other hand, consisted mainly of SiO_2 and the other components were not significant. The SiO_2 content of 93% satisfied ASTM C618 [5] requirement as a natural pozzolan and 3.7% LOI indicates complete burning.

The X-ray diffraction (XRD) patterns of POA and RHA are shown in Fig 2. The XRD pattern confirmed that POA and RHA were mainly amorphous silica (Fig 2). The scanning electron microscope (SEM) of POA and RHA are shown in Fig 3. After being ground, the SEM photo revealed that the POA and RHA ash consisted of very irregular-shaped particles with a porous cellular surface (Fig. 3).

Table 2 Physical properties of materials

Sample	Median particle size (μm)	Retained on a sieve No. 325 (%)	Specific gravity (g/cm^3)	Blaine fineness (cm^2/g)
OPC	15.0	-	3.14	3,600
POA	7.9	1-3	2.25	11,800
RHA	10.0	1-3	2.23	11,200

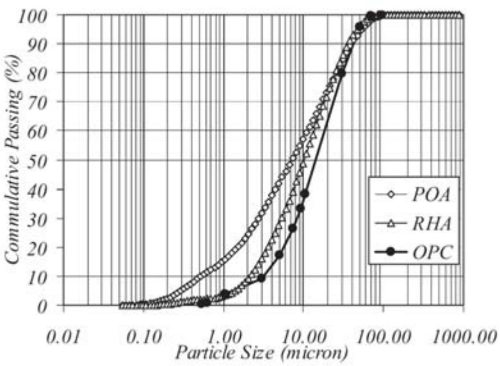


Fig. 1 Particle size of OPC, RHA and POA

Table 3 Oxides of OPC, RHA and POA

Oxides (%)	OPC	RHA	POA
SiO_2	21.0	93.0	63.6
Al_2O_3	4.7	0.5	1.5
Fe_2O_3	3.3	0.2	1.5
CaO	65.5	1.1	7.6
MgO	1.3	0.1	3.9
Na_2O	0.2	0.1	0.1
K_2O	0.4	1.3	6.9
SO_3	2.7	0.9	0.2
LOI	0.9	3.7	9.6
$SiO_2 + Al_2O_3 + Fe_2O_3$	-	93.7	66.6

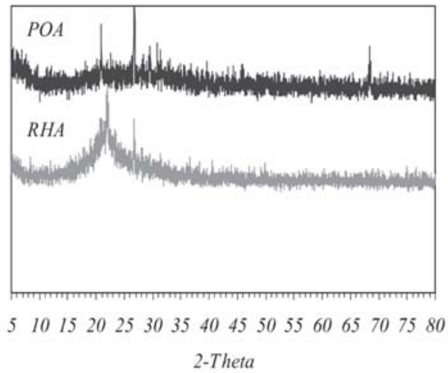
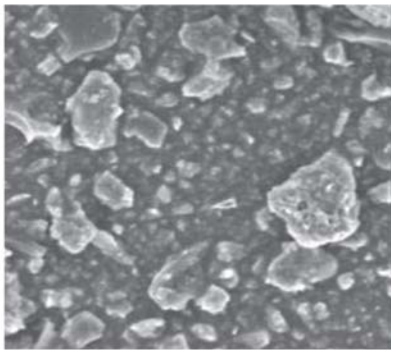
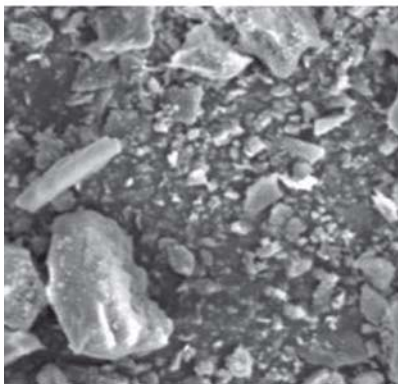


Fig. 2 XRD analysis of RHA and POA



(a)



(b)

Fig. 3 SEM of (a) POA and (b) RHA

3.2 Results of compressive strength

The compressive strength and normalized of mortars are given in Fig. 4 and 5. The strength development of OPC mortar was rather good. The 7, 28 and 90 day strengths are 46.5, 59.5 and 61.8 MPa, respectively (Fig. 4). At replacement dosage of 20%, the strengths of mortar containing POA and RHA were also high between 100-104% of those of OPC mortar at the same age (Fig. 5). For higher replacement level of 40%, reductions in strength at 7 days are apparent for mixes containing POA and RHA.

The 7 day strengths were 76-78% of that of OPC mortar at the same age. At the age of 90 days, strengths of POA and RHA mortar were 102-104% of that of OPC mortar at the same age (Fig. 5). The low early strengths and later age strength development was the common feature of pozzolanic materials [1, 2]. The fineness of pozzolans yielded a greater pozzolanic reaction and the small particles could also fill in the voids of mortar mixture, thus increasing the compressive strength of mortar [6].

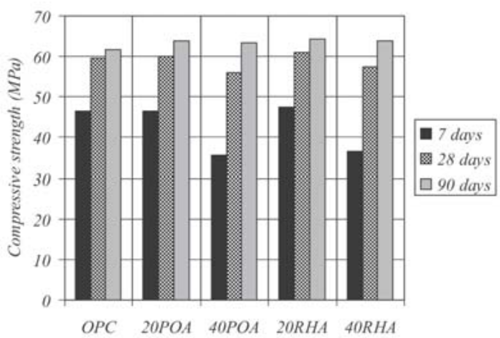


Fig. 4 Compressive strength (MPa)

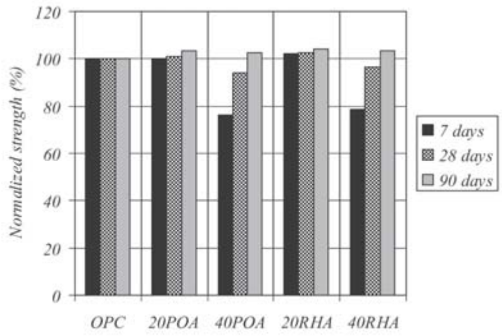


Fig. 5 Normalized strength (%)

3.3 Porosity results

The results of the porosity of mortars at 7, 28 and 90 days are shown in Fig. 6. At the age of 7 days, the porosities of mortar containing 20% of RHA and POA were lower than that of the control at all ages. The addition of fine particles of pozzolans caused segmentation of large pores and increased nucleation sites for precipitation of hydration products in cement paste [1, 7]. This resulted in pore refinement and a reduction of calcium hydroxide in paste. At high replacement level of 40%, the porosities of the mortars containing pozzolans increased in comparison with that of the control. The increases in porosity with a relative large amount of pozzolans resulted from the reduced amount of OPC. This resulted in less hydration products especially at the early age where the pozzolanic reaction was small. It should be pointed out here that although the porosity increased, the beneficial effect of pore refinement as a result of the incorporation of pozzolan existed [1].

The porosities of the mortars reduce with an increase in age as expected. This is due to the increase in the hydration of cementitious materials. At the later age of 90 days, the porosities of the mortars containing pozzolans decreased to similar values to that of OPC mortar.

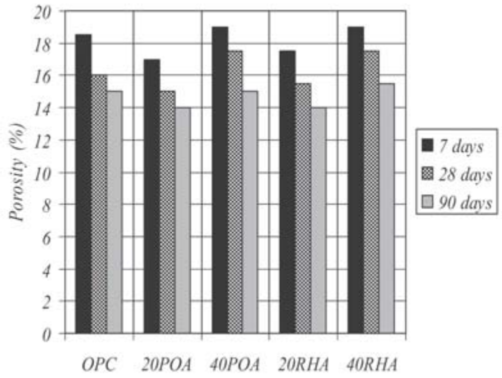


Fig. 6 Porosity of mortars (%)

4. Conclusions

The strengths of the mortar containing RHA and POA were relatively high. The strengths of mortar containing up to 20% of these pozzolans were higher than those of the OPC mortar. The use of blend of RHA and POA also produced mortars with relatively good strength. The increases in porosity with a relative large amount of pozzolans resulted from the reduced amount of OPC. The porosities of the mortars decreased with an increase in age as expected.

The results encourage the use of POA and RHA from agricultural by-products, as a pozzolanic material for cement replacement in concrete, which reduce the cost of cement, environmental effects, and the landfill area required for disposed of waste ash.

5. Acknowledgements

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