オイルパーム廃棄物の灰の電子顕微鏡写真及び性質に関する研究
(Properties and Scanning Electron Micrographs of Ashes From Oil Palm Wastes)

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Introduction: The oil palm wastes and oil palm by-products produced in significant quantities in the tropical region, especially, in Malaysia. It is estimated that nearly 45 million tones of biomass from oil palm wastes produced in the south Asia where 14.4 million tons are in Malaysia, only. The oil palm fruit bunch, palm husk fiber and shells are shown in **Fig.1**. and **Fig.2**. Currently around two hundred oil palm mills are in operation in Malaysia where palm fibers and palm kernel shells are being used as boiler fuel to produce steam for electricity generation and oil palm extraction process because of its good burning temperature (400-600^{o}C). The use of this fuel generates a huge volume of ash which is known as ashes from oil palm wastes (AFOPW). Disposal of these ashes not only created environmental problems but also gave no commercial return from these disposals. In order to solve the environmental problem and to reduce the amount of disposing materials, it is an urgent need today to develop a new technology that facilitates to reuse AFOPW. In view of these objectives, in this paper, an attempt is made to perform the physical, chemical and SEM analyses on several samples of AFOPW for their possible pozzolanic properties and partial cement replacement in concrete construction.

Fig.1 Oil palm fruit bunch

Fig.2 Oil palm husk and shell

Preparation of AFOPW: This ash (**Fig.3**), as mentioned earlier is the product of burning oil palm husk and palm kernel shell in the oil palm mill boiler. In the present study, ash was collected from APL Sunabra Palm Oil Mill, Jalan Bruras Batu 19 12400 Aytawar, Perak, Malaysia. After collection, the ash was sieved through 75-250μm sieve to remove any foreign material and bigger sized ash particles. The ashes were then grinded in a LosAngeles Abrasion Machine using steel bars (12 mm diameter and 800 mm long) instead of balls in it. A flow-chart for the production of AFOPW is shown in **Fig.4**.

Cement: Any type of cement can be used for comparing the engineering properties of Pozzolanic materials. Ordinary Portland cement (OPC), Type I, which is the most common for construction works and also available widely in the local market, is used in this investigation.

Results and discussion: Typical scanning electron micrographs (SEM) of OPC of Type I and AFOPW are shown in **Fig.5** and **Fig.6**, respectively. The SEM image given in **Fig.6** is for the ash that was obtained after burning the oil palm husk and palm kernel shell then sieved through 250μm and grinded it. In bulk, AFOPW is grayish in color that becomes darker with increasing proportions of unburned carbon. However, it is much finer than OPC and its density is about 2.2 g/cm^3. The particles have a wider range of sizes but, in general, they are relatively spherical as compared to OPC.

Fig. 3 Collection of ash after burning

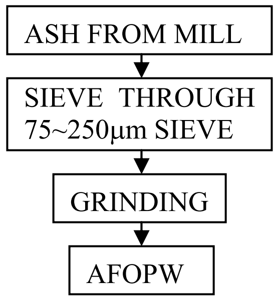

Fig.4 Preparation of AFOPW

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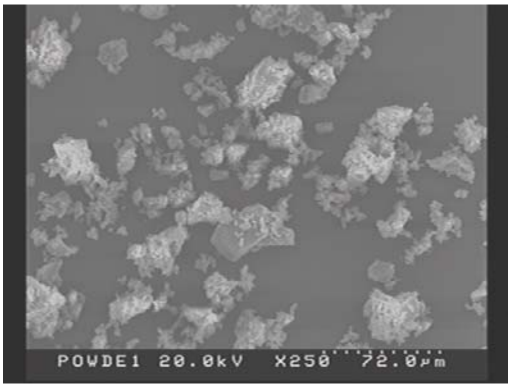

Fig.5 SEM image of OPC

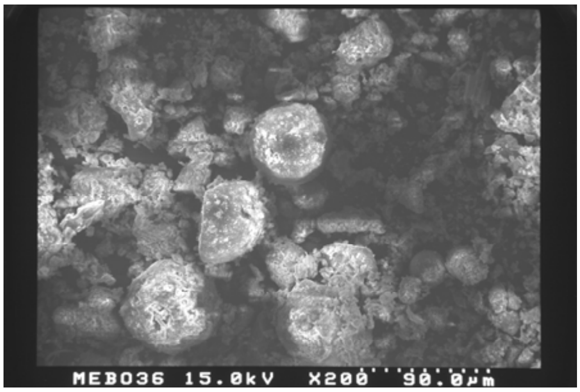

Fig.6 SEM image of AFOPW

Physical and chemical analyses: The physical and chemical analyses, illustrated in **Table 1** and **2**, respectively, revealed that AFOPW satisfies the requirements to be pozzolanic material and may be classified in between Class C and Class F according to the standard specified in ASTMC6 I 8-94a.

Setting Time: One of the most important properties of cementing materials is setting time that influences the fresh and hardened state properties of concrete. The setting time of concrete with 0% AFOPW (100%OPC) as well as of OPC with AFOPW at various replacement levels, measured in accordance with ASTM C 191-92, is shown in **Fig.7**. As can be seen in **Fig.7** that the inclusion of AFOPW in cement paste retards the setting time; the higher the amount of ash more was the retarding time. This is obvious, because when the ash content is high, less is the amount of cement that results in slower setting time. Test result on setting time also reveals that setting time of cement with 60% ash is within the limit as specified in ASTM C 150-94. However, the slight retarding effect with higher amount of ash is advantageous to concreting in hot weather condition during the day time in Malaysia and in other tropical countries as well as during summer in Japan and other developed countries.

Table 1 Physical property of OPC and AFOPW

Physical Properties	OPC	AFOPW
Fineness - Sp. surface area (m^2/kg)	315.00	520.00
Soundness - LeChatelier method (mm)	1.00	1.00
Specific gravity	3.29	2.24

Table 2 Chemical analysis of OPC and AFOPW

Chemical Analysis (%)	OPC	AFOPW
Silicon dioxide (SiO_2)	20.43	45.60
Aluminium Oxide(Al_2O_3)	5.70	11.80
Ferric Oxide(Fe_2O_3)	3.00	4.90
Calcium Oxide (CaO)	62.50	8.70
Magnesium Oxide (MgO)	2.60	5.80
Sulphur Trioxide (SO_3)	2.04	2.90
Sodium Oxide(Na_2O)	0.16	0.30
Potassium Oxide(K_2O)	0.87	3.00
Loss of Ignition (LOI)	2.70	17.00
28-day Strength Activity Index with OPC	--	112.00

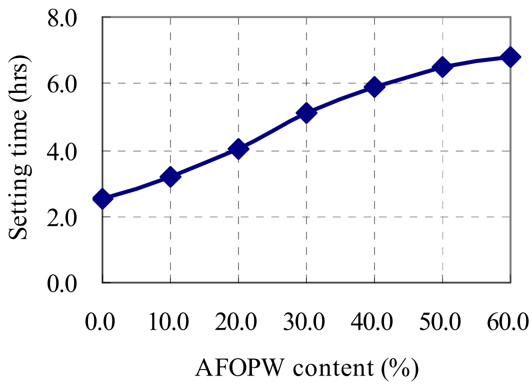

Fig.7 Setting time of fresh concrete

Conclusions: With the increasing construction activities in Southeast Asia, there has been a constant rise in demand for cement. However, in many countries its production has not matched the demand. Time has come for the cement industry to make a breakthrough and to look into new types of cement utilizing readily available waste materials with much more diversified functions and better performance. The results obtained in this study suggest that the inherent properties of AFOPW have resulted in significant Pozzolanic characteristics including enhancement of physical, chemical and setting time. Total percentage of silicon oxide, aluminium oxide and ferric oxide of POFA showed that it is 62.5% which fulfills the requirement of Pozzolanic material according to the standard specified in ASTMC6 I 8-94a. Considering other oxides contents of AFOPW, it can be classified in between Class C and Class F. It is also observed that inclusion of AFOPW in cement paste retards the setting time which is advantageous to concreting in hot weather condition.