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Compressive strength and chloride resistance of grout containing ground palm oil fuel ash

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ABSTRACT

This study investigates the compressive strength of grout and how the filler effect of ground palm oil fuel ash (POFA) contributes to its strength. POFA derived from the palm oil fruit bunches (POFA–FB) and also from the kernels (POFA–K) were ground to two different particle sizes and used to replace Type I Portland cement at 0–40% by weight of binder to cast the grout samples. The compressive strengths of ground POFA grouts were determined at various ages between 7 and 60 days. The results showed that the compressive strength of grout reinforced with POFA–K was much more noticeable as compared to that of POFA–FB. It is also reported that small particles of ground POFA promoted a filler effect that helped to increase the compressive strength of grouts. In contrast, larger particles of ground POFA decrease the value of compressive strength due to the development of more voids in the microstructure. Also, the inclusion of the ground POFA has reduced the charge passed of grout indicating its capacity as chloride resistance agent.

1. Introduction

Malaysia is currently the world's largest producer and exporter of palm oil. Malaysia produces about 47% of the world's supply of palm oil (Sumathi et al., 2008). They forecasted that in years to come, the demand for palm oil production will be higher in Malaysia with the increasing demand of world total oils and fats. Table 1 shows the projected production of palm oil for the year 2000–2020 in MnT for the two major world palm oil contributors. Malaysia produces about 10% of the global oils utilizing 4 million ha of land, which corresponds to 1.84% of the world's total 219 million ha of oilseeds. Due to their availability in Malaysia, palm oil residues are considered to be the most abundant biomass and the best options for alternatives recycling materials. Malaysia produces about 47% of the world's palm oil supply and can be considered as one of the world's largest producers and exporters of palm oil. Due to the intensive planting and mill operations, Malaysia generates huge quantity of oil palm biomass including oil palm trunks, oil palm fronds, empty fruit bunches (EFB), shells and fibers as residues from harvesting and processing activities. Every year, palm oil industry produces roughly about 17.08 Tg of EFB, 12.9 84 Tg of frond, 8.2 Tg of trunk, 9.66 Tg of mesocarp fiber and 5.3 Tg of kernel shell (Mohammed et al., 2011; Sabil et al., 2013; Shuit et al., 2009).

However, such endeavor comes with a price of palm oil wastes management. This is because after processing and extraction of oil, solid residues and liquid wastes will be generated from the fresh fruit bunches and resulted in varying by-product including empty fruit bunches fiber, shell, and effluent. As a result, air, river, sea and groundwater pollutions have increased in recent years due to the large amount of waste produced (Malaysian Palm Oil Board, 2014). Therefore, prevention should be taken to manage the agriculture by-products for sustainable future. In order to avoid environmental pollution, the by-products have to be reused and recycled for other purposes.

2. Potential uses of palm oil waste residues

The main products produced by the palm oil mills are crude palm oil and palm kernels. However, it also produces huge quantities of residues such as the mesocarp fiber, kernel shell and empty fruit bunches (EFB) as shown in Fig. 1. Dry residues from oil palm wastes can be utilized to produce various types of products. EFB was used to produce paper in a study by the Malaysian Palm Oil Board (MPOB) employing the total chlorine-free method (Poster, 2006). Paper and pulp products obtained by the processed oil palm wastes can be reused in different ways namely in the

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Table 1
Present and forecasted palm oil production for the year 2000–2020 in MnT (Mohammed et al., 2011).

Year	Malaysia	Indonesia	World total
Annual production			
2000	10,100 (49.3%)	6700 (32.7%)	20,495
2001	10,700 (48.1%)	7720 (34.7%)	22,253
2002	10,980 (48.4%)	7815 (34.5%)	22,682
2003	11,050 (47.7%)	8000 (34.6%)	23,149
2004	10,900 (45.6%)	8700 (36.4%)	23,901
2005	11,700 (45.6%)	9400 (36.6%)	25,666
Five-year averages			
1996–2000	9022 (50.3%)	5445 (30.4%)	17,932
2001–2005	11,066 (47.0%)	8327 (35.4%)	23,530
2006–2010	12,700 (43.4%)	11,400 (39.0%)	29,210
2011–2015	14,100 (40.2%)	14,800 (42.2%)	35,064
2016–2020	15,400 (37.7%)	18,000 (44.1%)	40,800

production of cigarette paper and bond paper for writing (Bernama, 2001). On the other hand, the shells of oil palm fruits are normally used to cover the surface of the roads in the plantation area (Alengaram et al., 2013; Shafigh et al., 2011, 2014; Yusoff, 2006).

Also, the EFB and palm fibers can be utilized to manufacture medium density fiber-boards (MDF) and blackboards (Husin et al., 2005). At present, Malaysia is the world's third largest exporter of MDF after Germany and France with a total export amounting to RM1.2 billion in 2008. Moreover, numerous studies employing the usage of palm oil EFB have been conducted by researchers (Ahmad et al., 2010, 2012; Al-Oqla and Sapuan, 2014; Bateni et al., 2011; Chauhan et al., 2008; Hejazi et al., 2012; Mujah et al., 2013; Park, 2009, 2011) denoting the suitability of such waste to be reused as reinforcing agent towards problematic soils. It can be concluded that EFB is effective in soil reinforcement based on the fact that it increases the soil shear strength parameters around 25%–35% (Ahmad et al., 2010).

Furthermore, it was reported that the palm oil shells can be used as fillers as substitute for aggregates in concrete mix due to their lightweight (Alengaram et al., 2013; Gungat et al., 2013; Kupaei et al., 2013; Lim et al., 2013; Shafigh et al., 2011; Teo et al., 2007) and their ability to withstand high heat treatment (Yew et al., 2014) properties. Shafigh et al. (2013, 2012) studied the engineering properties in terms of the tensile and the compressive strengths of palm oil shell lightweight concrete containing fly ash. Their results showed that palm oil shell concretes containing up to 50% fly ash are suitable for use as structural concrete elements. However, the 28-day compressive strength of the palm oil shell concrete was found to be 38%, 28% and 17% lower than that of granite concrete respectively.

Muntohar and Rahman (2014) presented the use of palm oil kernel shell waste as masonry block material and found that the maximum strength was obtained by mixing proportion of 1 cement: 1 sand: 1 palm oil kernel shell with the maximum strength of 22 MPa. Jumaat et al. (2009) studied the shear strength of palm oil kernel shell foamed in concrete beams. They predicted that the beams that contained shear links failed in flexure mode while those without links failed in shear mode. Their experimental results indicated that the shear capacities of the palm oil kernel shell foamed concrete beams without shear links are higher than those of the normal weight concrete beams. The shear strength of the beam reinforced with palm oil kernel shell was found to be 10% higher than the normal weight concrete beam.

3. Palm oil fuel ash (POFA)

POFA is derived from the by-product of the palm oil waste residues which were incinerated in a thermal power plant. It contains

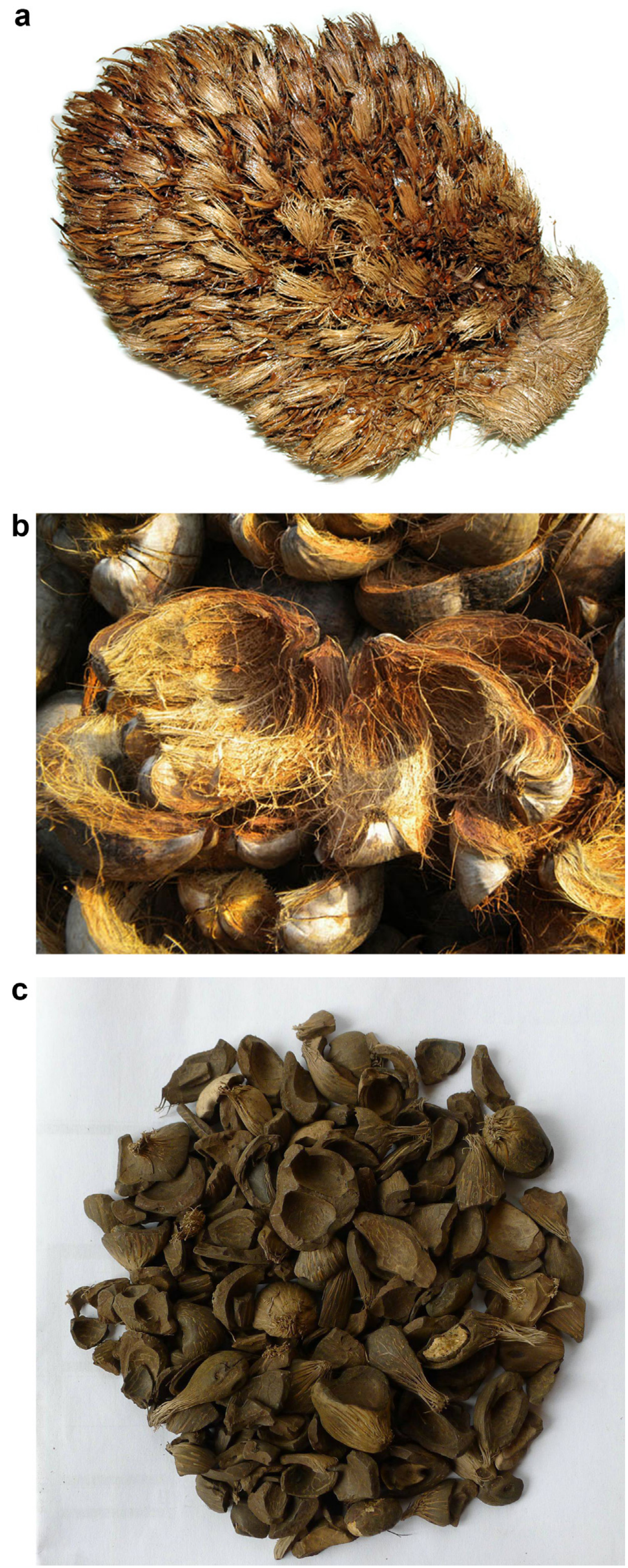

Fig. 1. Palm oil by-products. a: Fruit bunches; b: Fibers; c: Kernel shells.