ISSN : 1412-9612

44

RAPI KE 10 2011

FT UMS

PROSIDING

TEKNIK SIPIL

SIMPOSIUM NASIONAL KE-10

REKAYASA APLIKASI PERANCANGAN DAN INDUSTRI

TEMA

PERAN SAINS DAN TEKNOLOGI DALAM MEMBENTUK KARAKTER BANGSA YANG MANDIRI

Surakarta, 13 Desember 2011

FAKULTAS TEKNIK
UNIVERSITAS MUHAMMADIYAH SURAKARTA

THE COMPRESSIVE STRENGTH CHARACTERISTICS OF THE MASONRY BLOCK FROM THE OIL PALM SHELL

Agus Setyo Muntohar[1)], Muhammad Ekhlasur Rahman[2)]
1) Department of Civil Engineering, Universitas Muhammadiyah Yogyakarta
Jl. Lingkar Selatan, Taman Tirto, Yogyakarta
2) Department of Civil and Construction Engineering, Curtin University
Sarawak campus, Malaysia
E-mail: muntohar@umy.ac.id

Abstract

Indonesia and Malaysia is the two largest producer of palm oil. However, one significant problem in the processing of palm oil is the large amounts of waste produced and this is one of the main contributors to the nation's pollution problem. This paper presents the investigation of the use of oil palm shell waste as masonry block materials. The study was focused on the compressive strength and the durability. The masonry block was made by mixing the portland cement, sand, and oil palm shell waste. The specimen size was 220 mm in length x 110 mm in width x 80 mm thickness. The test results showed that the maximum strength was obtained by mixing proportion of 1 PC : 1 sand : 1 OPS. Addition a large amount of OPS was lowering the compressive strength. Overall results indicated that the shellcrete complied the specification standard for lightweight to medium concrete building brick which was suitable for load bearing purposes.

Keywords: shellcrete; oil palm shell; masonry; low cost building

Introduction

Indonesia and Malaysia, being the world's largest producer and exporter of palm oil, are well known for its palm oil industry. However on the other side, problem was rising after the production process that is the large amounts of waste produced and this is one of the main contributors to the nation's pollution problem. UN ESCAP (2007) reported that the oil palm residues in Indonesia, Malaysia, and Thailand contributed the huge volume among the ASEAN countries. The residues were approximately 45 and 50 millions tones respectively in Malaysia and Indonesia. Therefore, efforts have to be done to manage the agriculture by-product for sustainable development. At the mills, when the fresh fruit bunches (FFB) was processed and oil extraction takes place, solid residues and liquid wastes are generated. These by-products include empty fruit bunches, fiber, shell, and effluent. As the "zero waste policy" to increase the quality of environment, those by-product have been reused and recycled for other purposes e.g. the empty fruit fiber as fuel, and the ash as fertilizer. But, the oil palm shell waste (OPS) has not well managed and they were just dumped near the mills (Figure 1). The OPS was also known as palm kernell shell (PKS) was basically potential by-product for construction materials.

In developed countries, sustaining housing development especially to the medium/low-

Figure 1 Oil palm shell dump at oil palm mill

income group of the society has become a huge challenge particularly because of the huge capital outlay required to do so. Furthermore, utilization of industrial waste and by-product materials in infrastructure development is proven economically viable when environmental factors are considered and these materials meet appropriate performance specifications and standards (Kinuthia and Nidzam, 2011). Attempts have been carried out to use the oil palm shell as aggregate in concrete (Okafor, 1988; Okpala, 1990; Basri et al., 1999; Mannan and Ganapathy, 2004, Olanipekun et al., 2006; Teo et al., 2007; Shafigh et al., 2011). The research findings have brought immense change in the development of building structures using lightweight concrete (LWC). The shell is hard and does not easily suffer deterioration. The Los Angeles abrasion value of the OPS was about 4.8%. The aggregate impact value and aggregate crushing value of OPS aggregates were much lower compared to conventional crushed stone aggregate. The water absorption capacity range of 21 - 33% subjected to 24 hours of submersion. This value implies that the OPS have high water absorption compared to conventional gravel aggregates that usually have water absorption of less than 2% (Okpala, 1990; Shafigh et al., 2011).

Currently, the investigation is directed towards the potential use of oil palm shell (OPS) for the production of masonry block, later on called as “shellcrete”. The OPS was used to replace the amount of sand fraction in the common sandcrete masonry block. The research focuses on the compressive strength of the shellcrete. The expected outcome of this research is to produce a low cost residential building.

Research Methods

Materials Used

The cement used was CMS ordinary Portland cement (OPC), having specific gravity of 3.14. Its Blaine specific surface area was 3510 cm^2/g. The OPC contains of 63% CaO, 20% SiO_2, 5.2% Al_2O_3, 3.3% Fe_2O_3, 2.4% SO_3, and 2.5% loss of ignition (LOI). The OPC conforms to ASTM C150 Type I OPC. Local river sand with a fineness modulus of 1.32, specific gravity of 2.64, water absorption of 1.1% was used as the fine aggregate. OPS were used as the coarse aggregate. They were collected from a local crude palm oil producing mill, and comprised old discarded waste at the palm oil mill area, having fineness modulus of 5.78, specific gravity of 1.19, water absorption of 20%. The OPS have fibers up to 40% on the shell surface. The OPS were sieved, and OPS aggregate passing through the 9.5 mm and retained on 4.75 mm sieve were used in this research (Figure 2). The grain size distribution of sand is illustrated in Figure 3.

Figure 2 The OPS used in this research

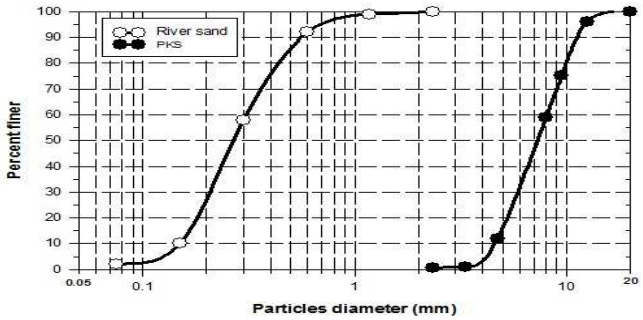


Figure 3 The particles size distribution of the sand and PKS

Figure 4 The compacted specimens of control and shellcrete

Specimen preparation and tests

In this research, the size of shellcrete was made of 200 mm x 100 mm x 80 mm. The ratio of cement, sand and OPS was designed as 1:1:1, 1:1.5:1.5, 1:1:2, and 1:1:3 by the volume ratio. The control specimens were made from 1:3 of cement and sand ratio. The cement and water ratio was adjusted accordingly about 0.3 to 0.6 to obtain a good workability. Before the OPS were used, they were soaked in water, and subsequently air dried in the laboratory to obtain approximately a saturated surface dry condition. The shellcrete was prepared by three steps. First, an amount of sand and cement was mixed and stirred in the mechanical mixer to obtain a homogenous mixture. Second, an amount of OPS were added in the mixer. The mixing continued and followed by addition of water till the mixture was homogenous. Duration of the mixing was about 10 to 15 minutes. The mixtures were placed in the mold and tampered manually by hand compaction. The specimens were dismantled from the mold and then placed on humidity control and cured for 28 days (Figure 4). After this curing period, the specimen was subjected to water absorption and compressive strength tests.

Water absorption test was conducted to the specimen after 28 days of curing. The specimen was immersed to water for 24 hours. Before immersed, the weight and specimen size were measured. The amount of absorbed water was calculated by Equation (1). The procedure was modified from ASTM standard C140 (2011).

$$w_{24} = \left(\frac{m_s - m_d}{m_d} \right) \times 100\% \qquad (1)$$

where, w_{24} = the absorbed water after 24 hours of immersion (%); m_s = mass of specimen after immersion (g); and m_d = mass of specimen before immersion (g).

Compressive strength test was performed to the dry and wet specimens. The wet specimen refers to the specimen was tested after the 24 hour of immersion, while the dry specimen is the air cured after 28 days. Capping was made on surface of the specimens to obtain a uniform loading distribution. The entire specimen was tested on the universal testing machine. The loading rate was adjusted to 1 kN per minute. The vertical force was applied to the specimen gradually until reach a failure. The maximum force was recorded to calculate the compressive strength by dividing the contact area.

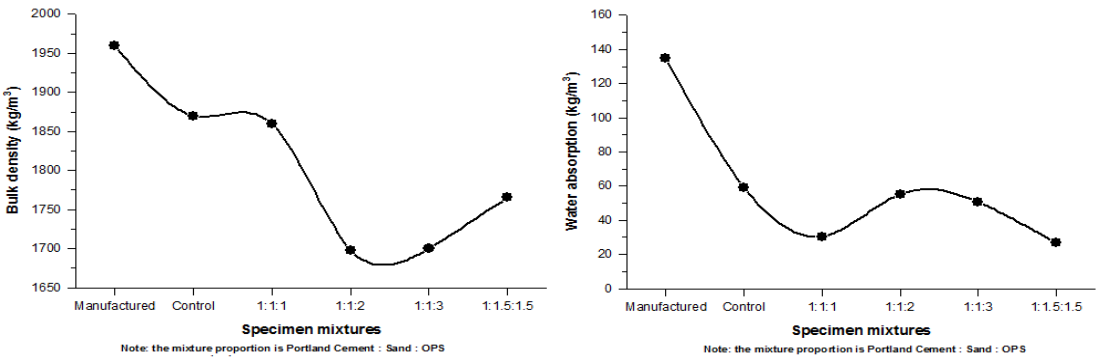
Results and Discussion

Bulk density

Density is the parameter to classify a lightweight building material. Figure 5a shows the variation of bulk density of the various mixture proportion of shellcrete. The density of a commercially concrete brick was also presented in Figure 5a for comparison. Replacing the sand fraction with OPS decreased the bulk density. The OPS had a low density among the mixing materials. As the consequence, the increasing of the OPS in the mixture will result in a low bulk density of the shellcrete. The ASTM standard C55 (2011) classified the lightweight concrete building brick if the dry density is lesser than 1680 kg/m^3, while medium weight is 1680-2000 kg/m^3, and normal weight is greater than 2000 kg/m^3. All specimens with the OPS replacement have densities of lesser 2000 kg/m^3 which is a requirement for lightweight concrete. Density is defined as the measure of how much particles of an element or material is squeezed into a given space. The more closely packed the particles, the higher the density of the material (Baiden and Asante, 2004).

Water absorption

The standard specification for concrete building brick or block requires the maximum water absorption. The maximum water absorption required for lightweight concrete building block is 320 kg/m^3 (ASTM Standard C55, 2011). Water absorption is defined as the transport of liquids in porous solids caused by surface tension acting to the capillaries. Figure 5b shows the water absorption of each shellcrete samples with different mixture proportion. The results revealed that all shellcrete specimens had lower water absorption if compared to the control and manufactured specimen. The mixture of 1 PC : 1 sand : 1 OPS had the lowest water absorption. The increases in OPS content in the mixtures tend to increase the water absorption of shellcrete. The possible reason of the increasing of water absorption is the existence of micropores on the shell surface (Alengaram et al., 2011). Okpala (1990) reported that the OPS had porosity about 37%. However, all shellcrete mixtures complies the specification for lightweight concrete building brick.



(a) (b)

Figure 6 (a) the bulk density, (b) the water absorption of the shellcrete with various mixtures

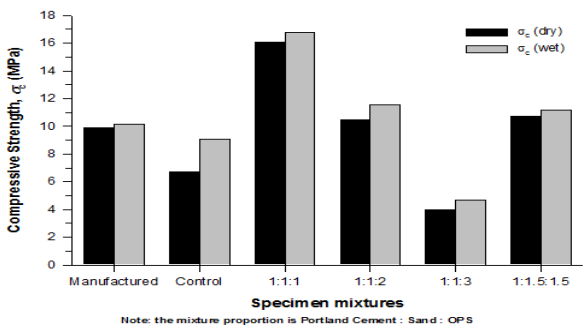


Figure 5 The variation of the compressive strength of the shellcrete

Compressive strength

The compressive strength of the shellcrete and the control specimens are shown in Figure 6. The results illustrated that compressive strength of shellcrete mixtures were higher than the control specimen excluding the mixture of 1 PC : 1 sand : 3 OPS. The maximum strength was obtained by mixing proportion of 1 PC : 1 sand : 1 OPS. Addition a large amount of OPS was lowering the compressive strength. The low compressive strength of shellcrete was attributable by a larger void of the block. The smooth skin and convex surface of the OPS contributed to the low compressive strength, since the bonding between the OPS reduced. Several researchers reported a poor bond between the PKS and the cement matrix that resulted in bond failure (Okafor, 1988; Okpala, 2002; Mannan and Ganapathy, 2002; Mannan and Ganapathy, 2004). The results in Figure 6 also show that the wet specimens produced the higher compressive strength. On the contrary, air-dry curing produced a lower level of compressive strength. This result is in agreement with study carried out by Ling and Teo (2011). The curing in full water immersion contributed to sufficient moisture and suitable vapor pressure, which were maintained to continue the hydration of cement. This process produced a higher strength.

The Indonesian standard SNI 03-0349 (1989) classified the concrete building block into four categories of compressive strength. The shellcrete mixtures of 1 PC : 1 sand : 1 OPS, and 1 PC : 1 sand : 2 OPS meets the requirement of class B2 for masonry block which the minimum compressive strength is 9 MPa. Meanwhile, the shellcrete mixture of 1 PC : 1 sand : 3 OPS meets the requirement of class A2 for masonry block which the minimum compressive strength is 4 MPa. The materials were suitable to produce a low cost residential building. Comparing the result with the Malaysian Standard, it can be observed that all shellcrete samples achieved the compressive strength more than the required strength as required by the MS 76 (1972) Class 1 for load bearing purposes which the minimum compressive strength is 5 MPa. In exceptional, the shellcrete mixtures of 1 PC : 1 sand : 1 OPS meets the requirement of class 2 for load bearing proposes.

Conclusions

Based on the results obtained in this investigation the following conclusions can be drawn:

1. The shellcrete mixtures of 1 PC : 1 sand : 1 OPS produced a high performance properties for lightweight concrete building brick.
2. The shellcrete mixtures of 1 PC : 1 sand : 1 OPS and 1 PC : 1 sand : 2 OPS meets the requirement of class B2 for masonry block. Meanwhile, the shellcrete mixture of 1 PC : 1 sand : 3 OPS meets the requirement of class A2 in compliance with Indonesian standard SNI 03-0349-1989. Furthermore, all shellcrete mixtures achieved the compressive strength more than the required strength as required by the Malaysian Standard MS 76: 1972 Class 1 and 2 for load bearing purposes.

Acknowledgement

The first author thanks to the Dean School of Engineering and Science, Curtin University for the opportunity to serve as Senior Lecturer at Department of Applied Geology and Department Civil and Construction Engineering during the year 2011. The paper is part of the research grant from the Curtin University, Sarawak campus Malaysia through Curtin Sarawak Research Fund (CSRF) 2011. The authors thank to the Curtin Sarawak Research Institute for the financial support.

References

Alengaram U J., Mahmud H., Jumaat M Z., 2011, Enhancement and prediction of modulus of elasticity of palm kernel shell concrete. *Materials and Design* Vol. 32, pp. 2143–2148

ASTM Standard C140, 2011, Standard test methods for sampling and testing concrete masonry units and related units, ASTM International, West Conshohocken, Pennsylvania, USA.

ASTM Standard C55, 2011, Standard specification for concrete building brick, ASTM International, West Conshohocken, Pennsylvania, USA.

Baiden B K., Asante C K O., 2004, Effect of orientation and compaction method of anufacture on strength properties of sandcrete block. *Construction and Building Materials* Vol. 18, pp. 717-725.

Basri H B., Mannan M A., Zain M.F.M., 1999, Concrete using waste oil palm shells as aggregate, *Cement and Concrete Research* 29, 619–622.

Kinuthia J M., Nidzam R M., 2011, Towards zero industrial waste: Utilisation of brick dust waste in sustainable construction, *Waste Management* Vol. 31, pp. 1867–1878.

Ling I H., Teo D C L., 2011, Properties of EPS RHA lightweight concrete bricks under different curing conditions. *Construction and Building Materials* Vol. 25, pp. 3648–3655

Mannan M A., Ganapathy C., 2002, Engineering properties of concrete with oil palm shell as coarse aggregate, *Construction and Building Materials Vol.* 39, pp. 441 – 448.

Mannan M A., Ganapathy C., 2004, Concrete from an agricultural waste-oil palm shell (OPS), *Building and Environm*ent Vol. 39, pp. 441 – 448.

MS 76, 1972, Specifications for bricks and blocks of fired brick-earth clay or shale: Part 2: Metric units, Department of Standards Malaysia.

Okafor F O., 1988, Palm kernel shell as a lightweight aggregate for concrete. Cement and Concrete Research Vol. 18, pp. 901-910

Okpala D C., 1990, Palm kernel shell as a lightweight aggregate in concrete. *Building and Environment* Vol. 25(4), pp. 291-296

Olanipekun E A., Olusola K O., Ata O., 2006, A comparative study of concrete properties using coconut shell and palm kernel shell as coarse aggregates, *Building and Environment* Vol. 41, 297–301.

Shafigh P., Jumaat M Z., Mahmud H., 2011, Oil palm shell as a lightweight aggregate for production high strength lightweight concrete, *Construction and Building Materials* Vol. 25, 1848–1853.

SNI 03-0349, 1989, Concrete brick for wall system. National Standardization Agency of Indonesia, Jakarta

Teo D C L., Mannan M A., Kurian V J., Ganapathy C., 2007, Lightweight concrete made from oil palm shell (OPS): Structural bond and durability properties, *Building and Environment* Vol. 42, 2614–2621

UN ESCAP, 2007. ESCAP Report: Biomass Increasingly Important in Indonesia and Thailand. E-news Environment and Sustainable Development Vol. 7(2), pp. 5.

Hasil Diskusi

Tanya : Rencana jangka panjang (long term) yang bagaimana dari penelitian ini, dan untuk material apa? Yang memiliki daya serap terhadap air (absorption) tinggi itu OPS (oil palm shell waste)-nya atau shellcrete-nya?

Jawab : Penelitian yang dilakukan masih on going, hasil sementara masih berupa prototype. Penelitian pemanfaatan limbah tempurung kelapa sawit untuk agregat beton ini diharapkan dapat menghasilkan lightweight masonry block (conblok ringan). Ke depannya diharapkan bisa menggandeng kalangan infestor dan industri untuk dapat memproduksi secara masal. Yang memiliki daya serap terhadap air tinggi adalah OPS-nya (individual), sedangkan shellcrete dari hasil campuran 1 PC : 1 sand : 1 OPS absorbsinya lebih rendah dari specimen pembanding hasil manufaktur. Apabila kandungan OPS pada campuran diperbesar, maka absorbsi shellcrete yang dihasilkan cenderung meningkat.