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Effect of water-cement ratios on oil palm shell (OPS) lightweight concrete for ecofriendly construction

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***Abstract*— To produce concrete which is a common construction materials, different types of aggregates are used. Those aggregates comes from the natural resources and artificial resources causing decrease of natural reasourches. Using huge amount of natural reasourches is a bad impact on the eco system. Now a days it is common consideration to use the agricultural waste as construction materials in production of concrete. The country like malaysia in tropical region produces a lot of agricultural waste in oil palm industries. The on going researches on oil palm shell encourage to use it in concrete as aggrigate replacement. The objective of this reasearch is to determine the effect of water/cementratios (w/c) on the mechanical properties of oil palm shell concrete (OPSC). The w/c changes by the changes of cement content in the concrete and all other parameters are fixed on the study. The compressive strength, spliting tensile strength, flexural strength changes are studied due to the changes of water/cement ratios from 0.30 to 0.55. the heighest compressive strength is 47 MPa at 28 day incorporating w/c=0.30. Though, using w/c=0.43 the compressive strength of concrete is 23MPa at 28 days which is the grade of structural lightweight concrete. The w/c ratios have significant effect on the compressive strength, splitting tensile strength and flexural strength of OPSC. However, it can be concluded that the maximum w/c=0.43 can be used to produce the structural lightweight concrete using waste oil palm shell as a coarse aggregate in concrete.**

***Keywords*—OPS, W/C, lightweight, OPSC**

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I. Introduction

Now a days green technology is commonly preferred to reserves natural resources for future generation. For green technology and reserve natural resources agricultural waste are widely used in concrete technology. The development of concrete using waste materials has led to substantial improvements in the concrete performance, environment, construction cost and working conditions. The lightweight concrete however possesses low tensile strength, limited ductility and little resistance to cracking. Those concrete are commonly used in slabs and joists in high rise buildings and bridge decks in highway bridge structures as well as offshore and marine structures. Knowledge on lightweight aggregate (LWA) concrete is inevitable [1] for advantageous construction of such structural elements.

A lightweight aggregate is common to use in production of lightweight concrete and high strength lightweight concrete. Now a day's agricultural waste are used as light weight aggregates are Oil palm shell, palm oil clinker, coconut shell etc. to produce lightweight concrete in green technology. Malaysia is the second largest palm oil producing country in the world and it produces more than half of world's palm oil. In those palm oil factories produces a lot of waste materials in palm oil industries such as oil palm shell, palm oil clinker etc. Contemporary studies have shown that OPS can be used as LWA for producing structural LWC with compressive strength in the range of 17-53.6 MPa which is a range of normal strength to high strength ranges of LWC. Although previous researches have shown that OPS can be successfully used as structural LWC [2-8], the LWC using OPS is still not a common construction material in the construction industry and there has been some reticence concerning its use in concrete structures.

The strength of concrete has been depends on the hydration of cement and bonding between the cement paste and aggregates. In case of attenuation of neutron radiation the presence of hydrogen in concrete radiation shield is important [9]. Hydrogen is containing into water in a large portion. Hence, in case of the effectiveness of concrete shields attenuating neutron, the water content of hardened concrete is very important parameter [10]. The water content of concrete also impacts on the thermal conductivity of concrete and consequently temperature distribution and thermal stresses in the shield [9].

However, the water to cement ratio (W/C) is always used to characterize the concrete mixture. Additionally, the W/C is inversely proportional to the strength of normal weight concrete: the lower W/C, the greater the strength [11]. Also the concrete paste porosity controlled by this ratio [12]. Moreover, the ratio is rarely studied in case of OPS lightweight concrete. Hence, the objective of the work is to investigate the effect of water cement ratio on the strength properties of OPS lightweight concrete for ecofriendly construction.

II. Materials and method

In this study the effect of water to cement ratio on OPS lightweight concrete has been investigated. To carry out the study, waste materials as coarse aggregate replacement was considered. Details of materials used and experimental works are given in the following section.

A. *Cement*

The Ordinary Portland Cement (OPC) was used with a specific gravity of 3.14 g/cm^3 for all the specimens. The class of OPC was type I 42.5 grade OPC cement. The Blaine's specific surface area of the cement was 3510 cm^2/g.

B. *Superplasticizer (SP)*

Sika viscocrete®-2199 as a high range water reducing admixture was used in the study. This admixture is chloride free according to BS 5075 and is compatible with all types of Portland cement including Sulphate Resistant Cement (SRC). The super plasticizer was used as 1.74% of cement weight.

C. *Aggregates*

Local mining sand with a specific gravity, fineness modulus, water absorption and maximum grain size of 2.66, 2.89, 1.17% and 4.75 mm, respectively, was used as fine aggregate. OPS coarse aggregates are considered as a renewable source of aggregate from waste materials. All the aggregate ranges were considered in same size. As in previous researches [3, 13-17] OPS in different shapes were used as the coarse aggregate. The OPS were collected from a local crude palm oil producing mill. Then it is stored in an open train about six months to wash the oil and remove the ash from the shell were reported by Shafigh et al. [17] on the advantages of using old OPS aggregate. Then it was washed and dried, after drying it was crushed with the stone crushing machine in the laboratory. The crushed OPS were sieved with 4.75 mm and 9.5 mm sieve. The particles in between the range of 4.75 mm and 9.5 mm were considered as coarse aggregate. OPS with specific gravity, compacted bulk density and 24 h water absorption of 1.22, 683kg/m^3 and 18.7% respectively, were used as coarse aggregate in a wet condition without free surface water. The measured ranges of shell thickness were 0.45–4.05 mm which is in the ranges shown by Shafigh et al., [18]. Also the chemical composition of OPS waste materials is shown in Table 1.

Table 1 Chemical composition of POC and OPS waste materials[19]

Oxides	SiO_2	K_2O	CaO	P_2O_5	MgO	Fe_2O_3	Al_2O_3	SO_3	Na_2O	Cr_2O_3
OPS	46.61	9.88	14.76	1.95	2.91	10.19	3.33	7.84	1.15	1.38

D. *Mixing proportion*

In actual field condition, trial mixes [20] are customarily used for the mix design of LWC. In this study four mix are considered with water to cement ratios of 0.30, 0.35, 0.43 and 0.55 by reducing the cement content in mixes to evaluate the influence of w/c on the properties of OPS lightweight concrete containing OPS as coarse aggregate. However, all other parameters are considered as constant. The details of the concrete mixes with their properties are presented in Table 2.

Table 2: Mix proportion (kg/m^3) and basic properties of concrete

Mix code	Cement	Water	W/C	OPS	Sand	SP	Slump
P0.30	550.0	165	0.3	333	891	3	57
P0.35	466.7	165	0.3	333	891	3	89
P0.43	383.3	165	0.3	333	891	3	112
P0.55	300.0	165	0.3	333	891	3	150

III. Results and discussion

A. *Fresh property of concrete*

Fig. 1 shows with the increase of water-cement ratio by reducing the cement content in mix reduces the fresh dencity of OPS lightweight concrete. The fresh density of concrete reduced due to the reduction of higher specific gravity materials in concrete as cement. The linear relationship of OPS concrete fresh density with water-cement ratio can be stated by the following equation:

$$\rho = 1433.6\ (W/C) + 2348.2 \qquad (1)$$

where, ρ is fresh density in kg/m^3 and W/C is water-cement ratio in OPS lightweight concrete.

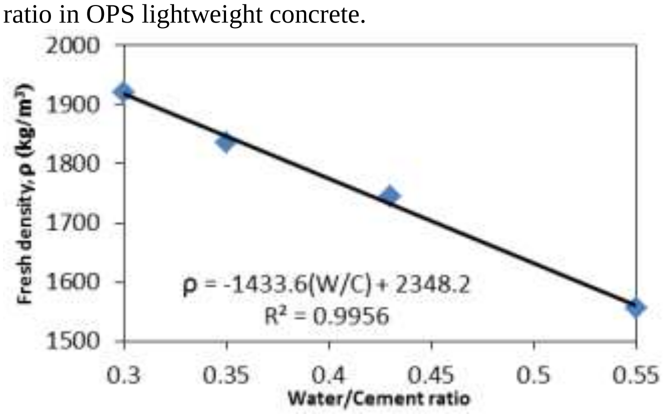

Figure 1: Relationship of fresh dencity with watercement ratio

Hoever in Fig. 2 the relationship of porocity of concrete with the increase of water-cement ratio of OPS lightweight concrete is shown. The porocity increases with the increases of water-cement ratio in fresh concrete due to the reduction of finer cement with the increase of water-cement ratio. The relationship can be shown by the following equation:

$$P = 38.89\ (W/C)^{1.86} \qquad (2)$$

where, P =percentage of porocity in OPS concrete.

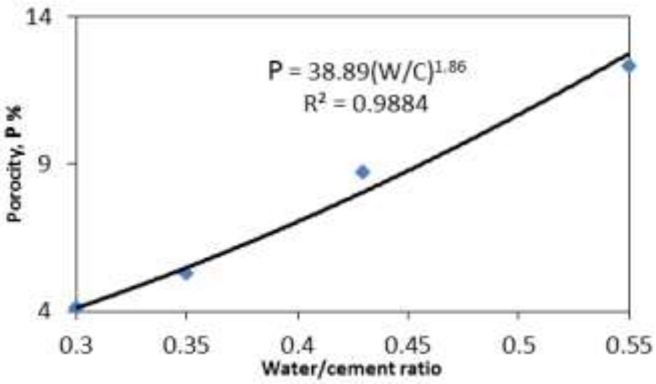

Figure 2: relationship of porocity with water-cement ratio

B. *Compressive strength of concrete*

With the increase of age of concrete the hydration in concrete is generally increases which causes in increase of concrete strength. Fig. 3 stated the relationship of compressive with increasing water-cement ratios at different age of concrete which is similar to the increase of normal weight concrete [21]. The minimum structural lightweight concrete strength is obtained at W/C = 0.43 and lower in case of OPS lightweight concrete.

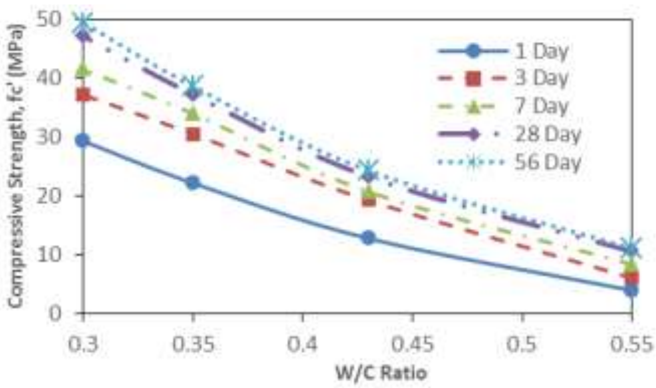

Figure 3: Relationship of compressive strength of concrete with W/C ratio

C. *Splitting tensile strength of concrete*

The minimum 28-day splitting tensile strength requirement for lightweight concrete to be used in structural elements is 2.0 MPa [22]. Generally, the splitting tensile strength/compressive strength ratio of normal weight concrete is 8-14% [23]. The 28-day splitting tensile strength/compressive strength ratio of all mixes varied between 14% and 7.5%. Due to the increase of W/C the percentage is increases. Though, these ratios were within the normal range. However, it should be noted that compared to normal weight concrete, the tensile strength/compressive strength ratio was lower for the lightweight aggregate concrete of equivalent grade [24]. Fig. 4 shows relationship between splitting tensile strength and compressive strength at the age of 28 days. The strong correlation of this relationship shows that Equation 3 can be used for predicting splitting tensile strength from compressive strength with good accuracy.

$f_t = 0.39\,(f_c^{'})^{0.57}$ (3)

where, f_t is splitting tensile strength in MPa and $f_c^{'}$ is cube compressive strength of concrete in MPa.

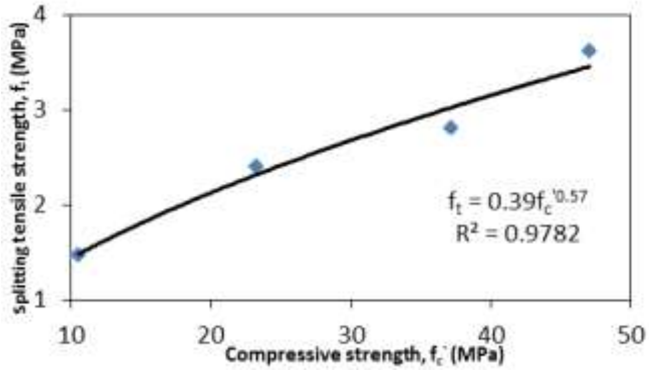

Figure 4: Relationship of splitting tensile strength with compressive strength at different water cement ratio at 28 day concrete

D. *Flexural strength of concrete*

Fig. 5 shows the relationship of flexural strength and compressive strength of OPS lightweight concrete at the age of 28 days. The correlation can be stated by the following equation.

$f_r = 0.18(f_c^{'})^{0.90}$ (4)

where, f_r is flexural strength and $f_c^{'}$ is cube compressive strength of concrete in MPa.

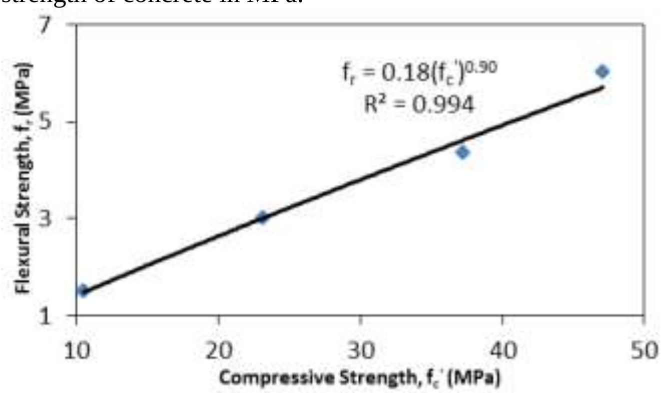

Figure 5: Relationship of flexural strength with compressive strength of OPS concrete

IV. Conclusion

The conclusions are comes from the study is given bellow:

a. The fresh density of oil palm shell lightweight concrete decrease with the increase of water-cement ratios because of reducing the amount of heavy component from the concrete.

b. Though the porosity increase with the increase of water- cement ratio because of the reduction of fine cement particles so void proportions increases in concrete.

c. The water-cement ratio can be used equal or less than 0.43 to produce structural lightweight concrete using oil palm shell as coarse aggregate.

d. Structural lightweight concrete splitting tensile strength achieve at the water-cement ratio equal or less than 0.43

e. A good relationship between splitting tensile strength and compressive strength is observed in a wide range of OPS lightweight concrete grade.

f. Also the flexural strength and compressive strength correlation ship is shown in this study which is applicable in wide range of OPS lightweight concrete.

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References

[1] G. C. Hoff, "High-Strength Lightweight Aggregate Concrete--Current Status and Future Needs," *ACI Special Publication,* vol. 121, 1990.

[2] F. O. Okafor, "An investigation on the use of superplasticizer in palm kernel shell aggregate concrete," *Cement and concrete research,* vol. 21, pp. 551-557, 1991.

[3] H. Basri, M. Mannan, and M. Zain, "Concrete using waste oil palm shells as aggregate," *Cement and concrete research,* vol. 29, pp. 619-622, 1999.

[4] D. C. Teo, M. A. Mannan, and J. V. Kurian, "Flexural behaviour of reinforced lightweight concrete beams made with oil palm shell (OPS)," *Journal of advanced concrete technology,* vol. 4, pp. 459-468, 2006.

[5] D. Teo, M. A. Mannan, V. Kurian, and C. Ganapathy, "Lightweight concrete made from oil palm shell (OPS): Structural bond and durability properties," *Building and environment,* vol. 42, pp. 2614-2621, 2007

[6] B. S. Mohammed, W. Foo, and M. Abdullahi, "Flexural strength of palm oil clinker concrete beams," *Materials & Design,* 2013.

[7] B. S. Mohammed, M. A. Al-Ganad, and M. Abdullahi, "Analytical and experimental studies on composite slabs utilising palm oil clinker concrete," *Construction and Building Materials,* vol. 25, pp. 3550-3560, 2011.

[8] B. S. Mohammed, W. Foo, K. Hossain, and M. Abdullahi, "Shear strength of palm oil clinker concrete beams," *Materials & Design,* 2012.

[9] M.F. Kallan, "Concrete Radiation Shielding. Longman Scientific & Technical, England.," 1989.

[10] ANSI/ANS-6.4-1985, "Guidelines on the Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants. American National Standard Institute (ANSI)/American Nuclear Society (ANS).", ed, 1985.

[11] D. P. Bentz and P. Aitcin, "The hidden meaning of water-to-cement ratio," *Concrete international,* vol. 30, pp. 51-54, 2008.

[12] A. Dowell and S. Cramer, "Field Measurement of Water-Cement Ratio for Portland Cement Concrete-Phase II: Field Evaluation and Development," 2002.

[13] M. Mannan and C. Ganapathy, "Long-term strengths of concrete with oil palm shell as coarse aggregate," *Cement and concrete research,* vol. 31, pp. 1319-1321, 2001.

[14] M. Mannan and C. Ganapathy, "Mix design for oil palm shell concrete," *Cement and concrete research,* vol. 31, pp. 1323-1325, 2001.

[15] M. Mannan, J. Alexander, C. Ganapathy, and D. Teo, "Quality improvement of oil palm shell (OPS) as coarse aggregate in lightweight concrete," *Building and environment,* vol. 41, pp. 1239-1242, 2006.

[16] U. Alengaram, M. Jumaat, and H. Mahmud, "Influence of cementitious materials and aggregates content on compressive strength of palm kernel shell concrete," *Journal of Applied Sciences,* vol. 8, pp. 3207-3213, 2008.

[17] P. Shafigh, M. Z. Jumaat, and H. Mahmud, "Oil palm shell as a lightweight aggregate for production high strength lightweight concrete," *Construction and Building Materials,* vol. 25, pp. 1848-1853, 2011.

[18] P. Shafigh, M. Z. Jumaat, and H. Mahmud, "Mix design and mechanical properties of oil palm shell lightweight aggregate concrete: A review," *International Journal of the Physical Sciences,* vol. 5, pp. 2127-2134, 2010.

[19] R. Ahmmad, M. Z. Jumaat, S. Bahri, and A. B. M. S. Islam, "Ductility performance of lightweight concrete element containing massive palm shell clinker," *Construction and Building Materials,* vol. 63, pp. 234-241, 7/30/ 2014.

[20] M. Mannan and C. Ganapathy, "Concrete from an agricultural waste-oil palm shell (OPS)," *Building and Environment,* vol. 39, pp. 441-448, 2004.

[21] P. Nixon, "Changes in Portland cement properties and their effects on concrete," *Building research establishment-information paper,* 1986.

[22] N. U. Kockal and T. Ozturan, "Strength and elastic properties of structural lightweight concretes," *Materials & Design,* vol. 32, pp. 2396-2403, 2011.

[23] S. H. Kosmatka and M. L. Wilson, "Design and Control of Concrete Mixtures: The guide to applications, methods, and materials," 2011.

[24] M. Haque, H. Al-Khaiat, and O. Kayali, "Strength and durability of lightweight concrete," *Cement and Concrete Composites,* vol. 26, pp. 307-314, 2004.