Cleaner Engineering and Technology 4 (2021) 100233

Contents lists available at ScienceDirect

Cleaner Engineering and Technology

journal homepage: www.sciencedirect.com/journal/cleaner-engineering-and-technology

Influence of palm ash on properties of light weight self-compacting concrete

Olatokunbo M. Ofuyatan, Ph.D [a,*], Festus Olutoge, Ph.D [b], David Omole, Ph.D [a], Adewumi Babafemi, Ph.D [c]

[a] Department of Civil Engineering, Covenant University, Ota, Ogun State, Nigeria
[b] Department of Civil and Environmental Engineering, University of West Indies, St. Augustine, Trinidad and Tobago
[c] Department of Civil Engineering, Faculty of Engineering, Stellenbosch University, South Africa

ARTICLE INFO

Keywords:
Lightweight concrete
Palm ash
Superplasticizer
Strength
Self-compacting concrete

ABSTRACT

The huge amount and non-utilization of oil palm biomass has created a major disposal problem. The use of lightweight concrete improves structural efficiency, as well as constructability for ease of repair and renovation works. Self-compacting concrete (SCC) reduces voids without vibration. This experimental work examined the effect of influence of Palm ash (PA) on lightweight self-compacting concrete (LWSCC). Palm ash was used to replace cement in the production of lightweight self-compacting concrete in order of 10, 20, 30, 40 & 50% respectively; slump flow, T_{50}, V-funnel and L-box test were carried out for the workability and passing ability test on fresh concrete. The control mix was without PA. While Compressive, flexural and split tensile strength tests were carried out on the hardened concrete. The result showed 20% palm ash replacement as the optimum replacement within which the standard strength requirement for hardened concrete remained satisfied. The result of this study can be applicable to effective concrete mixtures suitable for repairing existing structures and element in rural areas.

1. Introduction

Huge amounts of palm trunks, branches, stems are being deposited as waste from manufacturing industries. The sustainable use of this deposits will not only create a cleaner environment but will also reduce the cost of some building materials that will have better impact on the environment. The new trend of business opportunities from waste to wealth in palm biomass as a green potential has speed up the development of the palm biomass industry in terms of technology development, product improvement, process synthesis and supply chain optimization (Qin Ng, W. et al., 2012). However, by recycling the waste material, it can reduce the dumped waste as well as to ensure environmental sustainability. For decades, the interest to develop an excellent durable, good performance concrete that requires few proficient workers has been on the rise. The gradual decrease of proficient workers in construction sector brought about self-compacting concrete (Okamura et al., 2013). This concrete can flow freely and consolidate under its own weight which makes it suitable for placing congested reinforcement and difficult conditions in high ride buildings. Its use in construction minimizes related hearing damages on worksite caused by vibration of concrete machines. It decreases construction time and ensures enough compaction (Kwangwoo et al., 2018) (Sellevold, E.J, 1987) (Güneyisi et al., 2008). Some of the merits of structural lightweight concrete includes the reduction of dead load of a concrete structure, which allows the designer to reduce the size of the structural member, hence making it lighter than conventional concrete (Sideris et al., 2013). Light weight concrete has low density, reduces heat absorption, faster building rate, reduction of dead load, and low haulage and cost. The breaking load deflection was investigated with relation to the strength. ((Lo et al., 2007) and (Shi et al., 2005) reported a decrease in the load as the percentage replacement increased and when immersed in water. The POFA masonry bricks had a reduced breaking limit compared to the cement masonry bricks (Muhammad et al., 2014).

(Muller and Haist, 2004) reported the use of self-compacting concrete and lightweight properties gave a suitable filling, passing and segregation free type of concrete used in construction today.

* Corresponding author.
E-mail addresses: olatokunbo.ofuyatan@covenantuniversity.edu.ng (O.M. Ofuyatan), festus.olutoge@sta.uwi.edu (F. Olutoge), david.omole@covenantuniversity.edu.ng (D. Omole), ajbabafemi@sun.ac.za (A. Babafemi).

https://doi.org/10.1016/j.clet.2021.100233
Received 1 December 2020; Received in revised form 1 July 2021; Accepted 30 July 2021
Available online 2 August 2021

Investigation also carried out by (Kim et al., 2010) studied the characteristic of semi-lightweight SCC using two different artificial lightweight aggregate that, there was an increase in the flowability, but the segregation properties decreased. Furthermore, the use of lightweight aggregate in self-compacting concrete by (Abdul et al., 2015) developed lightweight concrete that was approved by German institute of construction and also implemented in the building practice. Statistical model analysis to determine the dataset on predictive compressive strength models of SCC was studied by (Jeffery et al., 2006) and concluded that water cement ratio, aggregate combination, superplasticizer and binder combination are variables that affect compressive strength for 7, 28 and 90 days (Awal et al., 1997) evaluated the performance of palm oil fuel ash (POFA) in reducing the expansion of mortar bars containing Tuff as a reactive aggregate. The effectiveness of POFA, like that of other fly ashes, increases as the level of replacement level increases. The replacement level of cement by 50% POFA affects the strength development of concrete as an early investigation has shown that a reduction in compressive strength occurs with the amount of ash content beyond 40%.

Durability properties of palm oil fuel ash (POFA) was examined by (Ofuyatan et al., 2018) at 14, 28 and 90 days and the effect of water absorption on the specimen, from the result it was observed that mixes with ash had low resistance to the acid and sulphate test compared to SCC with palm oil fuel ash which had high values. The durability behavior under chloride and sulphate attack of lightweight SCC was looked into by (Bashandy et al., 2019) and (Behnam and Shami, 2016). Different mix ratios at different curing conditions was investigated by (Ofuyatan et al., 2018). Other materials investigated were cassava peel ash (Ofuyatan et al., 2018), rice husk ash and pumice powder (RMoh et al., 2014), steel fibre (Shahid et al., 2015), metakaolin (Kim et al., 2012). It was seen that the concrete can be used for light construction works where high strength is not a major requirement, but durability is a major concern. Information on the studies is still lacking on the effectiveness of using this pozzolanic material on the fresh and hardened properties of lightweight concrete. It's been seen to be used mostly as source of renewable and sustainable energy and aggregate. This experiment investigated the effect of Palm ash on lightweight self-compacting concrete and its application as filler for cracks and for non-structural building element in support of (Kanadasan, et., al. 2014) that Utilizing POC in the construction industry will promote sustainability besides paving the way for the proper disposal of waste materials that will lead to a much cleaner and non-polluted environment.

2. Experimental method

2.1. Materials

The potable water used in this research meets the requirement (ASTM C1602/C1602M-18, 2012). The fine aggregate was obtained from natural river sand, located in Ogun state, Nigeria. Crushed, angular, porous graded granite having maximum size of 12.5 mm was employed as coarse aggregate (ACI Committee report 213R-03, 1992). The physical and composition qualities of the materials are shown in Table 2. The ordinary Portland cement; Dangote cement of grade 42.5r was used as binder and Conplast SP430 as chemical admixture in requirement of ASTM C1602. The palm ash used was obtained from a palm oil industry in Ogun state, Nigeria and the chemical composition is shown in Table 1.

2.2. Mix design

In this study, the key proportions for the mixes are done in accordance with (EFNARC 2005). Table 3 relates the different mixes adopted in this study. Palm ash is used as mineral admixture along with chemical admixture (superplasticizer -Conplast SP 430) with water to binder ratio of 0.45.

Table 1
Chemical composition of POFA and OPC.

Chemical composition	Portland cement (%)	POFA (%)
SiO_2	15.60%	54.47%
$Al2O_3$	3.02%	2.63%
Fe_2O_3	3.27%	5.23%
CaO	47.13%	4.70%
MgO	1.33%	3.67%
Na_2O	0.02%	0.18%
K2O	0.28%	7.55%
SO_3	3.08%	0.82%

Table 2
Physical properties of fine and coarse aggregate, POFA and OPC.

Property	Fine aggregate	Coarse Aggregate	Palm Ash	OPC
Specific gravity	2.55	2.73	1.91	3.18
Fineness modulus	2.73	6.8	9	13.6
Maximum size (mm)	3.76	12.5	90	92
Water absorption (%)	1.2	0.38		
Median particle size, d50 (mm)				
Passed from 45-mm (no. 325) sieve (%)				

Table 3
Mix proportion.

Constituent (kg/m^3)	NC (kg/m^3)	10%PA (kg/m^3)	20%PA (kg/m^3)	30%PA (kg/m^3)	40%PA (kg/m^3)	50%PA (kg/m^3)
Portland Cement	417.15	375.44	333.72	292	250.29	208.57
Fine Aggregates	952	952	952	952	952	952
Coarse Aggregates	653.54	653.54	653.54	653.54	653.54	653.54
Palm ash	0	41.72	83.43	125.15	166.86	208.57
W/C Ratio (%)	0.45	0.45	0.45	0.45	0.45	0.45
Superplasticizer	4.17	4.17	4.17	4.17	4.17	4.17

2.3. Test performed on SCC mixes

The experiment performed assessed the fresh and mechanical properties such as workability, compressive, split tensile strength and flexural strength of all mix variants. Details about the test procedures, standard followed are outlined in the following sub sections.

2.4. Tests on fresh properties

The workability of SCC is characterized by filling ability as seen in slump flow, passing ability which is tested in L-box and segregation resistance in the V-funnel which were carried out to determine the fresh properties of the light weight self-compacting concrete (EFNARC, 2005) is shown in Table 6.

2.5. Casting and curing concrete

Molds were filled with concrete after mixing, cube and cylinder molds of sizes of 150 × 150 × 150 mm and 150 × 300 mm respectively. The molds were cleaned of dust and lubricated with oil. It was filled with LWSCC containing Palm ash without compacting and were stored at room temperature for 24 h then marked and removed from the mold. In the determination of density for the hardened concrete with varied Palm ash replacements (10%–50%), the hardened concrete cubes were cured for 28 days. The cubes were dried and weighed in the air after curing. The density of the cubes was obtained by using a weighing balance and hence recorded is shown in Table 4.

Table 4
28days density and compressive strength.

Mix	28days	Density kg/m^3
Control mix	26.90	2519
SCC+10%	28.09	1850
SCC+20%	26.58	1735
SCC+30%	25.17	1715
SCC+40%	24.95	1710
SCC+50%	23.88	1702

2.6. Tests on hardened properties

Compressive strength test was carried out conforming to ASTM C39/C39 M, split tensile strength test ASTM C496/C496 M standard for carrying out test on cube was followed, cylindrical specimen and the flexural strength test were carried out on the beams removed from the water tank after the required days of curing. The specimen as shown in Fig. 1 (a) (b) and Fig. 2 was tested and loaded at a gradual constant rate until failure occurred. The load at which failure occurred was observed and recorded at 7, 14 and 28 days.

3. Results and discussion

3.1. Slump flow result

The flowability results are displaced in Table 5 and the flow of concrete in Fig. 3 (a) and (b) that signifies the passing ability, flow of ease and resistance to segregation of the fresh concrete that is determined by the slump flow, V-funnel, L-box and T_{50} flow. The limit of the various flow indicators recommended by EFNARC (2005) is shown in Table 3. A reduction in the slump flow was visible as the percentage content of ash increased. The Control mix flow was 680 mm, while the 20% replacement had a slump flow of 750 mm and a gradual reduction from 620 mm to 510 mm occurred at higher replacement. This could be due to the air contents creating voids in the paste. Table 3 represents the flow results for the concrete flow at varying palm ash replacement. As the percentage of cement replacement increases, there is a reduction in the workability due to the unburnt carbon of POFA. The T_{50} flow time as shown in Fig. 5 increases as the percentage replacement increase.

3.2. L-box result

The free flow against any form of bar was evaluated using the L-box. The result of test carried out for the different mixes with varying palm ash replacement for the fresh LWSCC is presented in the Fig. 4. The paste matrix with the aggregate provide a smooth transportation effects through the paste phase and an air passage for the passing ability performance of the concrete. The passing ability of the different mixes satisfy the standard requirement range for passing ability of fresh concrete. LWSCC is improved by palm ash addition of 20% as shown above and start to decrease from 30% to 50% PA. Also, observed that the concrete mix with 20% of POFA had the highest passing ability.

Fig. 2. Flexural test on beams.

Table 5
Result of workability.

Mixtures	Slump Flow(mm)	T50cm	V-Funnel (sec)	L-box (mm)
NC	680	3.5	8	0.85
SCC+10%	660	3	7	0.90
SCC+20%	750	2.5	6	0.92
SCC+30%	620	3.9	9.5	0.89
SCC+40%	570	4.2	10	0.85
SCC+50%	510	4.5	11	0.82

3.3. V-funnel result

The V-funnel flow time is dependent on the percentage replacement and the volume of paste as shown in Fig. 7. The rheology of the paste affects the viscosity and flow of the lightweight paste. From Fig. 5, the flow time for the various SCC samples were within 6–11 s. All samples were within specified limits. It could also be seen that SCC containing 20% was able to flow out of the v-funnel quickly, indicating substituting of palm ash with cement improves the workability of the concrete mix. The flow time decreased at 20% compared with the 10% replacement

A B

Fig. 1. (A) and (B) Crushing test carried out on the specimens (B).

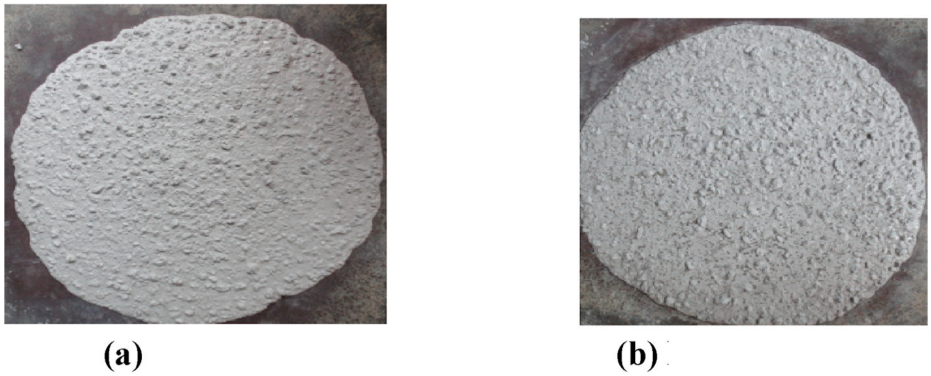

Fig. 3. **(a)** LWSCC without palm ash **(b)** LWSCC with Palm ash.

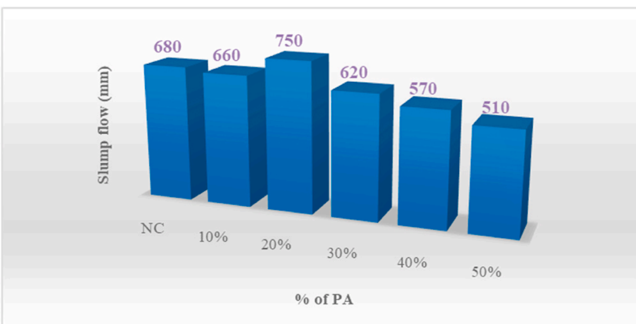

Fig. 4. Slump flow for the various samples.

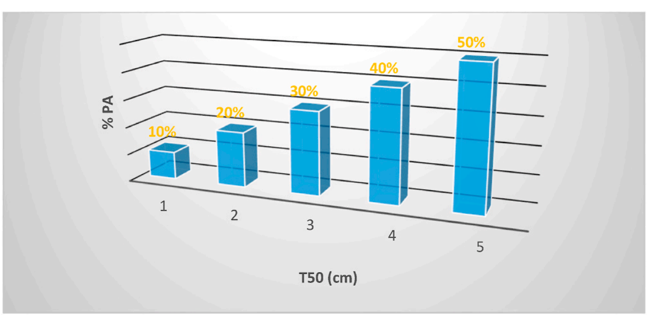

Fig. 5. Time for the T_{50}cm flow.

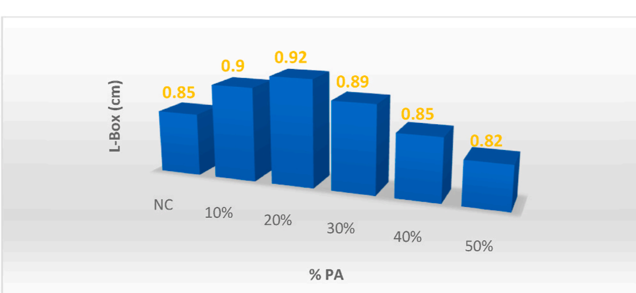

Fig. 6. L-Box result.

and a sudden rise in flow at higher percentage replacement. The superplasticizer enhanced the flow capacity of the paste. In addition, the low specific gravity of the palm ash reduced the weight of the concrete giving rise to an increase in flow rate. The aggregate size and paste volume for the control mix which had 8secs. 10% has 7secs flow time

Fig. 7. V-Funnel result.

and 20%, 6secs flow rate; reduced the cohesion between the aggregate, giving rise to a high viscous mix with a higher flow time, which happened at 30–50% at 9.5, 10, and 11 respectively.

3.4. Compressive strength

The compressive strength for 7, 14 and 28 days of the different samples containing different percentages of palm ash respectively is illustrated in the Fig. 8. Progressive increment can be seen from 7 days to 28 days compressive strength in Table 7. The samples containing high content of POFA at 10 and 50% gained gradual compressive strength in the early days of curing in comparison with the conventional SCC without POFA content. Increasing the POFA content resulted in reduction in early mechanical properties, (Navid et al., 2016) 15 and 20% gained lower compressive and flexural strength in the early days of curing in comparison with the conventional SCC properties. The initial increase in strength of SCC +10% palm ash may be attributed to the filler nature of the palm ash, filling up pores and reducing the amount of

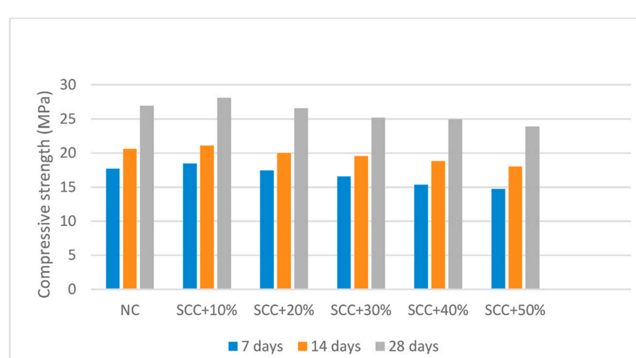

Fig. 8. Compressive strength.

Table 6
Acceptance criteria for Self-Compacting Concrete.

	Method	Unit	Typical range of values	
			Minimum	Maximum
1	slumpflow by Abrams cone	mm	650	800
2	T_{50cm} slumpflow	sec	2	5
3	J-ring	mm	0	10
4	V-funnel	sec	6	12
5	Time increase, V-funnel, $T_{5minutes}$	sec	0	+3
6	L-box	(h_2/h_1)	0,8	1,0
7	U-box	(h_2/h_1)mm	0	30
8	Fill-box	%	90	100
9	GTM Screen stability test	%	0	15
10	Orimet	sec	0	5

honey comb present thereby increasing the strength of the concrete. SCC +10% palm ash had the highest strength value of 26.58 MPa compared with the sample without palm ash. The compressive strength also increased with decreases in the replacement level of palm ash as seen from 20% to 50%. The decrease at 28days might be caused by the diffusion of the cement and PA (Lo et al., 2007) reported the compressive strengths of SCLC and SCC increase from 40 to 58 MPa and 44–60 MPa, respectively. Basically, the reaction process of PA and Cement concrete are in two major phase. The first phase is mostly ascribed to the mixture of cement and water; second stage is ascribed to pozzolanic activity of fine palm ash with the cement hydration reaction tri-calcium silicate and water giving rise to CSH gel and mineralogy crystal. This CSH gel causes the hardening effect that produces the strength factor, a reduction in the cement content will give rise to a reduction in the strength at early ages. This will therefore cause a slow and a delay in the reaction process. Pozzolanic reaction normally will increase the compressive strength at late days by enhancing the bonding between the mixtures. Also, the fineness of ground POFA improves the strength of concrete by filling the gaps between cement particles (Kwangwoo et al., 2018; Muhammad et al., 2014; Abdul et al., 2015).

3.5. Splitting strength

Shown in Fig. 9 is the split tensile strength for 7, 14 and 28 days of the samples containing different percentages of Palm ash respectively. All the samples showed a decrease due to the conformity in the interfacial transition zone of the hydrated cement matrix paste and palm ash. The maximum splitting tensile strength as seen in Fig. 5 was obtained at SCC +10% Palm ash. The concrete mix had a strength value of 2.27, 2.47 and 2.95 MPa compared to the other mix with palm ash, though the control mix was better. Split tensile strength also decreases with increase in substituting level of Palm ash percentage. But it was observed that the reference mix had high resistance value compared to the mixes with palm ash similar to (Alamgir et al., 2017) reported that the 28 days' strength was in the range of 1.29–2.90 MPa.

3.6. Flexural strength

In Table 3 the flexural strength of the mixes is shown. A gradual decrease in the strength was noticed in all the mixes. As the percentage of palm increased a decrease was observed which can be due to poor pozzolanic reaction of palm ash with the cement and water. Another reason is the poor bonding of the materials within the matrix. The flexural strength for the control mix at 7, 14 and 28 days was 2.89, 3.84, and 5.04, respectively. The highest flexural strength as shown in Fig. 10 at 28days was the control mix compared with the 10–50% SCC mix. The lowest flexural strength of 2.31 MPa was noticed at 50% replacement which was also observed with the compressive and tensile strength. The value at 28days for the control mix was 18% reduced to 10% palm ash at 28days. Mix with 10% palm ash compared with 20% replacement had a 9% reduction in strength. The highest reduction was −118%. As the palm ash increased the percentage drop in strength also increased compared to (Lo et al., 2007). Fig. 6 presents results for the flexural strength test carried out on the LWSCC for the different employed mixes for 7, 14, and 28 days respectively.

4. Conclusion

The study conducted aimed at determining the influence and effect of palm ash on lightweight self-compacting concrete. The physical, workability and mechanical properties was examined in producing the lightweight SCC concrete at varying percentages of palm ash with six samples. Based on this experimental study the following conclusions was drawn.

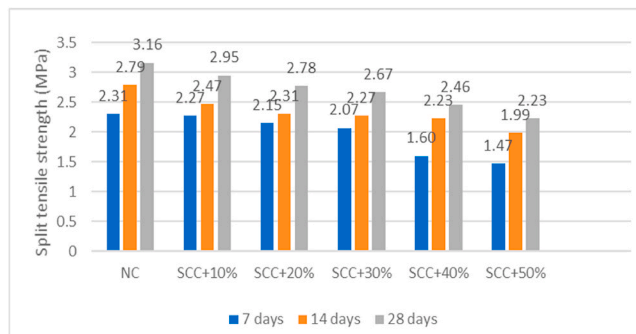

Fig. 9. Splitting tensile strength.

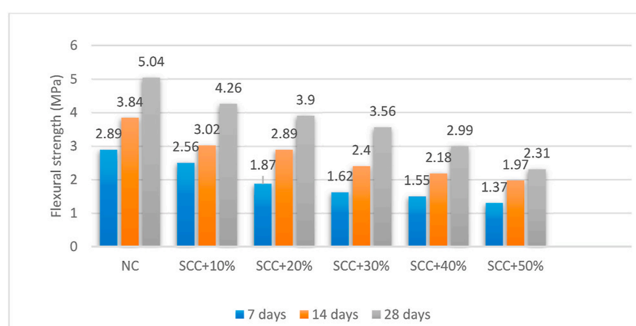

Fig. 10. Flexural strength.

Table 7
Results for Hardened concrete.

Mix	Compressive Strength (MPa)			Split Tensile strength (MPa)			Flexural Strength (MPa)		
Days	7days	14days	28days	7days	14days	28days	7days	14days	28days
Control mix	17.69	20.6	26.9	2.31	2.79	3.16	2.89	3.84	5.04
SCC+10%	18.44	21.11	28.09	2.27	2.47	2.95	2.56	3.02	4.26
SCC+20%	17.44	20	26.58	2.15	2.31	2.78	1.87	2.89	3.9
SCC+30%	16.56	19.56	25.17	2.07	2.27	2.67	1.62	2.4	3.56
SCC+40%	15.33	18.82	24.95	1.6	2.23	2.46	1.55	2.18	2.99
SCC+50%	14.73	18	23.88	1.47	1.99	2.23	1.37	1.97	2.31

1. The sample with SCC + POFA mix at 20% had better workability than the other mixes.
2. The utilization, recycle and reuse of Palm ash will not only help in proper disposal for a much cleaner and less polluted environment, it will also be useful in the construction sector for sustainability of light structures.
3. The addition of POFA exhibited a reduction in workability of the LWSCC; however, with the application of superplasticizer the fresh properties of the LWSCC palm ash were kept almost the same.
4. Compressive strength of 26.58 MPa was achieved at 28days with 10% palm ash which may be attributed to the filler nature of the palm ash, filling up pores spaces thereby increasing the strength of the concrete.
5. Splitting tensile strength decreased with increase in substituting level of palm ash percentage by 4.5% which reduced by significant margin in the strength;
6. The flexural strength had a gradual decreased by 9.3% at 20% of palm ash compared with the control mix that had a higher value of 5.04 MPa.
7. In general, the mechanical (compressive strength, splitting tensile strength and flexural strength) test properties of the Lightweight self-compacting concrete, SCC 10% Palm ash had suitable mechanical properties while further increment from 20% to 50% of palm ash demonstrated a substantial reduction in the mechanical properties. It was also observed that in both flexural and split tensile strength test the control concrete mix had better resistance compared to the other mixes with Palm ash.

Funding

There was no external funding for the study.

Compliance with ethical standards

This article does not contain any studies involving human or animal subjects.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

The authors would like to express thanks to Covenant University for the use of the laboratory and equipment.

References

Abdul Awal, A.S., Warid Hussin, M., 1997. The effectiveness of palm oil fuel ash in preventing expansion due to alkali-silica reaction. Cement Concr. Compos. 19 https://doi.org/10.1016/S0958-9465(97)00034-6, 367-312.

Abdul, M., Abdullah, A., Huzaim, O., Sofyan, I., Safwan, A., 2015. Utilization of Palm Oil Fuel Ash (POFA) in Producing Lightweight Foamed Concrete for Non-structural Building Material. The 5th International Conference of Euro Asia Civil Engineering Forum, pp. 739–746. https://doi.org/10.1016/j.proeng.2015.11.119.

ACI, 2003. Committee Report 213R-03 Structural Lightweight Aggregate Concrete. American concrete institute.

Alamgir, K., Johnson, A., Mohd, A., Jumaat, S., Yusoff, O., Afia, S., Iftekhair, I.B., 2017. Performance evaluation and some durability characteristics of environmental friendly palm oil clinker based geopolymer concrete. J. Clean. Prod. 161, 477–492. In: http://www.claisse.info/Proceedings.htm.

ASTM C1602/C1602M-18, Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete.

ASTM C39/C39 M, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens, ASTM International..

ASTM C496/C496 M, Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens, ASTM International..

Bashandy, A.A., Etman, Z.A.1, Azier, H.Y., 2019. Durability of lightweight self-compacted concrete. Int. J. Construct. Eng. Manag. 8 (5), 127–135. https://doi.org/10.5923/j.ijcem.20190805.01.

Behnam, V., Shami, N., 2016. Mix design of lightweight self-compacting concrete. Case Stud. Construct. Mater. 1–14. https://doi.org/10.1016/j.cscm.2015.10.002.

EFNARC, 2005. The European Guidelines for Self-Compacting Concrete: Specification, Production and Use. Surrey, UK, p. 68.

Güneyisi, E., Gesoğlu, M., Mermerdas, M., 2008. Improving strength, drying shrinkage, and pore structure of concrete using metakaolin. Mater. Struct. 41, 37–49. https://doi.org/10.1617/s11527-007-9296-z.

Jeffery, R., Salah, A., David, A., Klaus, R. Gregory R., 2006. "Effect of synthetic fibers on structural behavior of concrete slabs on ground. ACI Mater. J. 3–10, 103-M01.

Kanadasan, J., Hashim, A.R., 2014. Engineering and sustainability performance of self-compacting palm oil mill incinerated waste concrete. J. Clean. Prod. 89, 78–86. https://doi.org/10.1016/j.jclepro.2014.11.002.

Kim, Y.J., Choi, Y.W., Lachemi, M., 2010. Characteristics of self-consolidating concrete using two types of lightweight coarse aggregate. Construct. Build. Mater. 24, 11–16. https://doi.org/10.3151/jact.9.15.

Kim, O., Hwang, I., Lee, O., 2012. Impacts of metakaolin on lightweight concrete by type of fine aggregate. Construct. Build. Mater. 36, 719–726. https://doi.org/10.1016/j.conbuildmat.2012.06.020.

Kwangwoo, W., Han-Seung, L., Seungmin, L., Mohamed, A., Ismail, O., Mohd Warid, H., 2018. Effect of using micro palm oil fuel ash as partial replacement of cement on the properties of cement mortar. Adv. Mater. Sci. Eng. https://doi.org/10.1155/2018/5164030.

Lo, T.Y., Tang, P.W.C., Cui, H.Z., Nadeem, A., 2007. Comparison of workability and mechanical properties of self-compacting lightweight concrete and normal self-compacting concrete. Mater. Res. Innovat. 11 (1), 45–50. https://doi.org/10.1179/143307507X196239.

Muhammad, E.R., Ang, L.B., Agus, S.M., Md Nafeez, H.T., Vikram, P., 2014. Performance of masonry blocks incorporating palm oil fuel ash. J. Clean. Prod. 78, 195–201. https://doi.org/10.1016/j.jclepro.2014.04.067.

Muller, S.H., Haist, M., 2004. "Self- compacting lightweight concrete" Betonwerk und Fertigteil-Technik, 12/2004, 8-7.

Navid, R., Behnia, Arash, Alsubari, Belal, Birgani, Payam Moradi, Jumaat, Mohd Zamin, 2016. Durability and mechanical properties of self-compacting concrete incorporating palm oil fuel ash. J. Clean. Prod. 112 (2016), 723–730. https://doi.org/10.1016/j.conbuildmat.2012.06.020.

Ofuyatan, O.M., Olutoge, F.A., Olowofoyeku, A.M., 2018. "Durability properties of palm oil fuel ash self compacting concrete. Eng. Technol. Appl. Sci. Res. 5 (1), 753–756. https://doi.org/10.48084/etasr.524.

Ofuyatan, O.M., Ede, A., Olofinnade, R., Oyebisi, S., Alayande, T., Ogundipe, J., 2018. Assessment of strength properties of cassava peel ash concrete. Int. J. Civ. Eng. Technol. 9 (1), 965–974. IJCIET_09_01_095.

Okamura, H., Masahiro, Ouchi, 2003. "Self–compacting concrete". J. Adv. Concr. Technol. 1 (1), 5–15. https://doi.org/10.3151/jact.1.5.

Qin Ng, W., Lam, H.L., Yuen, F., Kamal, M., Lim, J., 2012. Waste-to-wealth: green potential from palm biomass in Malaysia. Journal of Cleaner Production 34, 57–65. https://doi.org/10.1016/j.jclepro.2012.04.004. ISSN 0959-6526.

RMoh, A., Azwar, M.O., Bambang, S., 2014. Rice husk ash and pumice in lightweight concrete of engineering materials to improve mechanical strength Portland cement composites. Int. J. Civil Environ. Eng. IJCEE 14 (3).

Sellevold, E.J., 1987. Condensed silica fume in concrete: a world review. in Supplementary Cementing Materials for Concrete 165–243.

Shahid, I.M., Ahsan, A.A., Klaus, H., Thomas, B., 2015. Mechanical properties of steel fiber reinforced high strength lightweight self-compacting concrete (SHLSCC). Construct. Build. Mater. 98, 325–333. https://doi.org/10.1061/(ASCE)MT.1943-5533.0002292.

Shi, C., Yang, X., Yu, Z., Khayat, H., 2005. Design and application of self-consolidating lightweight concretes. In: SCC'2005-China: 1st International Symposium on Design, Performance and Use of Self-Consolidating Concrete, pp. 55–64.

Sideris, K.K., Anagnostopoulos, N.S., 2013. Durability of normal strength self-compacting concretes and their impact on service life of Reinforced concrete structures. Construct. Build. Mater. https://doi.org/10.1016/j.conbuildmat.2016.04.089.