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Performance of Aggregate Incorporating Palm Oil Fuel Ash (Pofa) and Silt

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Abstract*: *Depletion of natural aggregate has created more research to explore the utilization of industrial waste as alternative aggregate in concrete construction. The use of industrial wastes in making of artificial aggregate will lead to greener environment. In this study an attempt has been made to find the suitability of waste materials of palm oil fuel ash (POFA) and water treatment sludge as possible substitute for natural coarse aggregate. Specific gravity, water absorption, crushing strength and impact value have been tested for this mixture. Both raw materials were mixed with lime and alkaline activator. The artificial aggregate was air-cured at non-sintered temperature. Results show that the different mix proportions of the POFA to silt affected the performance of the artificial aggregate. Specific gravity and water absorption increased with the proportion of silt. Lightweight aggregate comprising silt combined with POFA and alkaline activator has the potential to produce a good performance of concrete. These benefits contribute to the production of energy-efficient building materials.

Keywords* : *Artificial Aggregate, Waste Materials, POFA, silt

I. INTRODUCTION

Concrete is known as the extraordinary structural composite material in the construction industry [1]. The rapid development of the construction industry is indirectly affecting the production of construction materials due to its consumption amount. A considerable amount of natural resources or raw materials is exploited for concrete production worldwide [2]. At present, approximately 1.5 billion tonnes of cement and 11 billion tonnes of sand and aggregate are annually consumed for the manufacture of concrete by the construction industry [3]. The concrete sector is expected to face some problems on manufacture, such as quality decline on raw material, depletion and scarcity and exploration cost. These problems can be attributed to the continuous exploration of natural resources for concrete manufacture, which threatens the origin of the natural environment on earth [4]. The extraction process of gravel will introduce some negative impacts towards the ecosystem, biodiversity and soil quality [5].

Aggregates, which are also known as granular materials, are one of the complimentary elements used for concrete production. These materials can be obtained from various sources, such as stone, crushed stone and gravel, which are commonly applied in construction. To date, given that aggregates occupy 70% of the overall concrete volume, concrete consumption accounts for approximately 2 billion tonnes of natural aggregates annually [6]. This finding results in the high demand for natural aggregates, which causes irreparable damage to the environment and gradually reduces the resources of natural aggregates. Therefore, apart from considering disposal management by re-using waste materials, new sustainable development solutions are explored to minimise environmental issues [7].

Malaysia is one of the main producers and exporters of palm oil products. Million tonnes of palm oil waste is assumed to be generated annually from the burning process due to its large amount of productivity [8]. Based on Yap et al. [9], approximately 0.06 million tonnes of palm oil fuel ash (POFA) and other residues have been produced from 2007 until 2010 in Malaysia. This production continues to generate an increasing trend for the wastage problem. Therefore, disposing waste from the palm oil industry has become a critical problem. The exposure of these wastes to open areas will also negatively impact the environment and human health.

Sludge is one of the unwanted wastes generated daily. The rapid growth of the population has increased the water supply demand. Water treatment plants will generally produce almost a hundred thousand tonnes of sludge annually [10]. The generated sludge will directly drain into water bodies or dumps for landfill after the dewatering process. Although these methods are considered economical ways for sludge disposal, they are unreasonable solutions for sludge containing possible contaminants from chemical or metallic substances during the treatment process. Consequently, the industry players must consider sustainable sludge management strategies to minimise the effect towards the environment. The construction industries proposed methods of substituting unwanted wastes into the construction materials to address the decline in natural resources and the waste disposal problem. Studies on the transformation and modification of wastes have also been performed.

Artificial aggregates from industrial wastes and clay materials largely contribute in concrete production [11]. Consequently, artificial aggregates produced from different waste materials can be effectively utilised in the construction field. Synthetic aggregates manufactured from fly ash using rotary kiln firing method have been found suitable for asphaltic concrete. Emdadi et al. [12] found that lightweight aggregates (LWAs) are cost-effective and structurally stable due to their versatile structure with low weight. Numerous studies on artificial aggregate production have recently emerged due to the market value of this building material.

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Therefore, this research aims to preliminary study the properties of POFA and silt as raw materials for artificial LWA. The silica content for both raw materials is considerably high, which may contribute to aggregate production. Several activators are also added to improve the performance of aggregates. Application of the LWA on the construction industry has many advantages in terms of cost, stability and density (reduce the load weight). Furthermore, the current research intends to solve the issues of waste management, natural resources and impact on the environment.

II. Experimental Programme

The experimental work is carried out in order to find the specific gravity, water absorption, crushing strength and impact value. The specimens are casted, cured and tested for 28 days curing period. Microstructure analysis was carried out for the optimum option of artificial aggregate.

A. Materials

POFA was obtained from a palm oil mill (United Palm Oil Mill Sdn Bhd) located in Nibong Tebal. The raw POFA was dried in an oven for 24 h at a temperature of 105 ± 5 °C to remove moisture content. Then, it was sieved through a 300 µm sieve to remove all the unwanted particle impurities and unburned carbon. The fine ashes passing through the selected sieve will be collected and stored in airtight containers to prevent moisture absorption from the air and mixing with other materials. Water treatment sludge was collected from the Sungai Dua Water Treatment Plant in Seberang Perai. The dewatered sludge was dried to ensure water vapour evaporation. The sludge was then crushed and grounded into fine silt for uniform mixing, followed by sieving via 150 µm. A soil characteristic was identified by the method of Atterberg limits on silt. Plastic limit of 44.49%, plasticity index of 24.71% and plasticity index of 24.71% were obtained. Silt is considered highly plastic because its plasticity index exceeds 17. Lime kiln dust (LKD) was used for the mixture. Apart from accelerating the hydration rate, LKD acted as the cementation material to strengthen the bond between the raw materials. A mixture of sodium silicate (Na_2SiO_3) and 12 molarity of NaOH with 2.5 ratio was combined with the other mixture. The alkaline activator solution was prepared one day before mixing to facilitate the exothermic reaction.

B. Specimen Preparation

The prepared mix proportions for the aggregate are listed in Table I. Five different mixes were produced to identify the properties of artificial aggregates. Dry materials, such as POFA, silt and lime, were homogeneously mixed. Alkaline activator and water were then added until the required consistency was obtained. Wet mixture was extruded, cut into approximately 1 to 1.5 cm length and shaped into a sphere. All the fresh pellets were finally air-dried.

Table I. Mix proportion for POFA, silt, lime and alkaline activator

Sample code	Mix proportion (%)		Alkaline Activator (ratio)	Lime/binder (%)
	POFA	*Silt*		
AA1	50	50	2.5	25
AA2	40	60	2.5	25
AA3	30	70	2.5	25
AA4	20	80	2.5	25
AA5	10	90	2.5	25

C. Testing Programme

Characteristics of the artificial aggregate were identified by several tests, which include specific gravity, water absorption, aggregate impact value (AIV), aggregate crushing value (ACV) and scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM/EDX). AIV was conducted to determine the resistance of aggregate towards the sudden impact. The degree of toughness in which the aggregate can resist the impact load can then be defined. This testing process was conducted according to BS 812: Part 112 [13]. ACV was performed to determine the resistance capability of aggregate against the external crushing force. The crushing load of individual aggregate pellets was prepared and placed between two parallel plates and crushed under diametrical load [15]. This load was evaluated using the California bearing ratio testing machine based on BS 812: Part 110 [14].

III. Result and Discussion

A. Evaluation of Raw Materials

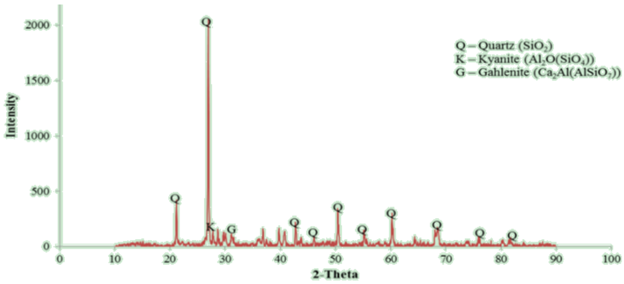
This Table II shows the chemical composition for POFA and silt. The major chemical composition of POFA is SiO_2 (54.98%), which accounted for more than 50% of the overall composition. SiO_2 demonstrated high reactive silica content. High SiO_2 content might help enhance the strength ratio because it is the core contribution to the material strength. Moreover, POFA had 10.77% of CaO; thus, it could be categorised as a Class C pozzolan material in accordance with ASTM C618-05 [18]. This categorisation enhanced calcium–silicate–hydrate (C–S–H) gel formation by reacting silica with itself and silts to achieve high strength. According to Priyadharshini et al. [16], large C–S–H gel formation can boost the hydration rate. Furthermore, the XRF results show that the pozzolanic property in POFA meets the requirement of ASTM C618-12a [19], demonstrating the sum of oxide compounds in silica, aluminium and iron oxides of 62.21%. The specific gravity of POFA is 1.90 based on the lab test result. The major compounds in silt include full silicon oxide (SiO_2) (43.26%) and aluminium oxide (Al_2O_3) (28.5%), which were acidic oxides. The high content of SiO_2 and Al_2O_3 contributed to their suitability as binding and filling agents to serve the water permeability with compatible engineering properties [17]. The magnesium oxide (MgO) and calcium oxide (CaO) contents for silt were low due to the absence of the carbonate mineral. The silica/alumina ratio (SiO_2/Al_2O_3) for silt is 1.52, and the specific gravity was 2.51. Figure 1(a) and (b) show the X-Ray diffraction (XRD) pattern for POFA and silt. Based on the XRD pattern, silicon oxide (SiO_2) was the most significant compound observed in the POFA sample.

The major minerals found in the POFA matrix include quartz (SiO_2), kyanite ($Al_2O(SiO_4)$) and gahlenite ($Ca_2Al(AlSiO_2)$). The main synthesised crystalline phases identified within silt include quartz (SiO_2), kaolinite ($Al_2Si_2O_5(OH)_4$) and rutile (TiO_2).

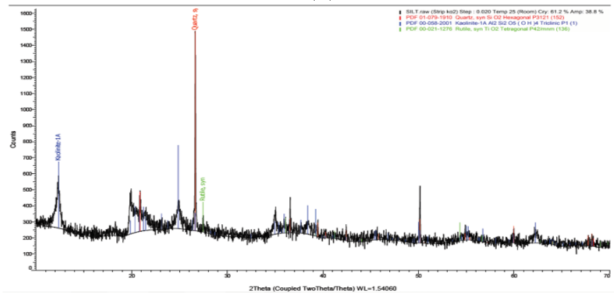
Table II. Chemical composition of POFA and silt

Composition	SiO_2	TiO_2	Al_2O_3	Fe_2O_3 (t)	MnO	MgO	Na_2O	CaO	K_2O	P_2O_5	SO_3	Cl
POFA (%)	54.98	0.19	3.27	3.96	0.14	5.02	0.40	10.77	9.50	5.64	4.09	1.78
Silt (%)	43.26	0.61	28.50	6.98	0.03	0.44	bdl[a]	0.14	1.70	0.22	n.d.[b]	n.d.[b]

[a] below detection limit
[b] not detected



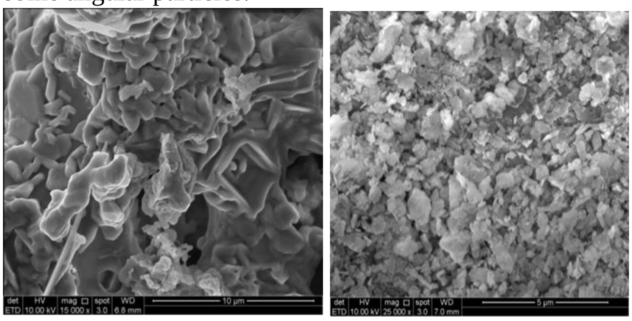
(a)



(b)

Figure. 1. X-Ray diffraction (XRD) spectra pattern of (a) POFA and (b) silt

As shown in Figure 2, the microstructure of silt and POFA particles was predicted to vary in structures with high probabilities of homogeneous mixing. The POFA had irregular longitudinal and porous texture form, whereas the silt had fine particles and almost similar variation in shape. Figure 2(a) shows the SEM for POFA particles in irregular, large and porous arrangement. The particles were irregular in shape and have porous texture. This sample revealed the uneven filler particle with some coarse and concentrated fine particles. The non-uniform distribution with fracture and pebble-shaped filler particles was also observed. Figure 2(b) shows the SEM of silt, which demonstrates numerous roughly angular spherical. Cenosphere indicates the acicular structure and provides needle plate-like form structure with some angular particles.



(a) (b)

Figure. 2. SEM of (a) POFA and (b) silt

B. Specific Gravity and Water Absorption of Artificial Aggregate

The average of the specific gravity for the artificial aggregate was only approximately 56% compared with that of the natural coarse aggregate. Figure 3 showed that specific gravity demonstrated a gradual increase from 1.109 to 1.142, which was directly proportional to the silt proportion in the mixture. The specific gravity was 1.51 for artificial aggregate produced with 90% silt proportion. Jayasinghe et al. [20] indicated the possibility of significant differences in the density of artificial aggregate production from different materials due to the varying specific gravity of silt and POFA. Similarly, Baykal et al [21] stated that specific gravity of the artificial aggregate was directly related to the relative density of the raw material used. In addition, the artificial aggregate with low density may be due to the low amount of geopolymer matrix formed in artificial aggregate and the presence of additional pores inside the aggregate. Overall, five mixtures of artificial aggregates were categorised under lightweight aggregate because they were within the required range. The loose bulk or the dry density less than 1.20 g/cm3 or 2.0 g/cm3, respectively, can address the definition for LWA [22].

The results of water absorption showed an increasing trend corresponding to the proportion of silt, except for AA2, which had the lowest water absorption of 27.8%. This finding could be attributed to the high pozzolanic reaction rate of the optimum mix within the mixture. The water absorption of artificial aggregate would be affected by the addition of lime [21]. As the lime content declined, the water absorption would increase due to the pozzolanic reaction rate. The presence of NaOH in the mixture led to the further occurrence of C–S–H gel and resulted in close and less porous structures [23]. The highest water absorption for artificial aggregate was AA5 (32.2%), which indicates that silt had high water absorption capacity. Furthermore, the binder content affected water absorption, and absorption property followed the trend of density. Current AA1 artificial aggregates do not have thick density but resulted in higher porosity and water absorption compared with those of AA2. Therefore, from the viewpoint of some researchers, the properties of lightweight and porous artificial aggregates would affect the saturation rate and the addition of water necessary for the concrete mix.

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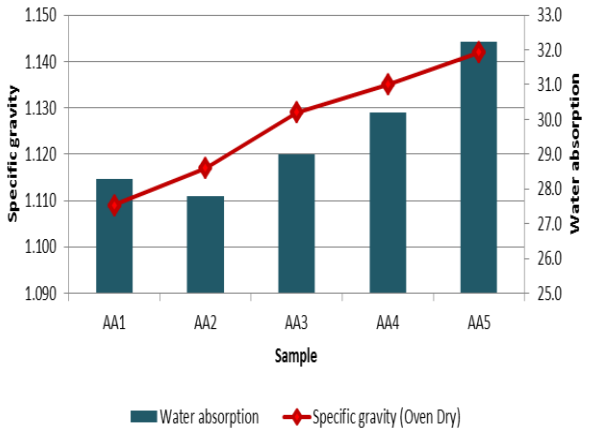

Figure. 3. Specific gravity and water absorption for artificial aggregate

C. Crushing Strength of Artificial Aggregate

The result of crushing strength average of individual artificial pellets is shown in Figure 4. The crushing strength was directly proportional to curing time. That is, crushing strength increased with curing time. The crushing resistance of aggregate dramatically increased from age 7 to 14 and then slowed down. This trend might be due to the almost completely pozzolanic reaction of the POFA and silt corresponding 28-day strength. Moreover, the presence of SiO_2 further enhanced the viscosity of artificial aggregate to form a vitrified surface against the high crushing force [24]. The results show that AA2 achieved the highest crushing strength of 1.14 MPa at 28 days of curing. This result indicates that the AA2 artificial aggregate had more strength and resistance against the crushing test compared with that of others. Compared with the natural gravel (8.11 MPa), the result gained by AA2 was still considered weak. However, the categorised artificial aggregate replaced the coarse aggregate for concrete production. AA1 demonstrated the lowest crushing value (1.00) for 28 curing days. The difference in crushing strength for all artificial aggregates was also observed for each age, demonstrating only slight variations. The crushing strength decreased as the content of silt increased due to the binding failure of the POFA proportion as the cementitious role with the high silt amount content in the mixture.

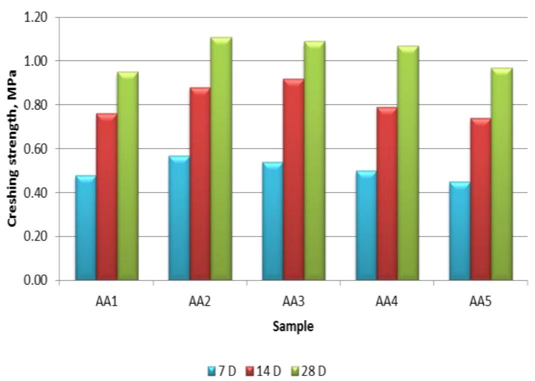

Figure. 4. Crushing strength for aggregate

D. Impact Strength of Artificial Aggregate

The impact value should be less than 45% for non-wearing surfaces or normal concrete application according to BS 882 Part 112 [13]. Estimating the possibility of aggregate failure rate subjected to load is crucial. Jeffry et al. [25] found that low percentage of impact value indicated the resistance of products towards impact test. Figure 5 shows the results for each sample, in which all samples satisfied the range of suitability as the aggregate materials. The high percentage of impact value indicated the slight resistance of aggregates towards sudden impact. AA2 achieved the lowest impact value (22.86%) amongst the five other samples. SS5 had the highest impact value of 28.28% but remained within the standard impact limit possibly due to the aggregate pore structure. Large amounts of open pores will affect the aggregate strength [26]. However, the artificial aggregate was less tough than that of the natural gravel. This finding can be attributed to the presence of internal void inside the artificial aggregate, which results in low strength. The pore inside the structure failed to withstand the application of strong sudden impact as it exited.

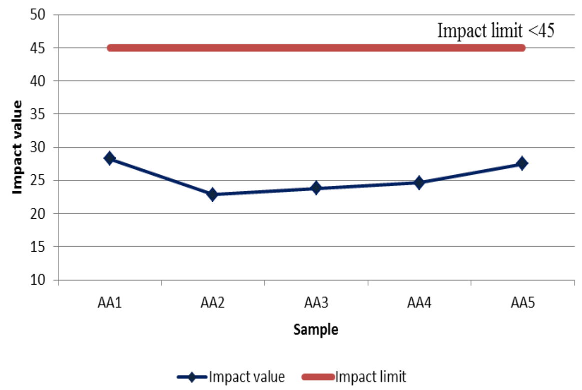

Figure. 5. Impact strength for artificial aggregate under impact limit (BS 882: 1992)

E. Microstructure of Artificial Aggregate

The microstructure of the AA2 is presented in Figure 6. The detailed image shows almost similar or homogeneous porosity, in which some macrovoids formed interphase of the artificial aggregate. Notably, the presence of the microvoid facilitated the hydration process. Figure 7 shows the SEM analysis, which interpreted the interface bond between silt and POFA under 1000 magnifications. Quantities of Na–S–H and C–S–H gels were formed using lime and alkaline activator and produced the binder matrix around silt to enhance the mixture. The SEM analysis also performed the examination and confirmation of information obtained from physical and mechanical testing. The AA2 structure provided the highest crushing strength and low water absorption for the aggregate mixture. The AA2 artificial aggregate produced two phases: the Na–S–H and the C–S–H gels. Most of the silt and POFA particles were hydrated, and a few pores were observed. This microstructure parameter simultaneously showed a high degree of reaction with the reduction of unreacted POFA silt particles.

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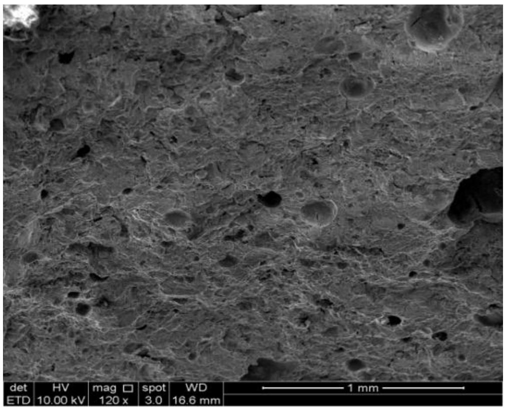


Figure. 6. SEM images for AA2 artificial aggregate: inner surface structure

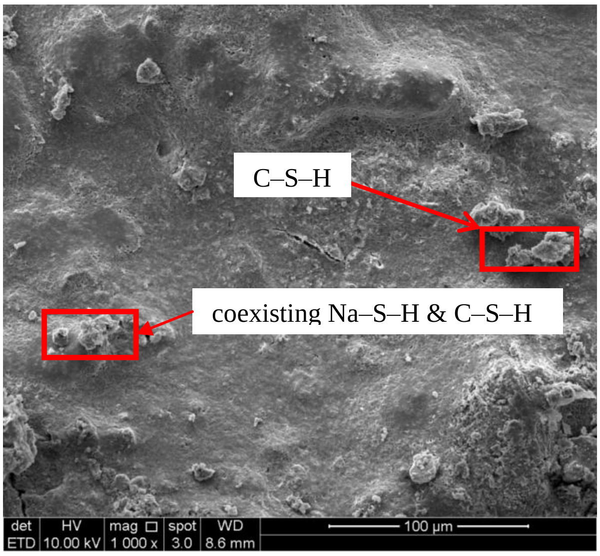
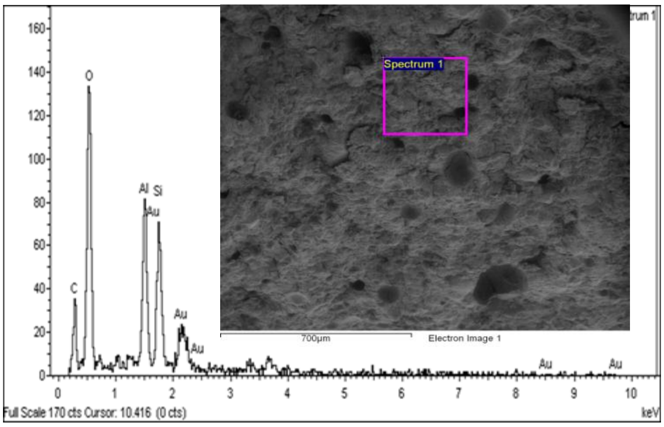
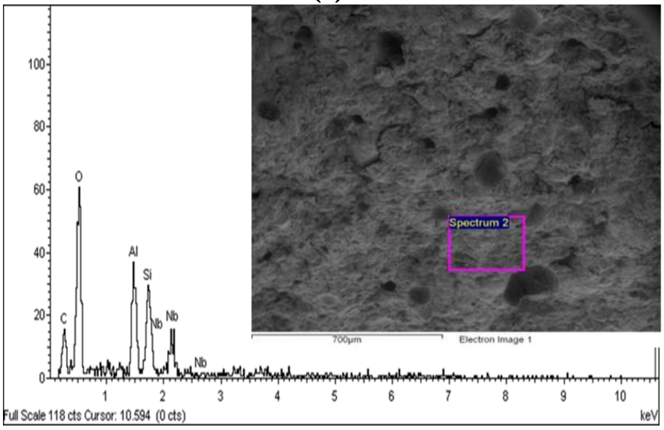


Figure 7: SEM test for AA2 artificial aggregate at magnification of 1000x

SEM was coupled with EDX to test the AA2 artificial aggregate and establish the mechanism reaction of the artificial aggregate. The EDX spectra were presented along with SEM micrograph to identify the elemental composition distribution within the AA2 artificial aggregate and the effect of reaction between materials. Two different spot regions were detected on AA2 aggregate to define the presence of chemical elements. As shown in Figure 8(a), spectrum 1 occupied the high oxygen percentage followed by carbon element, whereas spectrum 2 in Figure 8(b) did not contain carbon but has a peak value of oxygen. The available elements were influenced by the chemical reaction of the materials to form artificial aggregate. The distribution of aluminium and silicon elements for two different localised plots showed almost equal division with less percentage. Davidovits [27] claimed that the type of geopolymeric products can be predicted by the Si/Al elemental ratio. The two plotted regions had Si/Al of 0.96 and 1.00, which could be considered the polysialate (Si/Al below 1.5).



(a)



(b)

Figure. 8. Micrograph and elemental composition performed for the inner part of AA2 artificial aggregate (a) spectrum 1 and (b) spectrum 2

IV. CONCLUSION

The current study showed the physical and mechanical properties of artificial aggregate produced from POFA, silt, lime and alkaline activator. The overall conclusion for this research is presented as follows.

The production of artificial aggregate from the raw materials provided strength within the range of LWA; low-range strength was still observed. The mixture of waste materials had no high potential use for the construction industry. However, the application of the artificial aggregate into the manufacture of concrete should be further investigated to determine other alternatives to enhance the strength of artificial aggregate.

AA2 artificial aggregate with a mixture proportion of 60% silt and 40% POFA was suggested as the optimum mixture percentage for the production of artificial aggregate. This aggregate yielded the highest value amongst the other artificial aggregates and demonstrated an impact value below the impact limit. This optimum LWA exhibited a saturated dry density of 1.43, which was 52% lighter than that of natural gravel, crushing strength of 1.14 MPa and water absorption of 27.8% for 28 days curing time.

The density of the artificial aggregate was lighter than that of normal aggregate. Density occasionally varies depending on the general properties of raw materials used.

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High contents of silt proportion in the mixture increased the densification of artificial aggregate due to the high specific gravity of silt. Furthermore, the aggregate had higher porosity than that of normal gravel due to the presence of closed pores and the high percentage of water absorption. The water absorption corresponded to crushing strength, that is, high water absorption resulted in low crushing strength.

The EDX analysis shows that the S2 sample had high activator content, which provides moderate reacted dense aluminosilicate gel matrix through normal room temperature curing. Although the presence of unreacted silicate products will definitely weaken the reaction bond within artificial aggregates, the microstructure characteristic of the chosen aggregate will lead to extensive inter-structural interpretation. Therefore, artificial aggregate with less dense density is considered sufficient. Higher level of water absorption and inadequate strength should be examined and investigated further to improve the properties.

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REFERENCES

1. M. M. Norhasri, M. S. Hamidah, A. M. Fadzil, A. M., ''Applications of using nano material in concrete: A review'', Construction and Building Materials, 133, 2017, pp. 91-97.
2. E. Aprianti, ''A huge number of artificial waste material can be supplementary cementitious material (SCM) for concrete production–a review part II'', Journal of Cleaner Production, 142, 2017, pp. 4178-4194.
3. P. Shafigh, M. A. Nomeli, U. J. Alengaram, , H. B. Mahmud, M. Z. Jumaat, ''Engineering properties of lightweight aggregate concrete containing limestone powder and high volume fly ash'', Journal of Cleaner Production, 135, 2016, pp. 148-157.
4. M. Prabu, S. Logeswaran, D. S. George, ''Influence of GGBS and Eco Sand in green concrete'', International Journal of Innovative Research in Science, Engineering and Technology, 4(6), 2015.
5. T. Gondo, H. Mathada, F. Amponsah-Dacosta, ''Regulatory and policy implications of sand mining along shallow waters of Njelele River in South Africa'', Journal of Disaster Risk Studies, 11(3), 2019.
6. K. A. Olonade, M. B. Kadiri, P. O. Aderemi, ''Performance of steel slag as fine aggregate in structural concrete'', Nigerian Journal of Technology, 34(3), 2015, pp. 452-458.
7. E. Aprianti, P. Shafigh, S. Bahri, J. N. Farahani, ''Supplementary cementitious materials origin from agricultural wastes–A review'', Construction and Building Materials, 74, 2015, pp. 176-187.
8. N. A. Adam, A. Sulaiman, A. S. Baharuddin, M. N. Mokhtar, Z. Busu, T. E. T. Z. Mulok, ''Synthesis and Characterisation of Silica from Palm Oil Fuel Ash (POFA) Using Alkaline Fusion Method'', Journal of Science and Technology, 25, 2017, pp. 269-276.
9. S. P. Yap, U. J. Alengaram, M. Z. Jumaat, K. Y. Foong, ''Waste Materials in Malaysia for Development of Sustainable Concrete: A Review'', Electronic Journal of Structural Engineering, 13(1), 2013, pp. 60-64
10. T. Ahmad, K. Ahmad, M. Alam, ''Characterization of water treatment plant's sludge and its safe disposal options'', Procedia Environmental Sciences, 35, 2016, pp. 950-955.
11. M. Aslam, P. Shafigh, M. Z. Jumaat, ''Oil-palm by-products as lightweight aggregate in concrete mixture: a review'', Journal of Cleaner Production, 126, 2016, pp. 56-73.
12. L. Emdadi, D. Liu, ''One-step dual template synthesis of hybrid lamellar-bulk MFI zeolite'', Journal of Materials Chemistry A, 2(33), 2014, pp. 13388-13397.
13. British Standards Institution ''Testing Aggregates. Part 112: Methods for Determination of Aggregate Impact Value (AIV)'', 1990.
14. British Standards Institution ''Testing Aggregates. Part 110: Methods for Determination of Aggregate Crushing Value (ACV)'', 1990.
15. N. U. Kockal, T. Ozturan, ''Effects of lightweight fly ash aggregate properties on the behavior of lightweight concretes'', Journal of Hazardous Materials, 179(1-3), 2010, pp. 954-965.
16. P. Priyadharshini, M. G. Ganesh, A. S. Santhi, ''Experimental study on cold bonded fly ash aggregates'', International Journal of Civil and Structural engineering, 2(2), 2011, pp. 493.
17. C. F. Lin, C. H.Wu, H. M. Ho, ''Recovery of municipal waste incineration bottom ash and water treatment sludge to water permeable pavement materials'', Waste Management, 26(9), 2006, pp. 970-978.
18. ASTM C618-05, "Standard Specification for Coal Fly Ash and Raw or Calcinated Natural Pozzolan for Use in Concrete," ASTM International, West Conshohocken, PA, pp. 3, 2005, .
19. ASTM C618-12a, ''Standard specification for fly ash and raw material or calcined natural pozzolan for use as a mineral admixture in Portland cement concrete'', Part 5. ASTM Internationals, West Conshohocken, PA, 2012.
20. G. Y. Jayasinghe, I. L. Arachchi, Y. Tokashiki, ''Evaluation of containerized substrates developed from cattle manure compost and synthetic aggregates for ornamental plant production as a peat alternative'', Resources, Conservation and Recycling, 54(12), 2010, pp. 1412-1418.
21. G. Baykal, A. G. Doven, ''Lightweight concrete production using unsintered fly ash pellet aggregate'', 13th International Symposium on Used and Management of Coal Combustion Products, ACAA International, 2000, pp. 11-15.
22. J. Yliniemi, J. Pesonen, P. Tanskanen, O. Peltosaari, M. Tiainen, H. Nugteren, M. Illikainen, ''Alkali Activation–Granulation of Hazardous Fluidized Bed Combustion Fly Ashes'', Waste and Biomass Valorization, 8(2), 2017, pp. 339-348.
23. M. Google, E. Guneyisi, H. O. Oz, ''Properties of lightweight aggregates produced with cold-bonding pelletization of fly ash and ground granulated blast furnace slag'', Materials Structural, 45, 2012, pp. 1535-1546.
24. P. C. Lau, D. C. L. Teo, M. A. Mannan, ''Characteristics of lightweight aggregate produced from lime-treated sewage sludge and palm oil fuel ash'', Construction and Building Materials, 152, 2017, pp. 558-567.
25. A. Jeffry, S. Nur, R. P. Jaya, N. Manap, N. A. Miron, N. A. Hassan, '' The influence of coconut shell as coarse aggregates in asphalt mixture'', In Key Engineering Materials, 700, 2016, pp. 227-237.
26. P. Risdanareni, J. J. Ekaputri, ''The influence of alkali activator concentration to mechanical properties of geopolymer concrete with trass as a filler'', In Materials Science Forum, 803, 2015, pp. 125-134.
27. J. Davidovits, ''Geopolymer-Chemistry and Applications''. Saint-Quentin: Institute Geopolymer.

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Kwek Shi Ying finished her bachelor degree study in Building Surveying and received master degree in Building Technology in School of Housing, Building and Planning, USM. She had attended Sustainable Construction Congress and Conference to present the research works. Before that, she interned as a Quantity Surveyor in Construction firm and responsible for the measurement work on commercial buildings. Presently she is pursuing as a full-time PhD student in Universiti Sains Malaysia. Her research is mainly focusing on construction materials which modified the unwanted waste into useful building materials. Currently is doing about the artificial aggregate production from industrial waste.

Hanizam Awang joined School of Housing, Building and Planning, Universiti Sains Malaysia on 16 April 2001 as a lecturer in Building Technology Programme. She obtained her first degree from Universiti Teknologi Malaysia in civil engineering. She received her master's degree from Newcastle University and her Ph.D in civil and structural engineering from Universiti Kebangsaan Malaysia. She has some years of working experience with several civil & structural consultant, and contractor firms before joining Universiti Sains Malaysia. She has published her academic articles in indexed journals, and presented many international and local papers in the field of engineering, building material and building construction. She is leading few research projects on lightweight foamed concrete and supervising postgraduate students by research and coursework at MSc and Ph.D. levels at the school of Housing, Building & Planning, USM. Her specialization lies in the area of advanced concrete materials and lightweight concrete.