Progress in Engineering Application and Technology Vol. 2 No. 2 (2021) 321-337
© Universiti Tun Hussein Onn Malaysia Publisher's Office

PEAT

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 2773-5303

Comparative Study of Palm Oil Fuel Ash (POFA) and Rice Husk Ash (RHA) as Supplementary Cementitious Material (SCM) in Brick: A Review

Nurul Syadza Zamri[1], Suraya Hani Adnan[1]*

[1]Department of Civil Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/peat.2021.02.02.032
Received 13 January 2021; Accepted 01 March 2021; Available online 01 December 2021

Abstract: This study is to review the properties as supplementary cement material (SCM) in brick with Palm Oil Fuel Ash (POFA) and rice husk ash (RHA). POFA and RHA may reduce CO_2 emissions as new substitute for natural materials, sand, clay and cement from cement brick. The analysis involves characterization, optimal POFA and RHA ratios, water absorption, as well as compressive strength. The compressive strength, density and water absorption of brick is demonstrated in the findings when integrated in different levels of POFA and RHA as a part cement replacement in brick. Based on the previous study the density of brick and compressive strength decreased as the substitution percentage increased which is POFA at percentage range from 20% to 30% and this can be a method for a lightweight brick and a lasting brick. RHA are good in water absorption despite of greater porosity and high pozzolanic at percentage range from 10% to 30%. The results shows that the POFA and RHA as a waste management medium can be used in cement and sand substitution for lightweight brick.

Keywords: Brick, Palm Oil Fuel Ash (POFA), Rice Husk Ash (RHA), Supplementary Cementitious Material

1. Introduction

Since the beginning of development, constructionn materials have played a major role in the structure of the building and its impact on the surrounding environment. Brick is one of the principal building materials widely used in construction projects involving specifically the construction of walls, floors and other buildingg components. The structural savings by increasing the dead load of the building are also increased by up to 20.00 % where these properties allow it to reduce the damage of the building during an earthquake. Unfortunately, the production of Ordinary Portland cement (OPC) accounts for approximately 5.00 to 8.00 % of the global (CO_2) emissions. The demanding and excessive use of cement and sand dust pollutants in brick manufacture caused environmental effects of air pollution in the emission of gaseous carbon dioxide, (CO_2) into the air and general utilization of natural

---

*Corresponding author: suraya@uthm.edu.my materials such as sand and clay could probably give a negative impact for the environment or people in the future [1,2].

Today's worldwide trends are focused both on waste recovery and the use of waste as raw materials wherever possible in the construction sector [3]. The rapidly rising global population is being driven by higher demand for building materials and as a result, raw materials and natural supplies are increasingly diminished and building material costs increase. In this case, the challenge for engineers is to solve this potential sustainability problem [4]. In construction, it shows that it is necessary to explore more compact and tailor-made brick components and to maintain building standard requirements for low-cost and environmentally sustainable masonry systems.

Compatible bonding with aggregates (comparable with cement) and displaying good pozzolanic behavior are the important properties of supplementary cementitious materials (SCM) [5]. In Malaysia, the environmental pollution issue resulting from the disposal of palm oil fuel ash or POFA which is a product of palm oil mill with addition of rice husk ash has initiation for this research to incorporate with POFA waste and rice husk ash as replacement of cement and clay in lightweight brick making. Therefore, due to this issue happening, this research study is for an initiative of innovation brick design approach and due to the demand for low-cost materials for construction by using waste materials in making of brick and to reduce environmental pollution.

1.1 Problem Statement

A cement process which contributes about 7.00 % of the world's (CO_2) emissions is responsible for the environmental and greenhouse gas problem [6]. Dirty dust exposure and subsequent inhalation can cause upper respiratory tract symptoms such as throat irritation, persistent cough, and phlegm. Moreover, exposure to emphysema can be caused by cement particles. This problem will increase as many workers are not aware of this matter.

This study proposes a new approach to minimize the impacts of (CO_2) emissions on buildings and to increase their structural stability for a longer time as these would encourage the construction industry in Malaysia to utilize POFA and rice husk ash in their construction materials. Therefore, in this study of POFA and rice husk ash will be review in brick as an alternative solution to reduce the portion of cement used and reduce the uses of natural clay and sand dust.

1.2 Objective

This study will be conducted on a variety of forms of research of brick that are incorporated with POFA and rice husk ash based on the previous study.

The main objectives of this research works are:

i. To review the compressive strength and water absorption of POFA and RHA on brick.
ii. To make a comparative study on the performance of POFA and RHA on the brick.

1.3 Scope of the study

This study is focusing on the review based on the previous study of the possibility of palm oil fuel ash (POFA) and rice husk ash (RHA) to be incorporated as a replacement in cement and clay for brick. There are two types of performance test will be a review which is compressive strength and water absorption.

2. Methodology

The research methodology covers materials particularly palm oil ash (POFA) and rice husk ash (RHA) from the beginning of the working plans up to the end of the data collection study. POFA and RHA are evaluated physically for size and color and weighed following the proportion specified before designing the brick mixtures. A variety of tests known as compressive strength tests and water absorption tests will be reviewed to determine the efficiency of the concrete brick containing POFA as a partial substitute of cement and rice husk ash as a partial replacement of the fine aggregate and as supplementary cementitious material (SCM) in brick.

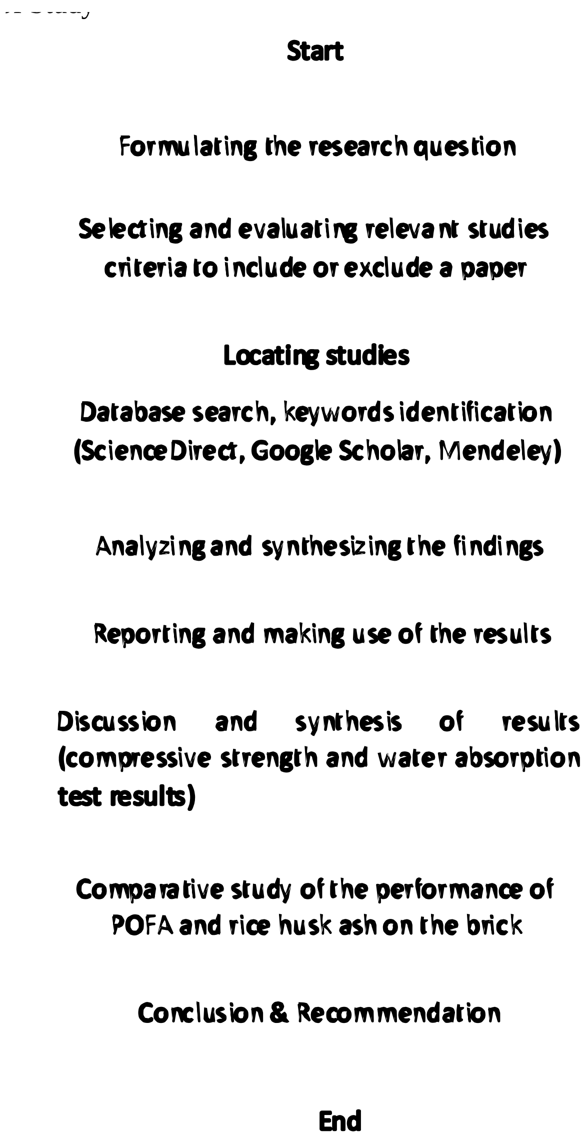


Figure 1: Research flowchart

3. Results and Discussion

At the end of this study, based on the previous result:

Table 1: A summary of the previous study for incorporating POFA and RHA into brick mixes

Waste Product	Usage	Dosage amount	Effect of usage of waste materials in brick	Reference
POFA and Rice Husk (RH)	Cement and Sand	● (2%-10% POFA) compressive strength decreased	● No water absorption recorded ● Compressive	[7]

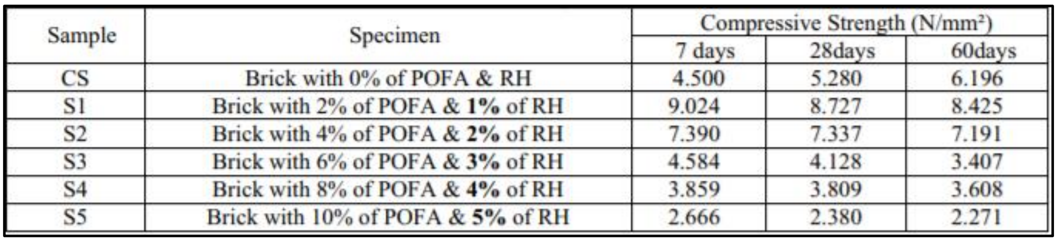
		● (1%-5% RH) compressive strength decrease	strength reduced ● Density slightly decreased from 28 and 60 day ● Specific gravity decreased	
POFA	Cement	● (5-25% POFA) compressive strength increased ● (20-40% EPS) compressive strength decreased ● (10-20% POFA with size particle 300 µm, 150 µm and, 75 µm) compressive strength increased	● Compressive strength slightly decreased ● compressive strength increased at 28 days ● Water absorption increased ● Larger porosity ● More void	[8] [9]
POFA	Cement	● (20% POFA) compressive strength increase ● (60% POFA) compressive strength decrease	● Compressive strength at 56 days is higher than at 28 days ● High pozzolanic activity ● Water absorption increased ● High pozzolanic activity	[10]

RHA	Cement	(5-15% RHA) compressive strength decreased	● Compressive strength reduced ● Water absorption increased ● Higher porosity	[11]
RHA	Cement	(40% and above RHA) compressive strength decreased	● Compressive strength reduced ● High porosity ● Water absorption increased	[12]
RHA	Clay	(5-30 % RHA) compressive strength decreased	● Compressive strength slightly decreased ● Larger porosity ● Water absorption increased ● Lower water absorption for brick fired at 1000 °C ● No efflorescence after 45 days	[13] [14]

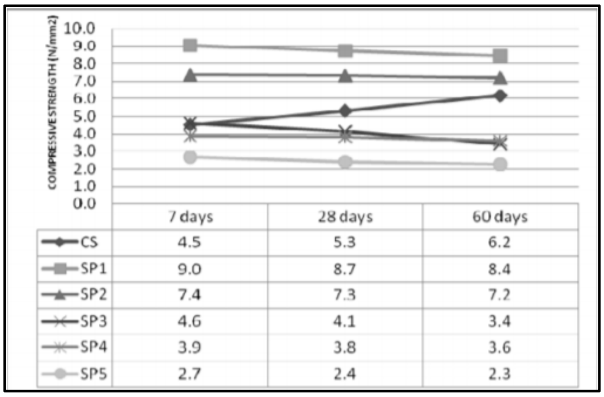
3.1 Compressive Strength of POFA and RHA

A study by Saleh A.M et. al., (2014) stated that the increased percentage of POFA and rice husk (RH) in the mixed design of brick reduced the compressive strength. Figure 1 shows the compressive force of various mixtures of samples of bricks. Table 2 shows the summary result of compressive strength. Brick with 2.00 % of POFA & 1.00 % of RH was the best combination of POFA and RH in this research that showed higher compressive strength than control brick which is 8.425 N/mm². As the curing time increased, the intensity of the control specimens increased. There is no water absorption result recorded by this author.

Table 2: Result of Compressive Strength [7]



Sample	Specimen	Compressive Strength (N/mm²)		
		7 days	28days	60days
CS	Brick with 0% of POFA & RH	4.500	5.280	6.196
S1	Brick with 2% of POFA & **1%** of RH	9.024	8.727	8.425
S2	Brick with 4% of POFA & **2%** of RH	7.390	7.337	7.191
S3	Brick with 6% of POFA & **3%** of RH	4.584	4.128	3.407
S4	Brick with 8% of POFA & **4%** of RH	3.859	3.809	3.608
S5	Brick with 10% of POFA & **5%** of RH	2.666	2.380	2.271



	7 days	28 days	60 days
CS	4.5	5.3	6.2
SP1	9.0	8.7	8.4
SP2	7.4	7.3	7.2
SP3	4.6	4.1	3.4
SP4	3.9	3.8	3.6
SP5	2.7	2.4	2.3

Figure 1: Compressive Strength of different mixture of POFA & RH [7]

A study by N.A. Kamarulzaman et. al., (2018) stated that the higher the expanded polystyrene beads EPS and POFA substitute, the lower the strength of the brick. However, the strength remains appropriate and for the non-load bearing structure still applicable to the bricks. Figure 2 and figure 3 represent the result of 7 day and 28 days compressive strength for all mix designs. The lowest compressive strength recorded is 3.7 MPa for a mixture of 50.00 % EPS substitution and 25.00 % POFA substitution at 7 days curing. At 28 days, control brick recorded the highest compressive strength with 27.9 MPa and brick with 50.00 % EPS, and 25.00 % POFA replacement recorded the lowest strength with 6.3 MPa. The highest waste content brick with a maximum waste replacement of 25.00 % POFA and 50.00 % EPS is the most successful result, and the compressive strength requirement for lighter bricks can be achieved. Figure 4 showed the compressive strength result of 56 days for all mix designs. Control brick and brick with 0.00 % EPS replacement and 5.00 % POFA replacement recorded the same highest strength with 28.6 MPa and brick with 50.00 % EPS and 25.00 % POFA replacement recorded the lowest strength with 5.4 MPa. The trend showed that the greater the brick strength, the greater EPS and, POFA replacement. Moreover, when OPC is replaced by POFA, water absorption is increased. Then, as sand is replaced by EPS, the absorption of water reduces. Reported the maximum water absorption is 13.40 % at E0P25 mixture, while at E50P0 mixture is 4.37 % which is the minimum water absorption as shown in Figure 5. The lowest water absorption properties of brick are at 0.00 % POFA and 50.00 % EPS replacement whereas brick with 25.00 % POFA and 0.00 % EPS replacement has the highest water absorption properties. From Table 2, it can be concluded that brick with higher EPS replacement can be assumed that has less void, and brick with higher POFA replacement has more porous and more voids.

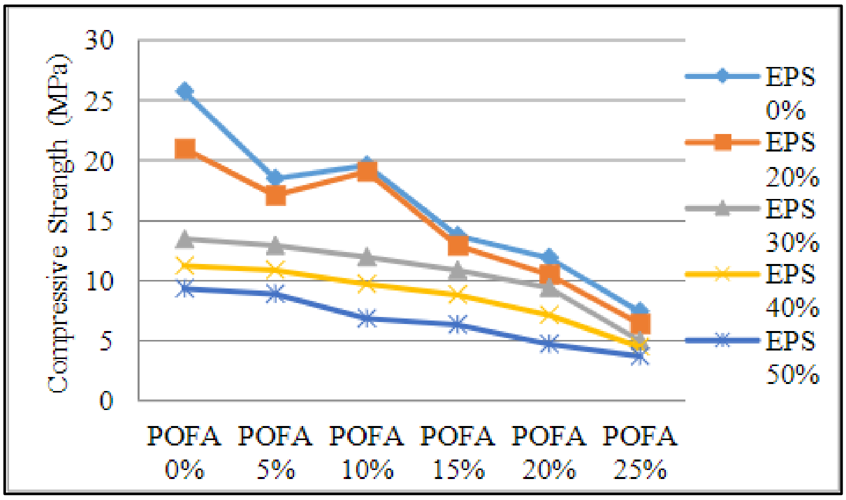


Figure 2: Compressive strength graph of 7-days bricks sample [8]

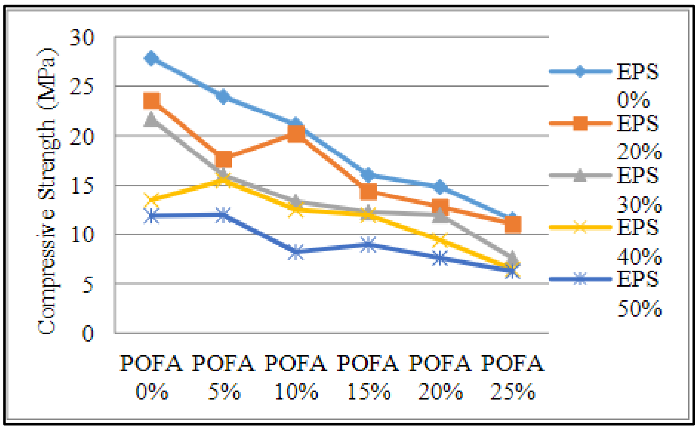


Figure 3: Compressive strength graph of 28-days bricks sample [8]

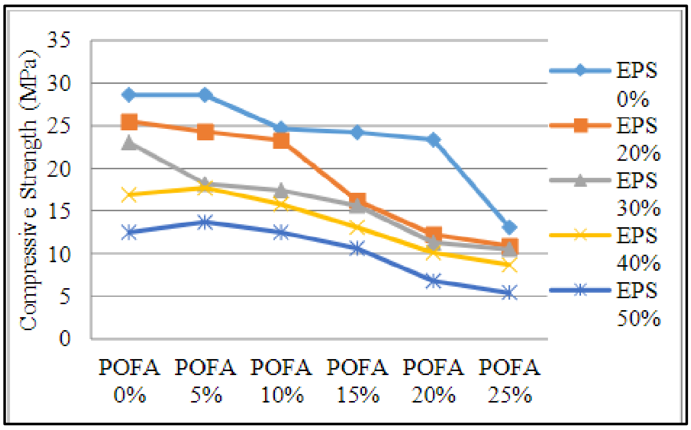
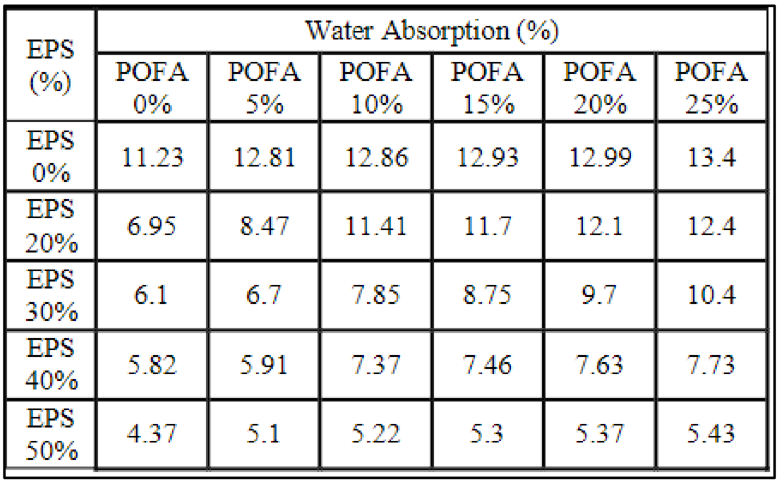


Figure 4: Compressive strength graph of 56-days bricks sample [8]



EPS (%)	Water Absorption (%)					
	POFA 0%	POFA 5%	POFA 10%	POFA 15%	POFA 20%	POFA 25%
EPS 0%	11.23	12.81	12.86	12.93	12.99	13.4
EPS 20%	6.95	8.47	11.41	11.7	12.1	12.4
EPS 30%	6.1	6.7	7.85	8.75	9.7	10.4
EPS 40%	5.82	5.91	7.37	7.46	7.63	7.73
EPS 50%	4.37	5.1	5.22	5.3	5.37	5.43

Table 3: Percentages of water absorption for various proportions at 28days [8]

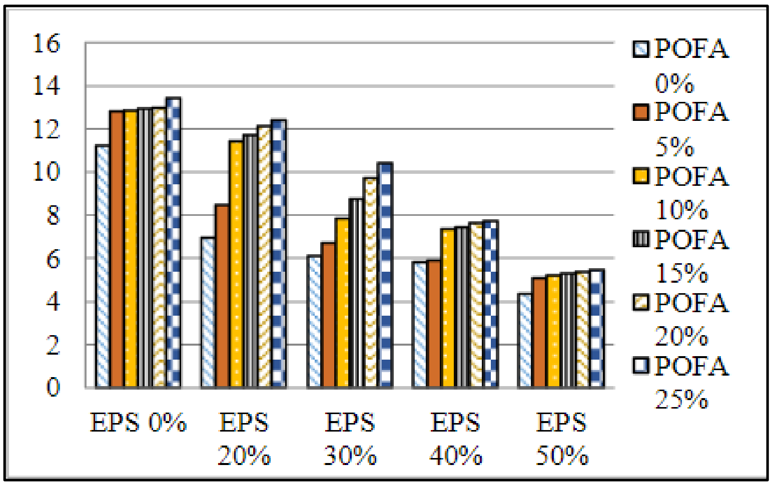
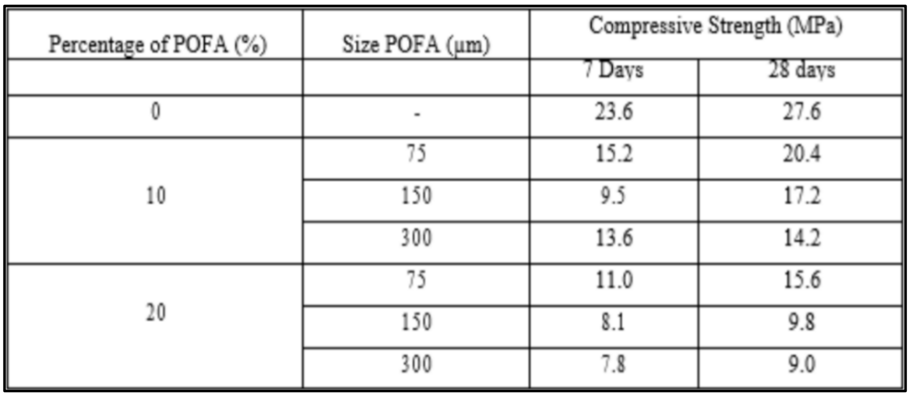


Figure 5: Percentages of water absorption for different percentage of EPS and POFA replacement at 28 days [8]

This observation was also corroborated by T. M. Zailani et. al., (2018) in which it was reported that the relation between the compressive strength of brick and the percentage of POFA replacement is a positive correlation where the compressive strength increases due to the all different size of POFA substitution under age of curing, is completely predicted to be of maximum brick strength by 28 days. For the size 75 µm, the POFA replacement by 10.00 % has the highest compressive strength sample at 28 days compared with other POFA sizes and percentages as shown in Figure 6. Table 4 represents the maximum compressive strength value for 7 days with 20.00 % POFA replacements is 11 MPa and 28 days is 15.6 MPa, which are respectively 75 µm of POFA. The best result can be obtained by using 10.00 % POFA substitute with sizes of 75 µm where the intensity of the compressive strength, 20.4 MPa is higher than the control samples, since the addition of 10.00 % POFA as a partial cement substitute promotes greater hydration and a pozzolanic reaction leading to a larger C-S-H gel that is the gel occupies the existing voids in brick making it denser and stronger the POFA percentage is better because it is slightly decreased in the amount of water absorption that is 10.82 % in 28 days, compared with control which is 11.36 % at 28 days. As the pozzolanic response of POFA also reduced the size of pores brick due to the pore refinement because POFA particles were more porous and have a greater specific surface. Figure 7 shows different water absorption for different percentage and size of POFA where the effect of water absorption at 10.00 % cement substitution with POFA is ideal at the size of 75 µm which is 10.82 %.

Table 4: The summary result of compressive strength for 10.00 % and 20.00 % POFA



Percentage of POFA (%)	Size POFA (µm)	Compressive Strength (MPa)	
		7 Days	28 days
0	-	23.6	27.6
10	75	15.2	20.4
	150	9.5	17.2
	300	13.6	14.2
20	75	11.0	15.6
	150	8.1	9.8
	300	7.8	9.0

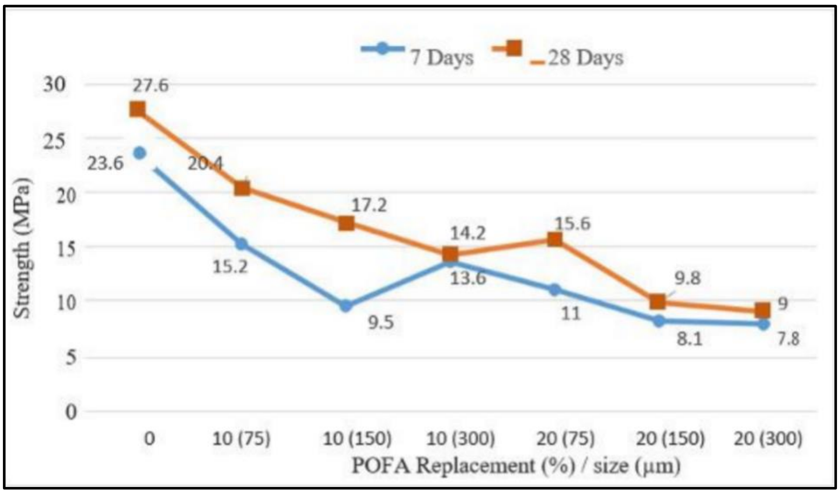


Figure 6: Compressive strength versus age for a different level of POFA

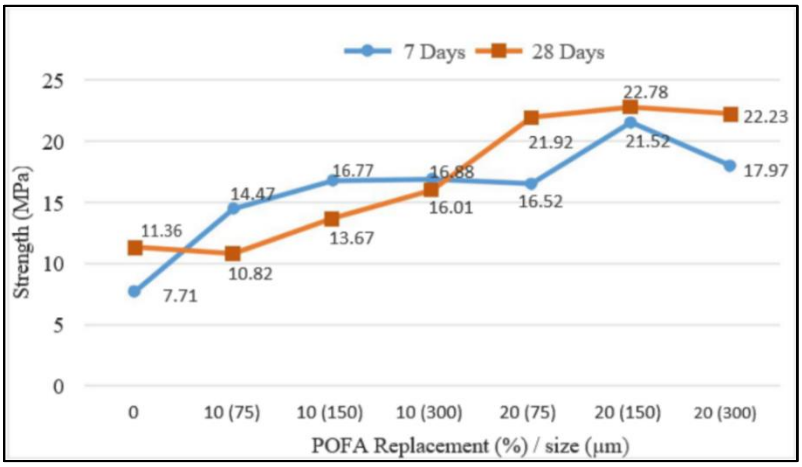


Figure 7: Water absorption variation percentage and size of POFA at 7 and 28 days [9]

3.2 Compressive Strength and Water Absorption of POFA

An investigation by M.E. Rahman et. al., (2014) stated that an increasing percentage of POFA substitution reduced the compressive strength and breakage load of the masonry blocks. However, it satisfies the requirements of Class 1 and Class 2 load-bearing masonry block according to Malaysian Standard MS76:1972. Figure 8 shows that 56 days of masonry blocks have a higher compressive strength than 28 days blocks. The reason can be cement responds continually with the time that generates additional CSH gel, giving the masonry block greater compressive strength. The pozzolanic activity steadily decreases the content of calcium hydroxide through the POFA reaction with silicon dioxide (Ahmad et al., 2007). Figure 9 shows with an increase of the POFA percentage, compressive strength decreased where the percentages of POFA are 0.00 %, 20.00 %, 40.00 %, and 60.00 %. The explanation for this phenomenon is possible because of the finer particles of POFA. The water absorption of the POFA masonry blocks is shown to be significantly higher (0.10 %) in comparison with the control masonry blocks. The explanation is the larger porosity of POFA that facilitates water absorption. The water absorption results are shown in Figure 10. The overall water absorption values were below the maximum water absorption capacity by ASTMC55-11 which is 208 kg/ for normal weight masonry block, 240 kg/ for medium weight masonry block, and 320 kg/ for lightweight masonry block.

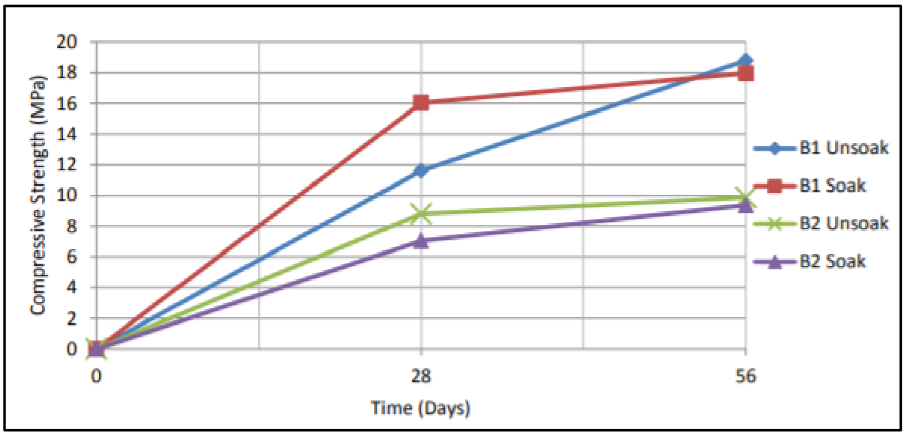


Figure 8: Average compressive strengths of masonry blocks for batches B1 (0.00 %) and B2 (60%) under unsoaked and soaked conditions [10]

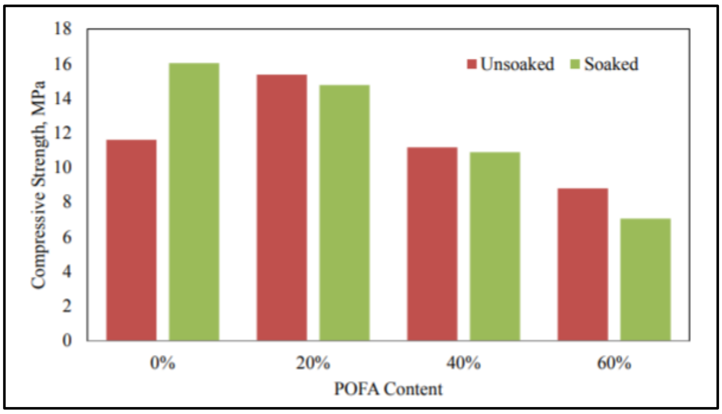


Figure 9: Average compressive strengths of masonry blocks at 28 days for soaked and unsoaked conditions [10]

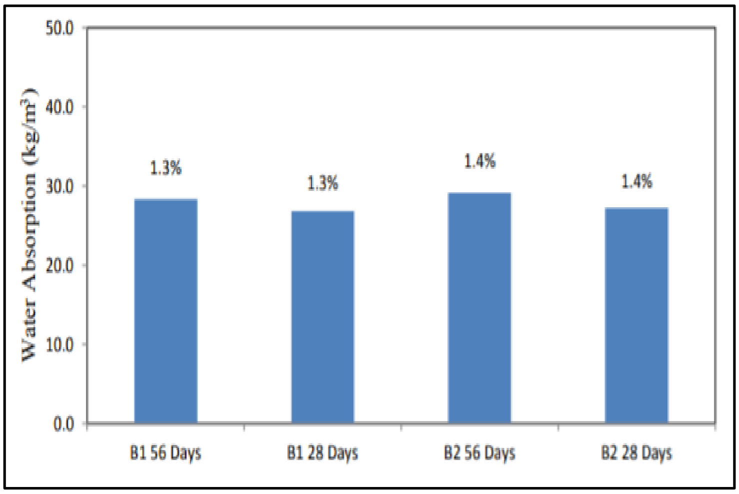


Figure 10: Water absorption of different batches B1 (0.00 %) & B2 (60.00 %) of masonry blocks [10]

3.3 Compressive Strength and Water Absorption of RHA

According to M.S. Sultana et. al., (2014), the compressive strength of brick does not increase with the use of various additives. The mechanical strength of the samples has ranged from 3.44-10.67 MPa shown in Figure 11. In addition to other characteristics, increasing or decreasing compressive strength often depends upon type of soil, type of kiln, and the manufacturing process. Increasing percentages of rice husk ash do not enhance the compressive strength of the sample as claimed by O. S. Obam and A. Y. Iorliam (2011). An increase in water absorption and porosity of all brick samples with an increase in RHA and fly ash (FA) percentages. Water absorption of the samples has ranged from 7.00 % to 11.00 % where maximum absorption obtained 10.34 % for 15.00 % RHA and 10.28 % for 15.00 % fly ash (FA). From Table 5, can be observed that the water absorption and porosity of all samples can be increased with increasing RHA and fly-ash percentages due to may be due to presence of more amorphous silica and which acts as filler material. Thus, both fly ash (FA) and RHA of 15.00 % could be used to boost those clay characteristics.

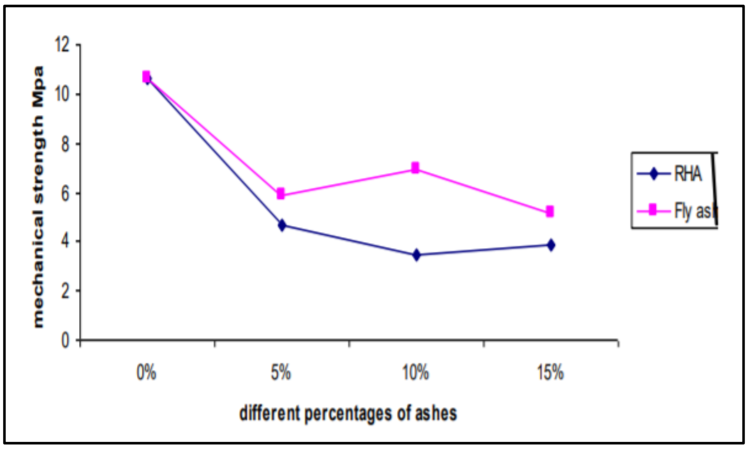


Figure 11: Compressive strength variation with different ashes [11]

Table 5: Physical properties of the prepared samples [11]

Properties	Clay without addictive	5% RHA	10% RHA	15% RHA	5% FA	10% FA	15% FA

Water absorption (%)	7.6	7.42	8.73	10.34	9.29	9.3	10.28
Porosity (%)	13.8	13.2	16.17	19.46	16.42	17.56	17.98

A study by Chao-Lung Hwang and Trong-Phuoc Huynh (2015) revealed that the compressive strength of all the brick samples increased with the curing age. Figure 12 shows the compressive strength of brick samples under different URHA replacement levels along with age (days). The positive correlation between the curing time and the comprehensive of the reaction between pozzolanic materials and alkali activator solution has led to this increase and greater gelling fills more pores within the bricks over time and builds an increasingly dense structure. However, using URHA as a sand substitute decreases the compressive strength of brick significantly as the amount of URHA increased. Figure 13 shows the brick samples after 28 days of age had a respective compressive strength of the brick samples with 0.00 %, 10.00 %, 20.00 %, 30.00 %, and 40.00 % of URHA replacement levels had a respective compressive strength of 31.5 MPa, 28.1 MPa, 24.4 MPa, 23.1 MPa, and 20.9 MPa. This means URHA is highly porous and the loss compactness of the bricks with higher URHA levels has resulted in lower compressive strength but the outcome clearly shows that the brick samples in good compressive strength and brick samples provided for the study complied with the grade M200 within TCVN 1451:1998, which is the criteria for designating the best quality of construction bricks. higher levels of URHA are associated with higher rates of water absorption, mostly due to the substantially more porous character of URHA particles. Figure 14 shows that the water absorption test result of 28 days sample bricks containing a variety of URHA percentages. The majority of brick samples had water absorption, both with and without URHA material of less than 16.00 % at that level required by TCVN 1451:1998. Thus, it shows that the water absorption of brick samples greatly improved when natural sand was replaced by URHA. Higher URHA substitute levels are correlated with higher water absorption, mainly due to the mentioned substantially more porous nature of URHA particles.

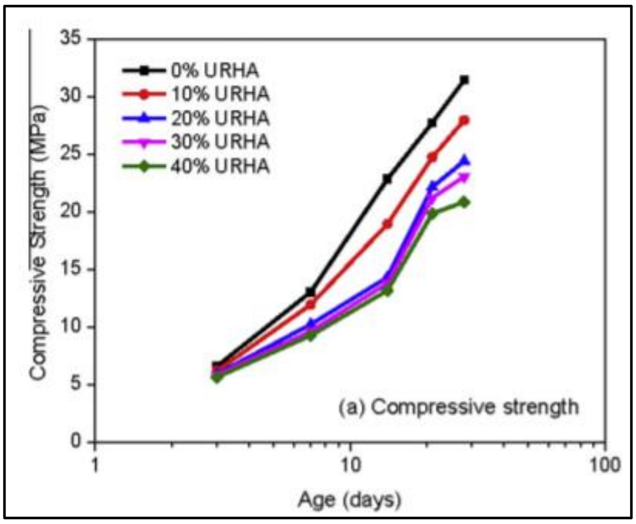


Figure 12: Compressive strength of brick sample under different URHA replacement levels [12]

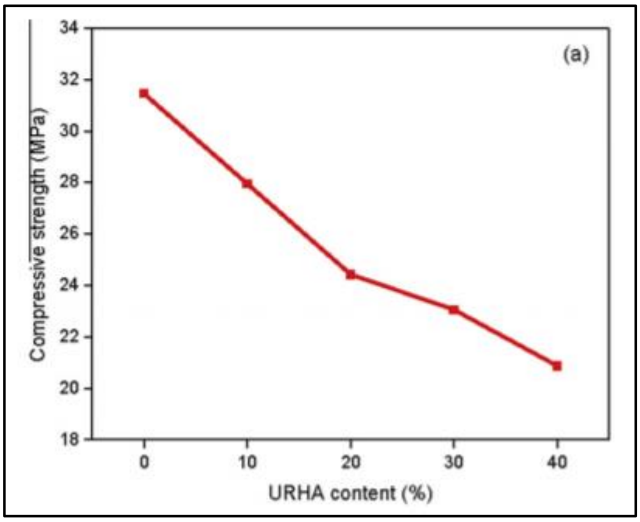


Figure 13: Impact of the URHA content in brick samples on compressive strength [12]

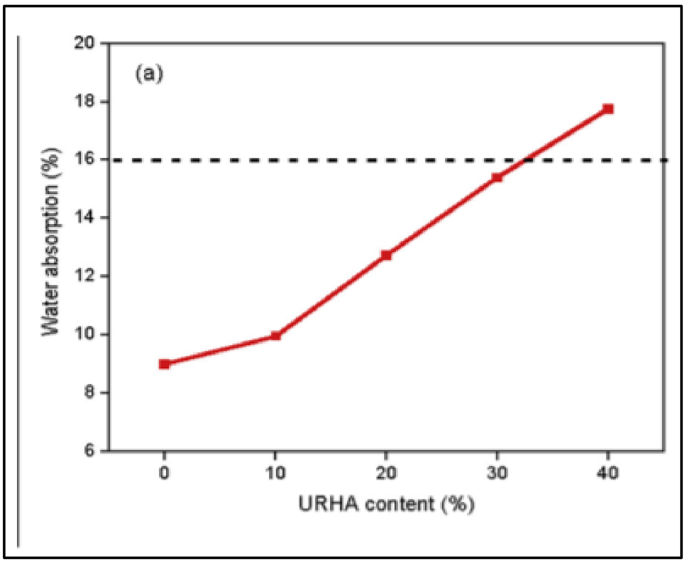


Figure 14: Effect of the URHA content on the water absorption [12]

The compressive strength values presented by S.M.S. Kazmi et. al., (2016), where brick specimens were fired at approximately 800 °C for 36 hours. The test results are shown in Figure 15 that the control specimen had higher compressive strength without the addition of sugarcane bagasse ash SBA and RHA. The rise in RHA and sugarcane bagasse ash SBA replacement decreased the compressive strength of brick. An approximately 14.00 % decrease was seen in the compressive strength of a brick specimen having a 5.00 % clay weight of SBA compared with the specimen without SBA. After incorporating 5.00 % of RHA and SBA, the compressive strength of 6.62 MPa and 7.18 MPa was shown in brick specimens, which satisfied the Building Code 2007 minimum compressive strength requirement. The compressive strength was lowered to around 5.00 % to 10.00 % and 15.00 % for the SBA substitution of clay. Similar compressive strength reduction with RHA substitution was observed. In general, the compression of brick samples is considered to depend primarily on their density, porosity, and pores. The increase in porosity has resulted in the reduction of mechanical strength properties compared to the control of bricks. water absorption increased with a higher percentage of sugarcane bagasse ash (SBA) and RHA replacement. However, brick specimens with RHA displayed lower water absorption than those with SBA. For example, bricks that incorporated RHA showed less than 21.00 % absorption. Figure 16 shows the water absorption for brick specimens incorporating SBA and RHA. A mixture of SBA showed up to 26.00 % water absorption with 15.00 % substitute clay for SBA. The porous nature of SBA can be responsible for this. For brick specimens containing 5.00 % SBA or RHA, water absorption was respectively 21.00 % and 18.00 %. Thus, bricks with lower RHA and SBA contents, i.e. 5.00 %, can be concluded within the defined water absorption limits leading to cost-saving and sustainable construction.

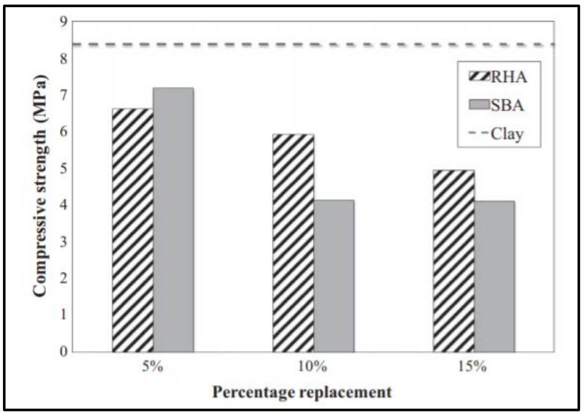


Figure 15: Effect of RHA and SBA wastes on compressive strength of brick [13]

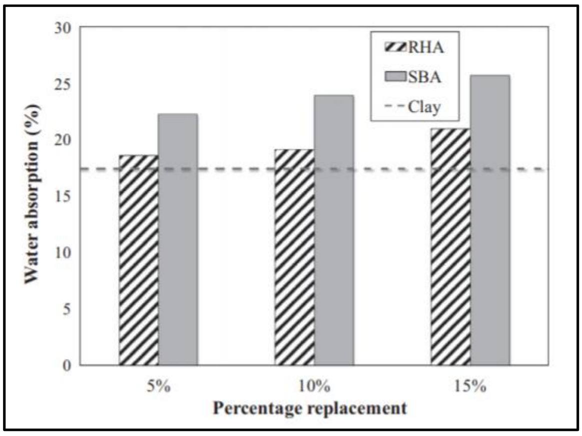


Figure 16: Effect of RHA and SBA on water absorption of brick specimens [13]

In a recent study by Eliche Quesada, et. al., (2017) on the compressive strength of RHA and wood ash (WA) especially for the samples with RHA, the reduction in compressive strength was more marked than for those with wood ash WA, a result of a decrease of the appropriate values for bulk density. Brick samples were developed by compression at 54.5 MPa and fired at a heat rate of 3 ℃ per minute at a temperature of 900 or 1000 ℃ for 4 hours. Figure 17 presents the compressive strength of the fired samples as a function of waste content and firing temperature. The data showed that RHA quantities of more than 10 wt% decreased compressive strength considerably. Bricks made of biomass ash were the lowest compression strength, and this property was lower when bricks were generated with the highest proportion of RHA due to greater porosity. The bricks with RHA showed higher absorption of water, reaching up to 32.90 % when 30.00 % of the waste was added. Figure 18 shows water absorption as a function of biomass ash content and firing temperature in the 900–1000 ºC range. For bricks fired at 1000 °C, much lower water absorption was achieved particularly with the addition of RHA contain more proportion of organic matter and wood ash (WA), which has a higher content of fluxing oxides. Moreover, the addition of more than 10 wt% of RHA waste led to bricks with high water absorption levels that do not conform with the conventionally manufactured bricks requirements. The added value of biomass ash increased for apparent porosity and water absorption.

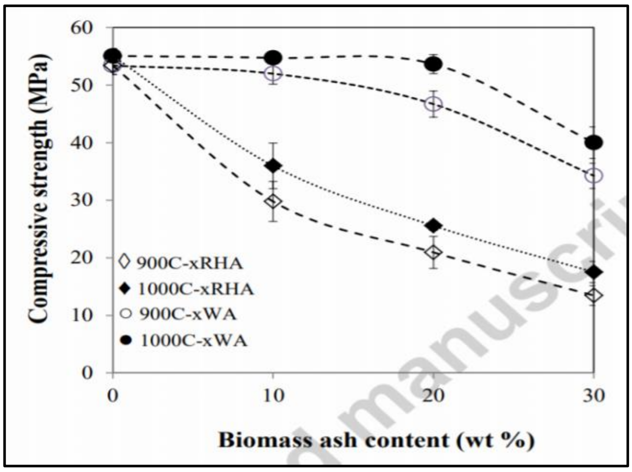


Figure 17: Compressive strength of biomass ash (RHA or WA) and firing temperature (900 or 1000 ºC) [14]

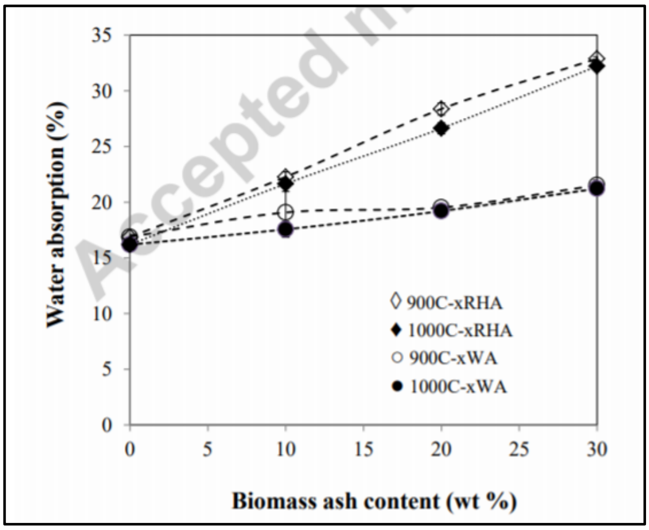


Figure 18: Water absorption as a function of biomass ash (RHA or WA) and firing temperature (900 or 1000 ºC [14]

3.4 Summary of Comparison of performance between POFA and RHA used as Supplementary Cementitious Material

In this study, besides the use of POFA and rice husk ash (RHA) in cement, clay, and sand-based applications, other prominent ashes are used for these activities. Table 1 shows some preferred ashes and their properties as several authors have stated. These ashes include wood ash (WA), sugarcane bagasse ash (SBA), expanded polystyrene beads (EPS), and fly ash (FA). The only method that used firing method for clay brick was by Eliche Quesada et. al., (2017), the results of ceramic brick were better at higher a firing conditions, with increased vitrification. Noted that, one of the previous studies consists of compressive strength result and density only [7]. From table 1 it can be concluded that the brick incorporated with POFA had a low compressive strength slightly decreased as a high percentage used at 28 days and 56 days. Meanwhile, the compressive strength of brick incorporated with RHA had a slightly decreased from 7 days to 28 days and 56 days as high used of RHA percentage. However, RHA is greater in water absorption as the age days increase at 56 days with increasing of RHA percentage. The same goes for the brick with 25.00 % POFA replacement has the highest water absorption properties. Most of the studies reported an optimum POFA content of 10.00-20.00 % by mass of cement. Although the compressive strength is mostly lowered by using POFA and RHA as a cement replacement, brick made with the inclusion of POFA and RHA still have acceptable strengths for various structural and plastering applications. To maintain the integrity of the brick, the use of POFA and RHA in load carrying applications should be minimized, however, the compressive strength can be increased by incorporating brick-chemical admixtures.

4. Conclusion

According to the study review of comparative of Palm Oil Fuel Ash (POFA) and Rice Husk Ash (RHA) as supplementary cementitious material (SCM) in brick, the objectives have been achieved. The properties of bricks incorporating rice husk ash (RHA) and POFA were investigated. Based on the previous researchers have used different types of waste materials incorporating with POFA and RHA such as fly ash, sugarcane bagasse ash, EPS, and wood ash with the type of brick which is clay brick, ceramic brick and cement brick in varying amounts and employed different methods of producing bricks included in the previous study. On developed bricks, different tests were performed to determine their properties following the various available specifications. Compressive strength and water absorption are two common parameters that many researchers consider as needed by different standards. Although many of the studied waste materials bricks meet the various standard specifications and several patents have been accepted, commercial production and application of waste material bricks are still very small. Bricks with greater porosity are commonly seen as having good thermal properties. The use of POFA and RHA as supplementary cementitious material has been highlighted and it is the opinion of the author that the material has some positive evaluation in some areas while it was deficient in others. However, its strength lies in its morphology and particle size which have been shown to have strong correlation with pozzolanic activity. This, in turn, helps in improving the rate of hydration subsequently resulting in enhanced compressive strength. It is therefore a worthy material capable of being used as an alternative to the more prominent and conventional supplementary cementitious materials currently being used for most construction works.

Acknowledgement

The authors would like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] Khankhaje, E., Hussin, M. W., Mirza, J., Rafieizonooz, M., Salim, M. R., Siong, H. C., & Warid, M. N. M. (2016). On blended cement and geopolymer concretes containing palm oil fuel ash. Materials & Design, 89, 385-398.

[2] Siddika, Ayesha & Mamun, Md & Alyousef, Rayed & Mohammadhosseini, Hossein.(2020). State-of-the-art-review on rice husk ash: A supplementary cementitious material in concrete. Journal of King Saud University. 10.1016/j.jksues.2020.10.006.

[3] Ghazali, Norhaiza & Muthusamy, Khairunisa & Wan Ahmad, Saffuan. (2019). Utilization of Fly Ash in Construction. IOP Conference Series: Materials Science and Engineering. 601. 012023. 10.1088/1757-899X/601/1/012023.

[4] Ibrahim, Hussein Adebayo & Abdul Razak, Hashim. (2016). Effect of palm oil clinker incorporation on properties of pervious concrete. Construction and Building Materials.115. 70-77. 10.1016/j.conbuildmat.2016.03.181.

[5] Al-Kutti, Walid & Islam, A. B. M. & Nasir, Muhammad. (2017). Potential use of date palm ash in cement-based materials. Journal of King Saud University - Engineering Sciences. 31. 10.1016/j.jksues.2017.01.004.

[6] Alsubari, Belal & Shafigh, Payam & Jumaat, Zamin & Alengaram, U.Johnson. (2014). Palm Oil Fuel Ash as a Partial Cement Replacement for Producing Durable Self-consolidating High-Strength Concrete. Arabian Journal for Science and Engineering. 39. 8507-8516. 10.1007/s13369-014-1381-3.

[7] Saleh, A. ., Rahmat, M. ., Mohd Yusoff, F. ., & Eddirizal, N. . (2014). Utilization of Palm Oil Fuel Ash and Rice Husks in Unfired Bricks for Sustainable Construction Materials Development. MATEC Web of Conferences, 15, 01032.

[8] Kamarulzaman, N. A., Adnan, S. H., Sari, K. M., Osman, M. H., Jeni, M. A., Abdullah, M. S., & Anuar, M. W. (2018). Properties of Cement Brick Containing Expanded Polystyrene Beads (EPS) And Palm Oil Fuel Ash (POFA). Journal of Science and Technology, 10(4).

[9] Mohd Zailani, T., Adnan, S. H., & Abdullah, M. S. (2018). The performance on concrete brick containing palm oil fuel ash (POFA) as replacing cement.

[10] Rahman, M. E., Boon, A. L., Muntohar, A. S., Hashem Tanim, M. N., & Pakrashi, V. (2014). Performance of masonry blocks incorporating Palm Oil Fuel Ash. Journal of Cleaner Production, 78, 195–201.

[11] Sultana, Mst & Hossain, M & Rahman, Aminur & Khan, Majharul. (2014). Influence of Rice Husk Ash and Fly Ash on Properties of Red Clay. JOURNAL OF SCIENTIFIC RESEARCH. 6. 421-430. 10.3329/jsr.v6i3.15343.

[12] Hwang, Chao-Lung & Huynh, Trong-Phuoc. (2015). Investigation on the Use of Fly Ash and Residual Rice Husk Ash for Producing Unfired Building Bricks. Applied Mechanics and Materials. 752-753. 588-592. 10.4028/www.scientific.net/AMM.752- 753.588.

[13] Kazmi, S. M. S., Abbas, S., Saleem, M. A., Munir, M. J., & Khitab, A. (2016). Manufacturing of sustainable clay bricks: Utilization of waste sugarcane bagasse and rice husk ashes. Construction and Building Materials, 120, 29–41.

[14] Eliche-Quesada, D., Felipe-Sesé, M. A., López-Pérez, J. A., & Infantes-Molina, A. (2017). Characterization and evaluation of rice husk ash and wood ash in sustainable clay matrix bricks. Ceramics International, 43(1), 463–475.