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A Review on Production of Bricks From fly ash and Palm oil Fuel ash as Partial Cement Replacement by Using Cementing Method

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Abstract: Brick has been used for a long time and is an important construction material. The conventional construction of bricks has made the raw material such clays come to the depletion of sources. Bricks made of concrete have contributed to the large scale of CO_2 emission. The partial replacement of cement as bricks has come as helper in reducing the used of raw material and also the cement. Cement replaced with locally fly ash (FA) and palm oil fuel ash (POFA) has significant potential to address the environment impact, especially in the construction industry by contributing to safe, clean and sustainable production. The aim of this study is to review on the potential of FA and POFA as partial cement replacement in bricks production. The chemical properties such as the chemical composition and loss of ignition are taken into consideration. To determine the potential of these bricks, compressive test and water absorption value were taken into account at different percentage of FA and POFA used. Based on study, the result shows that, the highest chemical composition in ordinary Portland cement (OPC) calcium oxide (40%-75%), FA is silicon dioxide (30%-60%), POFA silicon dioxide (40%-70%). The loss on ignition in OPC is in range of (0.9%%-3%), FA is in range of (0.1%-6%) and POFA is in (2%-15%) followed the standard requirement. 20% FA content appears to be the optimal mix for the production of bricks. The value of compressive strength for 7 and 28 days of curing shows increment. However, the increase the percentage of FA used the decrease the compressive strength. The compressive strength of POFA indicated the increase the percentage of POFA used, the decrease the compressive strength. Water absorption bricks made of FA increase as the FA percentage used increased. The water absorption of bricks contains POFA also shows increment as the percentage of POFA used is increased.

Keywords: Fly Ash, Palm Oil Fuel Ash, Concrete Bricks, Cementing Method

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1. Introduction

Brick is part of construction material which has widely been used for long time ago. The brick is historic material that frequently and worldwide used for more than 10 thousand years ago [1]. The clay-based brick consist of clay and shale and usually undergo firing process upon production and emit danger gases [2]. These types of bricks that made of natural resources can cause raw material depletion and pollution if it has continuously been used. The Indian Construction industry also giving the fact that for nearly 22% of the total greenhouse emissions is came from the construction materials production. There are many researcher studies the other alternative material for manufacturing of bricks in order to avoid the extinction of the natural sources material, fulfill the bricks demand and also to support sustainability in construction while preserve the environment [3]. In this study, the focus is on the production of brick from fly ash and palm oil fuel ash as partial cement replacement by using cementing method. The production of FA and POFA as waste happen all the time.

Researcher have made lots of study to look into the way to make use of the huge quantities of FA in brick production effectively [4]. Malaysia as the main contributor of POFA in the world has raised the waste production of palm oil industry and the governments need to come out with additional landfill to dispose waste. However, the wastage from the palm oil industry can be utilized as additional material to cement in production of construction material [5]. The selection factor of FA and POFA material to make brick is not only on the production amount of it, but also the structural behavior which can replaced the basic brick made of natural resources. The production of bricks by using cementing method can have the strength due to its cementing material. Cementing method does not use kiln firing but depends on the cementing from waste material or additional cementing materials [6]. POFA is a high pozzolanic material which can increase the durability and compressive strength of concrete.

The objective of this study was to review the chemical properties of OPC, FA and POFA as material in bricks production and to review the compressive strength and water absorption of bricks containing FA and POFA as partial cement replacement. The significant of studies were to provide a useful review for future reference on the bricks production made of FA and POFA as partial cement replacement.

2. Literature Review

Cement production is a power extensive procedure and dangerous to the environment. Around the world, 1.5 billion tons of concrete is utilized every year. Concrete production releases roughly one ton of CO_2 for every tons of cement generated, that makes up 7% of all CO_2 discharges created around the world [7]. Cement is a critical component in the manufacture of bricks. Nonetheless, excessive cement consumption has a negative impact on the environment. By contributing to cleaner manufacture, cement replaced with locally accessible waste products has a considerable potential to address this ecological impact, particularly in the building and construction industry [8]. There are many researcher studies on the utilization of FA and POFA as partial cement replacement in bricks. Table 1 and Table 2 shows the used of FA and POFA as waste material in bricks production.

Table 1: Utilization of Fly ash (FA) as waste material in brick production

Author	Cementing Material	Description
[9]	Fly Ash Class C Limestone powder (LP) Silica fume (SF)	Scientists have developed new construction materials made from waste materials as a result of European legislation concerning waste emissions and the need to reduce solid waste volume. In the manufacture of masonry bricks, LP, class C FA, SF, and water are employed.

Table 1: Utilization of fly ash (FA) as waste material in brick production (continued)

[10]	Fly Ash Class F Quarry dust (QD) Billet scale (BS)	This research presents the results of a non-conventional method investigation on bricks built from ash FA Class F, QD, and BS. This research may help to reduce the value of BS, QD, and ash disposal, lowering the cost of treatment, reducing the use of nonrenewable materials and energy resources, lowering the risk of environmental contamination, and supporting sustainability.
[11]	Fly Ash Class F Sand Hydrated lime	The Seyito'mer power station facility was explored for the production of light weight bricks in this study. To make brick samples, FA, sand, and calcium hydroxide mixtures were steam autoclaved under various test settings.

Table 2: Utilization of palm oil fuel ash (POFA) as waste material in brick production

Author	Cementing Material	Description
[12]	Palm Oil Fuel Ash (POFA) Ordinary Portland Cement (OPC) River Sand	POFA as a partial replacement for cement while maintaining suitable masonry block structures. By mass of the full cementitious product in the masonry block, the percentages of POFA are limited to 0 percent, 20 percent, 40 percent, and 60 percent. For mechanical qualities, the investigations on masonry brick examine at compressive strength and breaking load, as well as water absorption and efflorescence for resilience. POFA appears to offer a lot of potential for concrete replacement in the masonry block industry.
[13]	Palm Oil Fuel Ash (POFA) Rice Husks (RH) Ordinary Portland Cement (OPC)	POFA and RH are used in order to study the potential to be green brick. The mix composition of the block's weight was found to contain 2 percent to 10% of POFA and 1 percent to 5% of RH, according to laboratory examinations. POFA was improved in order to reduce concrete usage, and RH was introduced to partially replace sand in the bricks.
[14]	Palm Oil Fuel Ash (POFA)**,** Cement Sand	The use of POFA in the production of interlocking compressed bricks will assist to minimize the energy used in the traditional clay brick fire process, as well as the environmental damage caused by greenhouse gas emissions.

The chemical composition, loss on ignition, compressive strength and water absorption of bricks are the main things been focused in order to investigate the durability of the bricks made of waste as partial cement replacement. Table 3 and Table 4 show the overview on the compressive strength and water absorption properties of waste bricks.

Table 3: Overview on Compressive Strength of Waste Bricks

Author	Cementing Material	Brick size	Curing Condition	Methodology	Result
Turgut [9]	Fly Ash (FA), Silica Fume (SF), Limestone Powder (LP)	(105 mm × 75 mm × 225 mm), (105 mm × 90 mm × 75 mm)	7-, 28- or 90-days water curing	After curing, based on ASTM C67. Servo controlled compression test equipment with an 800 kN capacity was used to measure the compressive strength. The load was applied to the sample's face, which measured 105 x 90 mm.	SF 20% weight of FA, FA 23% weight of LP, Compressive strength : 26.5 MPa

Table 3: Overview on Compressive Strength of Waste Bricks (continued)

Shakir [10]	FA, Quarry Dust, Billet Scale, Ordinary Portland Cement (OPC)	200 mm × 90 mm × 60 mm	1 percent sulphuric acid and 3.5 percent sodium chloride, 7, 14, 28, and 56 days	A universal testing equipment with a 1000 kN capacity was used to perform compression strength tests according to ASTM C 67-03, 2003 at 7, 14, 28, and 56 days.	At the end of 28 days, the compressive strength was measured. 7.7 MPa to 26.3 MPa in Series A 6.2 MPa to 16.0 MPa in Series B. Conventional bricks, such as clay bricks and cement bricks, had compressive strengths of 15 MPa and 12 MPa, respectively.
Rahman [12]	Palm Oil Fuel Ash (POFA), OPC, River Sand	200 mm × 100 mm × 70 mm	28 and 56 days of curing	Because it takes 28 days for the cement paste to reach roughly 80% of its entire strength, the masonry blocks were tested after 28 days. The compressive strengths of the masonry blocks were measured at 28 and 56 days	Compressive strength: 60% POFA at 28 days for soaked and unsoaked condition equal to 7 and 8 MPa respectively.
Asrah [14]	POFA, OPC, River sand, Clay soil	Less than 337.5 mm × 225 mm × 112.5 mm	12 and 24 days	Compressive test done after 12 and 24 days of curing.	UF-10 with 30.4 MPa and 32.9 MPa

Table 4: Overview on Water Absorption of Waste Bricks

Author	Cementing Material	Brick size	Curing Condition	Methodology	Result
Turgut [9]	Fly Ash (FA), Silica Fume (SF), Limestone Powder (LP)	105 mm × 90 mm × 75 mm	7, 28 or 90 days water curing	On the basis of ASTM C67, the water absorption of a material is determined. Water absorption and density tests were performed on samples with dimensions of 105 mm x 90 mm x 75 mm after 28 days of cure. SF FA accounts for 20% of the total weight, while LP accounts for 23% of the total weight.	Water Absorption: 16.5% Passing load-bearing and non-load-bearing concrete masonry unit specifications.
Shakir [10]	FA, Quarry Dust, Billet Scale, Ordinary Portland Cement (OPC)	200 mm × 90 mm × 60 mm	at 22°C	At the age of 28 days, water absorption was measured in accordance with BS3921-1985. In Series A, 15% cement, 50% quarry dust, and 25% fly ash and billet scale were employed. In Series B, the billet scale and fly ash ratios were increased to 40%, while cement and quarry dust were reduced to 10% and 50%, respectively.	Series A: (13–14.2)% Series B: (12.9–19.1)%

Table 4: Overview on Water Absorption of Waste Bricks (continued)

Author	Cementing Material	Brick size	Curing Condition	Methodology	Result
Zailani [15]	POFA, OPC	102.5 mm x 215 mm x 65 mm	7 and 28 days	The water absorption test is performed on samples prepared at 7 and 28 days of age. The water absorption test was carried out according to BS 1881: Part 122: 1983.	10% POFA: 10.82% (size 75 μm) 20% POFA : 21.92% (size 75 μm) 10% POFA: 13.67% (size 150 μm) 20% POFA : 22.78%.(size 150 μm)
Kamarulzaman [16]	Expanded Polystyrene Beads (EPS), POFA,OPC	215 mm × 102.5 mm × 65 mm	7, 28 and 56 day air-curing.	Water Absorption: BS 1881 : Part 122	25% POFA and 50% EPS: 5.43%

3. Methodology

The methodology of this study was done by reviewing information and collecting data from previous research made by various researchers. Due to the pandemic of corona virus, the finding of the previous research was done by using several online search engines. All the information was gathered based on the subtopic which related to the title of the study. The data collected were complies with objective of the study and research question that has been made in order to have consistent work and on to keep track. After several data has been identified, it was extracted into table form in order to have clearer vision of data. The data that has been identified were the chemical composition and loss on ignition of ordinary Portland cement (OPC), fly ash (FA) and palm oil fuel ash (POFA), compressive strength and water absorption. All the data and information is then were used in to support details in discussion.

4. Results and Discussion

The result consists of chemical properties, compressive strength and water absorption of different percentage usage of Fly Ash (FA) and Palm Oil Fuel Ash (POFA) for 7 and 28 days of curing. The production of brick by replacing partial of cement with FA and POFA is by using cementing method. Cementing method is method where firing is not necessary. This method does not need kiln burning because it depends on the cementing reaction of the waste used or other additional cementing material.

4.1 Chemical composition of OPC, FA and POFA

The result in Table 5 showed that the highest percentage of composition in OPC was calcium oxide with percentage range of 40 to 75 and followed by silicon dioxide and iron oxide with range of 2% to 10% and 2% to 5% respectively. The lowest percentages of composition in OPC were the phosphorus pent-oxide and titanium oxide with both was below than 1%. The high percentage of calcium oxide in OPC is because of the production of OPC itself which is made up of clinker where when it was heated, 60 to 67 of lime in the clinker will left deposited calcium oxide [17].

The FA has silicon dioxide as its highest chemical composition with 30% to 60%. The second and third high compositions were the aluminum oxide which was 4% to 35% and iron oxide was 3% to 13%. The lowest percentages were represented by sodium oxide and titanium oxide which was 0.1% to 1.5% and 0.5% to 1.5% respectively. The FA has high range percentage of silicon dioxide and followed by aluminum oxide and iron oxide is due to its natural existence which consist of the quartz (SiO_2), mullite ($3Al_2O_3.2SiO_2$), hematite (Fe_2O_3), and magnetite (Fe_3O_4) as primary mineral in the fly ash [18] and due to types of coal burned (i.e., lignite, subbituminous, bituminous, semi-bituminous, semi-anthracite and anthracite) [7].

The POFA showed that the highest percentage was represented by silicon dioxide which was 40% to 70%. Other compositions followed were the calcium oxide and aluminum oxide with 4% to 9% and

1.5% to 12% respectively. In POFA, sodium oxide was the lowest chemical composition with 0% to 1%. The high percentage of silicon dioxide in POFA is also same as FA which is due to its natural existence which quartz (SiO_2) was dominating the POFA [19]. Other than that, the high composition of silicon oxide is also due to the reduction of large particle sizes and unburned fibers in POFA [20].

From the result, it can be seen that, the total of silicon dioxide, aluminum oxide and iron oxide is in FA and POFA are more than 50% and 70% which it fulfill the chemical requirement based on ASTM C618 [7].

Table 5: Chemical composition of OPC, FA and POFA

Elements	Formula	Composition (%)		
		Ordinary Portland Cement (OPC)	Fly Ash (FA)	Palm Oil Fuel Ash (POFA)
Silicon Dioxide	SiO_2	8 - 22	30 – 60	40 – 70
Calcium Oxide	CaO	40 - 75	0.5 – 35	4 – 9
Aluminum Oxide	Al_2O_3	2 - 10	4 – 35	1.5 – 12
Iron Oxide	Fe_2O_3	2 - 5	3 – 13	1.4 – 7
Magnesium Oxide	MgO	0.1 - 3	0.7 – 5	2 – 6
Sodium Oxide	Na_2O	0 - 2	0.1 – 1.5	0 – 1
Potassium Oxide	K_2O	0.3 - 2	0.1 – 3.5	2 – 9
Sulphur Trioxide	SO_3	1 - 5	0.1 – 7	0.2 – 3
Phosphorus Pent-oxide	P_2O_5	< 0.5	0.3 – 2	< 10
Titanium Oxide	TiO_2	< 0.5	0.5 – 1.5	-

4.2 Loss on Ignition of OPC, FA and POFA

Table 6 shows the loss on ignition (LOI) in OPC, FA and POFA based on the previous research by various researchers. The LOI in OPC is in the range from 0.9% to 3%, FA in the range of 0.1% to 6% and POFA is in the range of 2% to 15%. LOI is used in the tracking of residual carbon content in material. LOI has severe impact on the product properties. According to ASTM C618, the maximum value of LOI allowed in pozzolans is 10% for class N, and 6% for class F and C. From the result, FA used has good LOI percentage which is fulfill the requirement. The result of LOI in POFA is higher than the ASTM requirement maybe due to several reasons such as the origin of the coal, the combustion condition and the installation of air pollution control equipment [21].

Table 6: Loss on ignition of OPC, FA and POFA

Loss on Ignition (%)		
Ordinary Portland Cement (OPC)	Fly Ash (FA)	Palm Oil Fuel Ash (POFA)
0.9 - 3	0.1 – 6	2 – 15

4.3 Compressive strength of brick made of FA as partial replacement of cement combined with other cementitious binder

Figure 1 and Figure 2 shows the result on the compressive strength that been tested to the bricks that contain FA. The percentage of FA used is varying from 0% to 60%. From the graph, it can be seen that the compressive strength value was experience increment when using FA with percentage of 0% to 30%. The compressive strength value start to decrease when 40% to 60% of FA been used. Based on the curing days, each bricks showed the increment in compressive strength from day 7 to day 28. In comparison to the mixes with 0 to 60 percent of FA content, the sample with 20% FA content appears to be the optimal mix for the production of bricks. The value of compressive strength for 20% of FA mix with cement, quarry dust and billet scale is 9.60 Mpa for 7 days of curing and 16.20 Mpa for 28 days of curing, while the value of compressive strength for 20% FA mix with POFA, OPC and sand is 12 Mpa for 28 days of curing. , bricks with mix proportion of Fly ash, Granulated Blast Furnace Slag (GBFS) and Ordinary Portland Cement did not meet the minimum specification for the compressive strength of the brick which is not less than 7.0 MPa for 28 days curing period.

The increment and decrement of compressive strength value is maybe due to the amount of hydration produced, porosity and pore structure [22] fineness of FA [23], the amount of water in the brick, formulation, forming pressure, curing regime [24], and the binder agent [4].

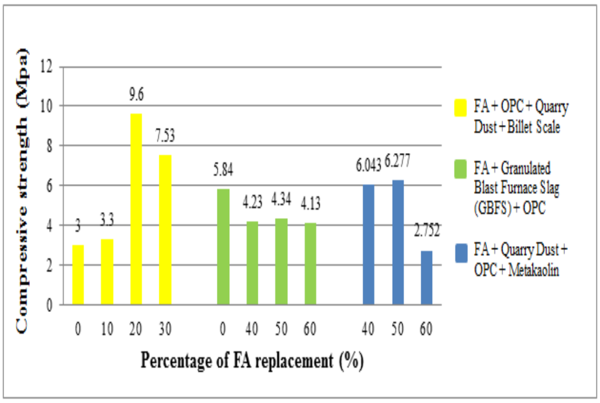

Figure 1: Compressive strength of brick made of FA as partial replacement of cement combined with other cementitious binder for 7 days of curing

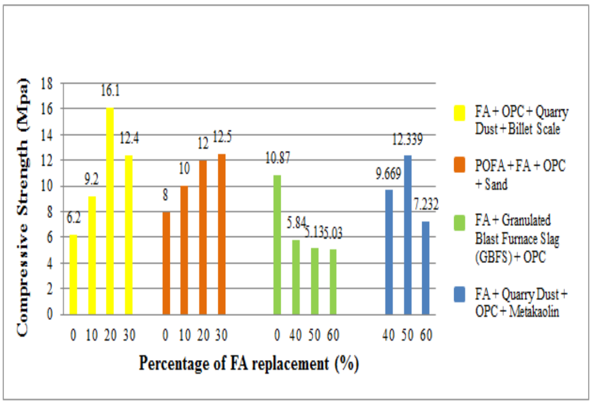

Figure 2: Compressive strength of brick made of FA as partial replacement of cement combined with other cementitious binder for 28 days of curing

4.4 Compressive strength of brick made of POFA as partial replacement of cement combined with other cementitious binder

Figure 3 and Figure 4 shows the result on the compressive strength of bricks made of POFA combined with other cementitious binder. The percentage used of POFA is in between 0% to 60%. From the result, it can be seen that, the increase the percentage of POFA used, the decrease the compressive strength. However, based on the curing days, the result showed from day 7 to 28, the compressive strength value experience increment. The highest compressive strength is when 10% of POFA is mix with OPC and fine aggregate with value of 15.2 Mpa for 7 days of curing and 20.4 Mpa for 28 days of curing. The lowest compressive strength value for 7 days of curing is 9.3 Mpa which when 20% of POFA is used together with Polystyrene Beads, OPC and sand but it increase when compressive test was done for 28 days of curing. The lowest compressive strength for 28 days of curing is 9.36 Mpa which when 60% of POFA is used with OPC and river sand. The decrement of compressive strength for brick made of POFA is maybe due to the mix proportion [25], fineness [12] and curing time [26].

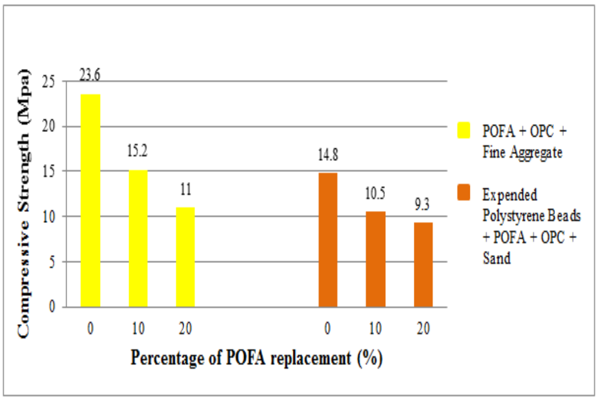

Figure 3: Compressive strength of brick made of POFA as partial replacement of cement combined with other cementitious binder for 7 days of curing

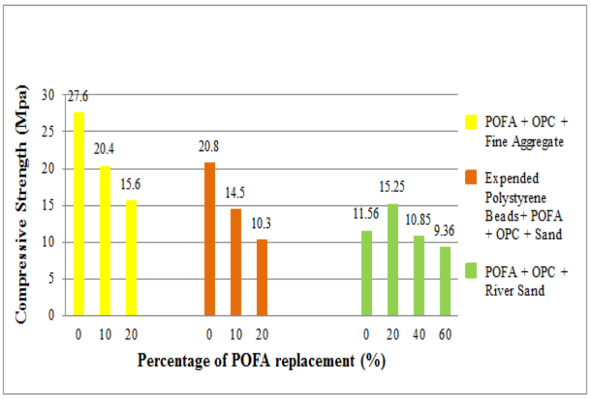

Figure 4: Compressive strength of brick made of POFA as partial replacement of cement combined with other cementitious binder for 28 days of curing

4.5 Water Absorption of brick made of FA as partial replacement of cement combined with other cementitious binder

Figure 5 and Figure 6 shows the result for water absorption of bricks made of FA combined with other cementitious binder. The result shows that, the increase the FA percentage used the increase the percentage of water absorption. The water absorption was done at 7 and 28 days of curing. The highest water absorption value was 19.90% at which the 60% of FA was used in the combination of FA + granulated blast furnace slag + OPC. The lowest water absorption value was 13.20% at which the 10% FA was used in the combination of FA + quarry dust billet + billet scale. According to ASTM C62-12, the water absorption value should not be more than 20%, thus the result for the three mix combination of FA bricks at 28 days of curing is fulfill the requirement. Certain condition can affect the water absorption such as the ability of fly ash as water absorbent [10], fineness [27], fly ash to cement ratio [28], pore structure [11] [4], and porosity [3] [4].

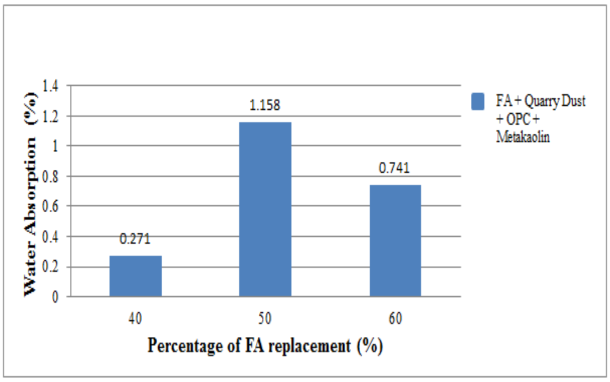

Figure 5: Water absorption of brick made of FA as partial replacement of cement combined with other cementitious binder for 7 days of curing

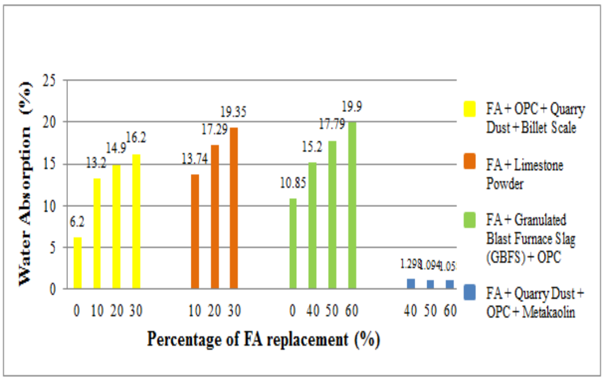

Figure 6: Water absorption of brick made of FA as partial replacement of cement combined with other cementitious binder for 28 days of curing

4.6 Water Absorption of brick made of POFA as partial replacement of cement combined with other cementitious binder.

Figure 7 and Figure 8 shows the result for water absorption of bricks made of POFA with other cementitious binder. There are three combinations of POFA mix. The percentage of brick mix of POFA is in between 0% to 20% and this test was done at 7 and 28 days of curing. From the graph it showed that the water absorption is increase as the percentage of POFA used is increase. The control brick for combination of expended polystyrene beads + POFA + OPC + sand has the lowest water absorption with 6.95% for 28 days of curing. The highest water absorption is in the combination of POFA + OPC + fine aggregate with 16.52% for 7 days of curing and 21.92% for 28 days of curing. It can be concluded that, the higher the percentage of POFA used in the mix proportion, the higher the water absorption percentage. The increment of water absorption percentage is maybe due to porosity [12], and fineness [29].

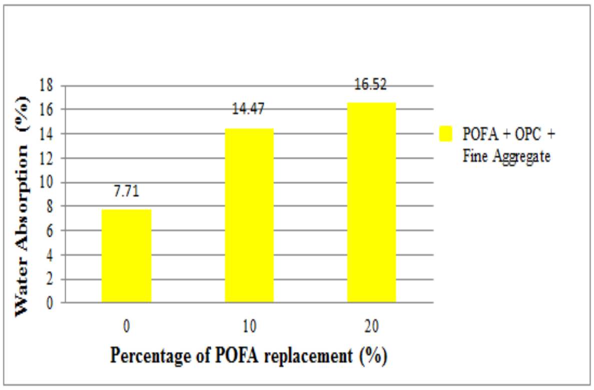

Figure 7: Water absorption of brick made of POFA as partial replacement of cement combined with other cementitious binder for 7 days of curing

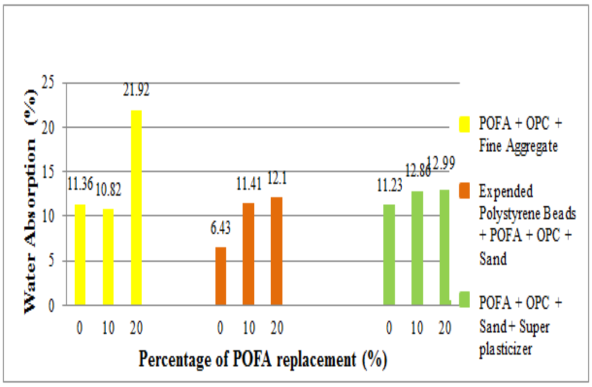

Figure 8: Water absorption of brick made of POFA as partial replacement of cement combined with other cementitious binder for 28 days of curing

5. Conclusion

Bricks are one of the most commonly utilized masonry elements in construction. Various sorts of waste have been researched in order to be mixed into bricks due to ongoing demand. Based on the result, it can be concluded that the highest chemical composition in OPC is calcium oxide (40%-75%), FA is silicon dioxide (30%-60%), while POFA presented silicon dioxide (40%-70%) as the highest chemical composition. Based on the BS 12: 1996 and ASTM C618, chemical composition in OPC, FA and POFA have fulfilled the requirement. The loss on ignition in OPC is in range of 0.9% to 3%, FA is in range of 0.1% to 6% and POFA is in 2% to 15% followed the standard requirement. 20% FA content appears to be the optimal mix for the production of bricks. The value of compressive strength for 7 and 28 days of curing shows increment. However, the increase the percentage of FA used the decrease the compressive strength. The compressive strength of POFA indicated the increase the percentage of POFA used, the decrease the compressive strength. Water absorption bricks made of FA increase as the FA percentage used increased. The water absorption of bricks contains POFA also shows increment as the percentage of POFA used is increased.

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