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Effects of Consistency and Elemental Analysis on Cement Paste Using Lime Activator POFA

Nuradila Izzaty Halim[1*], Muhd Norhasri Muhd Sidek[2], Aidan Newman[1], Hamidah Mohd Saman[2]

[1] *Faculty of Civil Engineering, Universiti Teknologi MARA, MALAYSIA.*
[2] *Institute for Infrastructure Engineering and Sustainable Management (IIESM), Universiti Teknologi MARA, 40450 Shah Alam, Selangor, MALAYSIA.*
**Corresponding Author (Email: nuradilaizzaty@yahoo.com)*

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Abstract

The utilisation of waste products as an additive in cement is vastly growing in the world of construction. The waste products such as Rice Husk Ash (RHA) and Palm Oil Fuel Ash (POFA) have frequently been used as additives in cement. This paper presents the experimental investigation conducted on Cement Paste incorporating agro-industrial waste, POFA which is the supplementary cementitious material and lime activator solution to evaluate its consistency and elementary at 1, 3, 7, and 28 days of age. For this study, three different mixes were prepared using a cube specimen size of 50 mm x 50 mm x 50 mm with the inclusion of sodium hydroxide and sodium silicate at a 1kg to 200ml ratio while 5% POFA was utilized as pozzolans that partially replaces cement. All samples including Ordinary Portland Cement (OPC) cement paste were tested using Vicat apparatus and XRF analysis to perform the consistency and elementary analysis. Through this research, both mixtures of 5% POFA with sodium base consisted of a high element of calcium which gave a fast-setting cement result that is good for construction in patching and repairing concrete.

Disciplinary: Civil Engineering & Technology, Green & Sustainable Technology.

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1 Introduction

In our modern era, cement stands out as an important material in construction material and it is being demanded nowadays since there is the rapid growth of industrialization and urbanization. In addition, a huge amount of raw materials and natural resources is required in bulk quantity for concrete production worldwide. In the meantime, a significant amount of industrial and agricultural waste disposal is causing a serious issue to the environment (Aprianti, 2017). There are numerous causes of global warming, and one of the reasons is due to CO_2 from the calcination process of the Ordinary Portland Cement (OPC) main materials. For every ton of cement production, about 5% of the total amount of CO_2 emission is released into the atmosphere and this emission of CO_2 can be reduced by improving the production process of cement manufacturing (Sooraj, 2013). As the measure of cement manufacturing being produced extensively is expanding around the world, environmental concern on the high amount of carbon dioxide being released from the production has led to an interest in the field of supplemental cementitious materials with a specific end goal to lessen the amount of cement required for making concrete (Altwair & Kabir, 2010). Palm oil production is important for the economy of Malaysia as the product comes the second world's largest producer after Indonesia. Also, it has been listed as one of the main products to be exported worldwide as Malaysia is now focusing on the biotechnology industry which is estimated to generate improved quality of agriculture products as enclosed in the Ninth Malaysian Plan (RMK-9) (Ahamed & Siddiraju, 2016).

According to Ahmad and Mohd Noor (2009), the industrial sector in Malaysia has produced a large amount of waste with more than 10 million tons per year. The utilization of waste may decrease the cost of production in building materials and reduce the environmental impact of the waste. Instead of eliminating, the waste may be reused in construction materials as pozzolans. Local Malaysian wastes such as POFA, rice husk, and fly ash are the most interesting combustion wastes and they are usually being studied by engineers and scientists. Various researchers have investigated the use of pozzolans in concrete since the partial replacement will improve construction material that encounters the disposal problem of better waste management. Pozzolans can be defined as siliceous or siliceous and aluminous material that produces cementitious properties when the particles react with calcium hydroxide from the cement. POFA is ash and it is produced from the burning of palm oil husk and palm kernel shell in palm oil mill boilers (Nguong & Awal, 2010). Zarina et al. (2013) described POFA as a waste from the power plant that produces electricity using palm fiber, shell, and unfilled fruit bunch as fuel when it is burnt at 800-1000°C. These POFA ashes are usually disposed of with no commercial value as a reward and it will cause environmental pollution. However, due to its good pozzolanic content, this waste is used widely in the construction industry as a concrete mix. By contributing POFA in concrete mix design, the disposal effects are reduced. Besides that, the use of waste as a supplementary cementing material in concrete may decrease the amount of cement used in the concrete mix and makes the concrete mixture becomes extra economical. This research was undertaken to determine the consistency and elemental analysis of Cement Paste using Lime Activator POFA.

2 Literature Review

Most of the researchers are replacing pozzolans in concrete with a different ratio in order to test their compressive strength, RHA (Tikalsky et al., 2001) and fly ash (Huang et al., 2013; Hossain et al., 2016; Moghaddam et al., 2019). Besides, numerous researchers also found that POFA had pozzolanic properties, which can be used as a replacement for cement in concrete (Tay, 1990; Galau & Ismail, 2015; Aprianti, 2017; Zeyad et al., 2017; Hamada et al., 2018). Previous researchers only utilized POFA in concrete and cement paste without incorporating an alkaline activator. As to fill the gap of previous research, this study was done to investigate the effect of using POFA on the performance of alkaline activated cement paste. The alkaline activated POFA based cement paste was evaluated on its consistency, setting time, and elemental analysis.

3 Materials and Method

3.1 Preparation of Cement Paste

Cement paste for this study included three cases with OPC having no replacement of cement in the concrete. For 5SH, it consisted of 5% of partially replaced cement with POFA and 1kg: 200ml ratio of water with sodium hydroxide, while 5SS was a mixture of 5% partially replaced cement with POFA and 1kg: 200ml ratio of water with sodium silicate.

Table 1: Design Mix (please give unit of Alkaline Activator).

Sample	Cement (kg/m^3)	Water (kg/m^3)	POFA (kg/m^3)	Alkaline Activator ((kg/m3))
OPC	380	205	0	0
5SH	360	163	20	42
5SS	360	163	20	42

3.1.1 Palm Oil Fuel Ash (POFA)

Step 1: Finding

POFA was obtained from the incinerated palm oil waste of United Palm Oil SDN BHD factory at Sungai Kecil, Nibong Tebal, Pulau Pinang, Malaysia.

Step 2: Sieving

Then, POFA was sieved into 212µm to remove the coarse particles as small particles were used for better control over the filler effect.

Step 3: Storing

To ensure its purity, the sieved POFA was stored in a clean, dry, and airtight humidity-controlled room inside the laboratory.

Step 4: Liquidation of POFA

POFA was liquefied using the ratio of 1kg total amount of water with 200ml alkaline activator solution. This liquefied POFA was used during the replacement of cement using the liquidation technique.

3.1.2 Raw Material

Phase 1: Water

Normal tap water was used in this study for the concrete mix design.

Phase 2: Cement

Ordinary Portland Cement (OPC) obtained from Tasek Corporation Sdn. Bhd. was used in this study. Due to the replacement of cement with POFA, each mixing used a different weight of cement. The percentage of POFA used for this procedure was 5%.

3.2 Mixing, Handling a Test on Consistency, and Elemental Analysis of Cement Paste

3.2.1 Consistency Test

For control sample preparation of cement and POFA on consistency test, 400g cement was prepared. The sample with POFA, 5% of cement weight was replaced and liquefied using the ratio of 1kg total amount of water with 200ml alkaline activator solution. Then the cement was mixed with 130 ml water as a starter and the Consistency test for this research used a Vicat apparatus. After the cement paste was filled inside the mould, the plunger was brought into contact with the top surface of the cement paste and released.

3.2.2 Setting Time Test

Setting time test for this research was based on ASTM-C172. The needle on Vicat's apparatus was replaced. Initial setting time was said to take place when the needle can only penetrate 5mm and below. After the initial setting time took place, the needle was replaced for the final setting time. The final setting time was said to take place when the needle was gently brought to the surface that penetrated 5 mm and the circular cutting edge failed to make an impression on top of the cement paste.

3.2.3 XRF Analysis

The elemental analysis of cement paste estimated the proportions of each element present in the sample which was performed using the X-Ray Fluorescence (XRF) by S1 TITAN Handheld XRF Spectrometer. The XRF machine used polarized energy dispersion. The samples of XRF analysis for each condition were four cubes in which each cube was per trial mix of 0.000125 m3. Each sample was analysed for 1, 3, 7, and 28 days, refer to Table 2 on the specimen preparation of this study.

Table 2: Specimen Preparation

Design Mix	Day 1	Day 3	Day 7	Day 28
OPC	3	3	3	3
5SH	3	3	3	3
5SS	3	3	3	3

4 Result and Discussion

4.1 Consistency

The result of consistency and setting time of this study is shown in Tables 3 and 4. Figure 1 shows the relationship between consistency and setting time of OPC, 5SH, and 5SS.

Table 3: Optimum water percentage.

Design Mix	Amount of water (ml)	Amount of sodium (ml)	Penetration (mm)	Percentage of water (%)
OPC	119	0	6	29.8
5SH	112	28	6	35.0
5SS	124	31	5	38.8

Table 3 indicates the result of the consistency test in which 5SS contributed the highest percentage of water followed by 5SH while the control sample had the lowest percentage of water with 38.8%, 35 %, and 29.8%, respectively. According to the study by Tikalsky et al. (2001), most of the natural pozzolans produce a cohesive mixture that maintains plastic consistency. Due to this condition, 5SH and 5SS that contained natural pozzolan such as POFA absorbed more water in order to maintain plastic consistency. Hence, the increase of paste consistency is due to the water absorption by POFA.

Table 4: Data on Setting Time

Design Mix	Initial setting time (min)	Final setting time (min)
OPC	178	292
5SH	280	289
5SS	58	62

The amount of water used during the consistency test directly affected the setting time for each sample. The data on setting time is shown in Table 4. As observed in Table 4, 5SS paste exhibited the lowest initial setting time followed by those of plain OPC and 5SH paste with a reading of 58, 178, and 280 minutes. The lowest final setting time was recorded by 5SS paste with a reading of 62 minutes followed by 5SH and OPC paste with a reading of 289 and 292 minutes. From the study, 5SS paste tends to have a higher initial and final setting time compared to OPC. The increase in setting time could be the result of higher demand for the mixing water to achieve the desired workability (Khankhaje et al., 2016). However, as it mixes with an alkali activator, the setting time decreases for both initial and final setting time which contributes to faster hardening. Sodium silicate in the form of silicate mineral paint is used in the concrete as a setting accelerator which enhances waterproofing and improves durability. It can be concluded that POFA and alkali activator solutions accelerate the initial and final setting time.

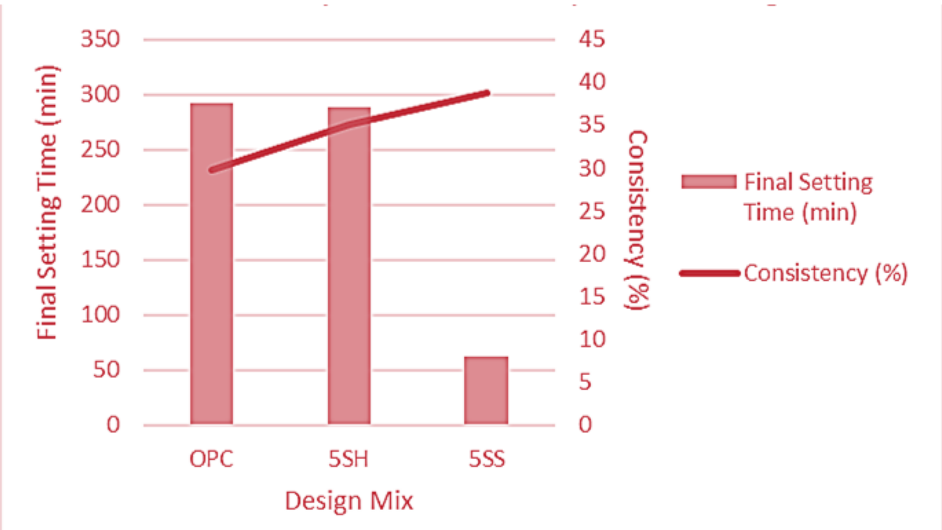

Figure 1: Relationship of consistency and setting time

Figure 1 shows the relationship between consistency and setting time for each sample. Figure 1 shows that 5SS gave the highest value of consistency with a shorter time of final setting time, followed by 5SH and OPC. Tikalsky et al. (2001) stated that the amount of water is one of the important parameters that will be greatly affected when using a natural pozzolan as a cement replacement. As the water used is high, it will take a longer time for the cement paste to harden. However, in this study, POFA with an alkali activator solution tends to accelerate in the final setting time.

4.2 XRF Analysis

Based on the XRF analysis of elemental analysis, the calcium and silicate elements of each design mix are shown in Tables 5, 6, and 7.

Table 5: Elemental analysis of Calcium and Silica in OPC.

	CaO (%)	SiO_2 (%)
OPC Day 1	65.04	23.38
OPC Day 3	78.69	1.99
OPC Day 7	94.05	<LOD (minor)
OPC Day 28	60.49	26.63

Table 6: Elemental analysis of Calcium and Silica in 5SH.

	CaO (%)	SiO_2 (%)
5SH Day 1	65.83	21.36
5SH Day 3	64.31	25.20
5SH Day 7	87.29	1.08
5SH Day 28	93.89	<LOD (minor)

Table 7: Elemental analysis of Calcium and Silica in 5SS.

	CaO (%)	SiO_2 (%)
5SS Day 1	78.44	9.88
5SS Day 3	87.52	3.18
5SS Day 7	87.41	3.79
5SS Day 28	91.31	0.31

From Table 5, we can see that the calcium element increased over time. However, the Silica element gave a high result on day 1, decreased until day 7, and on day 28, the silica increased higher compared to day 1. Based on the XRF analysis shown in Tables 6 and 7, 5SH and 5SS consisted of high elements of calcium compared to the control sample and this explained the result of fast setting cement. However, high elements of calcium played a lesser role in affecting the final binder since the silica element in both 5SH and 5SS decreased over time.

5 Conclusion

This study finds that both 5SS and 5SH contribute to accelerating the setting time compared to the control sample since the cement paste hardens faster. This gives a benefit in construction on patching and repairing concrete.

6 Availability of Data and Material

Data can be made available by contacting the corresponding author.

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Nuradila Izzaty Binti Halim is a student at Faculty of Civil Engineering, Universiti Teknologi MARA, Malaysia. She obtains her Master of Science in Structural Engineering from Universiti Teknologi MARA, Malaysia. Her research focuses on the contribution of POFA in Cement Paste and Concrete.

Aidan Newman is a student at Faculty of Civil Engineering, Universiti Teknologi MARA, Malaysia. He obtains his Master of Science in Structural Engineering from Universiti Teknologi MARA, Malaysia. His research focuses on the contribution of SCMs such as POFA and WPSA in Cement Paste and Concrete.

Dr. Muhd Norhasri Muhd Sidek is a senior lecturer at the Faculty of Civil Engineering, Universiti Teknologi MARA, Malaysia. He obtained his Ph.D from Universiti Teknologi MARA, Malaysia. His research interest includes Concrete, Nano Materials, Advanced Materials, and UHPC Technology.

Prof. Dr. Hjh Hamidah Mohd Saman is the Deputy Dean at the Faculty of Civil Engineering, Universiti Teknologi MARA, Malaysia. She obtained her Ph.D in Civil Engineering from the University of New South Wales, Australia. Her research areas include Durability in Concrete, Lightweight Concrete, High-Performance Concrete and Bio-concrete, International Construction, Strengthening and Repairing Materials for Concrete Structures using Non-corrodible Materials. Nano, Bio-Concrete and High Resistance Cement Materials to Fire.