Compressive Strength and Porosity of POFA Blended Concrete Admixed with Micro Silica

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Abstract. Blended Palm Oil Fuel Ash (POFA) concrete as an alternative sustainable material depends on the quality of POFA. Microsilica can improve the quality of blended POFA concrete; however, the optimum quantity must be determined. This study investigates the effect of micro silica content, POFA content, and concrete age of the blended POFA concrete admixed with silica fume. Portland Composite Cement concrete was the control mix with a target strength of 20 MPa. The blended POFA concrete contains 0%, 20%, and 40% POFA as cement replacement material using various microsilica contents (0, 5, 10, and 15%). Three series with twelve mixtures were cast and cured for 28 days in water. Compressive strength and porosity at 3, 7 and 28 days were measured. The results show that compressive strength and porosity of blended POFA concrete admixed with microsilica were influenced by concrete age, micro silica content, and POFA content. The highest strength shown by concrete without POFA that using microsilica of 10%. In contrast, the lowest strength was concrete with 40% POFA and without microsilica. Porosity is also reduced by using 10% micro silica in the mixes. Adding microsilica affects the strength and porosity of the resulting blended POFA concrete.

1 Introduction

The palm oil sector contributes significantly to Indonesia's economy. With 140 businesses generating 6,660 tons of tbs of palm oil every hour, Riau Province is Indonesia's largest palm oil processing sector (BUMN, 2014). The palm oil produced by this industry will meet the needs of Indonesian population. It will create residual waste—also called as waste—from the refined products of the palm oil industry. According to study done in 2014 by Haryanti & Norsamsi [1], oil palm bunches, fibers, and shells make up the majority of the solid waste produced during the manufacturing of palm oil. If not correctly managed, palm oil waste will continue to develop and build and may pollute the environment Haryanti [1].

According to research by Ting [2], using POFA as a cement substitute material can help minimize the need for cement and the quantity of trash generated by the palm oil sector,

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which is positive for the sustainability of the environment. It has been determined by research by Hamada [3] that POFA is a material with a high silica (SiO2) concentration, making it a suitable pozzolanic material. According to Ofuyatan and Edeki [4], adding POFA to concrete mixtures can make concrete more resistant to sulfate and chloride penetration. According to research by Ofuyatan & Edeki [4], the use of POFA in concrete can lessen weight loss brought on by low chloride penetration and sulfuric acid.

Concrete technology is always evolving in an effort to raise the caliber and effectiveness of concrete. The addition of pozzolanic elements to concrete mixtures, such as adding microsilica like silica fume, is one innovation that consistently shows up in tests conducted in Indonesia and even around the world [5]. Microsilica, also known as silica fume, is a fine-grained pozzolanic substance with a high silica content that is extracted from blast furnaces or silicon production waste [6]. Silica fume works well as an ingredient in concrete mixing materials due to its extremely small particle size. Because these tiny particles can fill up the spaces in the concrete, the concrete will become impermeable and its porosity will decrease, improving the concrete's quality [7]. According to study by Mazloom [8], silica fume will be used a lot more in concrete compositions going forward. The findings of a study by Mazloom [8] demonstrated that boosting the quantity of silica fume use can improve concrete's mechanical qualities after 28 days. In this work, silica fume additives that replace 10-15% of the concrete in POFA is optimized. The impact of micro silica in POFA mixed concrete, specifically POFA 0, 20, and 40%, is highlighted in this study.

2 Materials and Method

In this investigation, coarse aggregate, fine aggregate, PCC cement, POFA, silica fume, and water were employed in the POFA concrete mix with silica fume additions. POFA from PT Perkebunan Nusantara V, Kampar Regency, Riau Province, was used in this investigation. Coarse aggregates used have specific gravity of 2.52, absorption 1.63% and fineness modulus of 6.81. Fine aggregates has fineness modulus of 2.98, specific gravity of 2.67, absorption 1.16% Table 1 provides information about PCC and POFA's chemical composition.

Table 1. Chemical composition of portland composite cement (PCC) and palm oil fuel ash (POFA)

Oxides (%)	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	P_2O_5	SO_3	LOI	Others
PCC	23.04	7.40	3.36	0.63	57.38	-	-	-	1.78	-	5.89
POFA	57.00	10.30	1.35	4.76	7.17	0.15	12.60	4.46	1.99	13.50	-

This work used a parametric study to carry out POFA concrete optimization. According to Abdurrahman [9], the parametric study approach is an optimization technique that uses specified parameters to produce a particular configuration. The parameters vary depending on how much POFA was used to replace cement and how much silica fume was added. Samples were created using 20 MPa plan compressive strength. By weight of cement, the range in cement substitution by POFA was 0%, 20%, and 40%. The silica fume composition adjustments that were found to produce the best mixture were 0%, 5%, 10%, and 15% by weight of cement. Concrete test items for compressive strength and porosity are cylindrical molds with dimensions of 10.5 x 21 cm. choosing the best blend based on the results of tests for compressive strength at 3, 7, and 28 days old. Variations in the test object mixture based on the parametric method are shown in Table 2 below to find the optimal mixture.

Table 2. Parameters used in this study

Series	Concrete Mixes	POFA replacement (%)	Silica Fume (%)
0% POFA	POFA0_SF0	0	0
	POFA0_SF5	0	5
	POFA0_SF10	0	10
	POFA0_SF15	0	15
20% POFA	POFA20_SF0	20	0
	POFA20_SF5	20	5
	POFA20_SF10	20	10
	POFA20_SF15	20	15
40% POFA	POFA40_SF0	40	0
	POFA40_SF5	40	5
	POFA40_SF10	40	10
	POFA40_SF15	40	15

The summary of POFA blended concrete composition is shown in Table 3. The mixture composition was calculated using absolute volume method.

Table 3. Experimental mix design on PCC-POFA admixed with micro silica in various percentage

Series	Mixtures	POFA replacement (%)	Micro silica (%)	Quantities (kg/m^3)						
				Cement	Coarse Agg.	Fine Agg.	POFA	Silica Fume	Water	SP
0% POFA	POFA0-SF0	0	0	350.98	1027.37	761.35	0.00	0.00	201.99	1.75
	POFA0-SF5	0	5	350.98	1027.37	761.35	0.00	3.62	201.99	1.77
	POFA0-SF10	0	10	350.98	1027.37	761.35	0.00	7.24	201.99	1.79
	POFA0-SF15	0	15	350.98	1027.37	761.35	0.00	10.86	201.99	1.81
20% POFA	POFA20-SF0	20	0	280.78	1027.37	761.35	55.04	0.00	201.99	1.68
	POFA20-SF5	20	5	280.78	1027.37	761.35	55.04	3.62	201.99	1.70
	POFA20-SF10	20	10	280.78	1027.37	761.35	55.04	7.24	201.99	1.72
	POFA20-SF15	20	15	280.78	1027.37	761.35	55.04	10.86	201.99	1.73
40% POFA	POFA40-SF0	40	0	210.59	1027.37	761.35	110.09	0.00	201.99	1.60
	POFA40-SF5	40	5	210.59	1027.37	761.35	110.09	3.62	201.99	1.62
	POFA40-SF10	40	10	210.59	1027.37	761.35	110.09	7.24	201.99	1.64
	POFA40-SF15	40	15	210.59	1027.37	761.35	110.09	10.86	201.99	1.66

A concrete mixer machine was used to create the test specimens. The ingredients needed to make the test specimens, such as the fine and coarse aggregate, POFA, silica fume, PCC, water, and superplasticizer, were weighed in accordance with the composition that was intended. The materials for the coarse and fine aggregates were first added to the concrete mixer, and they were then thoroughly mixed while being stirred. The concrete mixer was then mixed thoroughly before PCC and POFA were added. The water and weighed superplasticizer were combined before to being gently added to the concrete mixer. Silica fume, an additive, should be added to the concrete mixture after it has been dispersed evenly. Three layers of the completed mixture are inserted into the mold. To eliminate air spaces in the mixture, each layer was 25 times crushed with a compactor stick.

After the manufacturing process has been completed for 24 hours, the test specimen dries, at which point it can be removed from the mold and begin the curing procedure. These specimens are properly hydrated during the curing process in order to achieve the desired compressive strength and preserve humidity.

3 Results and Discussion

3.1 Compressive Strength

According to SNI 1974-2011 [10], the compressive strength test was performed to ascertain the maximum load that can be supported per unit area. The cylinder-shaped compressive strength test object has dimensions of 10.5 x 21 cm and is evaluated after 3 days, 7 days, and 28 days of curing.

The compressive strength of concrete with 0% POFA replacement can be shown in Figure 1, which also demonstrates that the compressive strength of concrete rises with concrete age. The POFA0_SF15 concrete outperformed the control concrete in terms of compressive strength, measuring 26.83 MPa after 28 days. Concrete with a 10% silica fume content (POFA0_SF10) increased in compressive strength by 18%, or 25.84 MPa, while concrete with a 5% silica fume content (POFA0_SF5) grew in compressive strength by 15%, or 25.15 MPa. This demonstrates how silica fume can dramatically boost the compressive strength of concrete mixtures. As the age of the concrete increases, its compressive strength keeps growing. Additionally, early-stage concrete can benefit from and be improved by the application of silica fume.

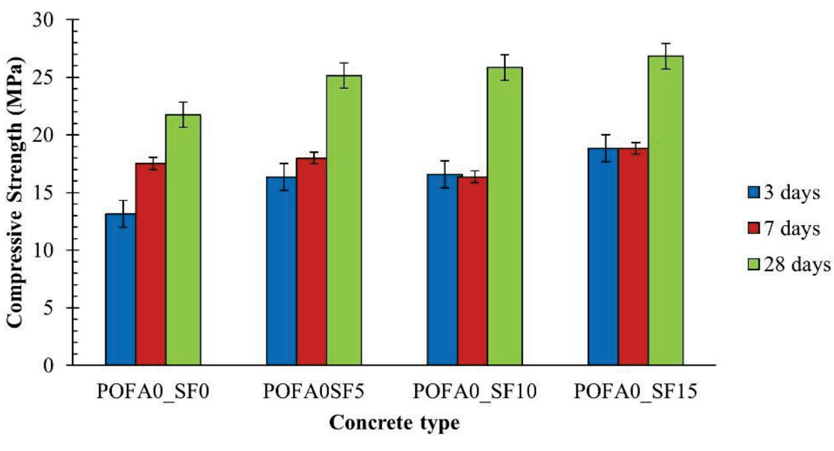

Fig. 1. Compressive strength of concrete with 0% POFA

Figure 2 shows that the POFA20_SF10 concrete has a compressive strength of 17.32 MPa, which is the ideal mix for the 20% POFA replacement mix group. Comparing this mix to POFA20_SF0 concrete, the 10% silica fume addition raised the compressive strength by 22%. Concrete made using POFA20_SF0 has a compressive strength of 14.17 MPa. While POFA20_SF15 concrete's compressive strength improved by 20% to 17.02 MPa and

POFA20_SF5 concrete's compressive strength increased by 8% to 15.39 MPa, respectively. A higher compressive strength of POFA concrete with silica fume content might be inferred from this.

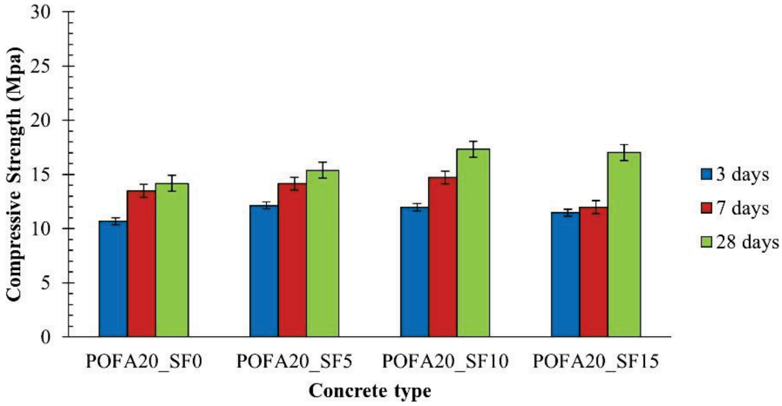

Fig. 2. Compressive strength of concrete with 20% POFA

Figure 3 shows that the POFA40_SF10 mixture, with a compressive strength value of 12.97 MPa at the age of 28 days, is the best blend for 40% POFA replacement concrete. Concrete made with 40% POFA without silica fume has a compressive strength of 11.75 MPa at the age of 28 days. The compressive strength of the POFA40_SF5 concrete mix rose by 8% to 12.77 MPa. At the age of 28 days, the POFA40_SF15 concrete mixture's compressive strength had improved by 3%. Comparable to other combinations, the usage of 40% POFA substitution has a lower compressive strength. The use of POFA as a cement substitute decreased the compressive strength of concrete, as was the case in Yazici's [11] research. The difference in compressive strength below the compressive strength of the control concrete increases with the amount of POFA replacement used. However, silica fume used as an addition can improve concrete's compressive strength.

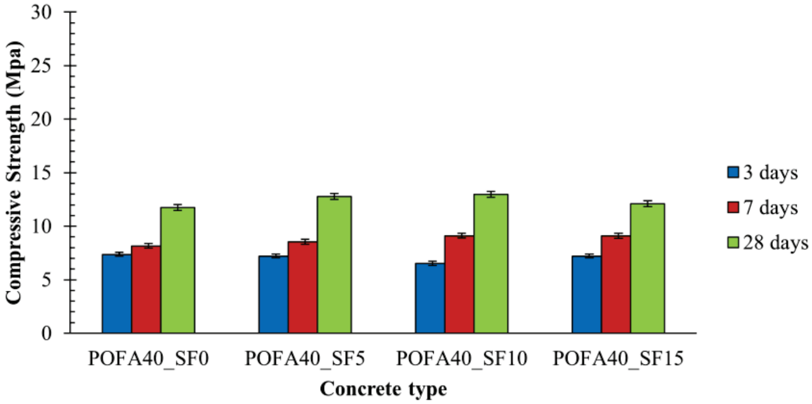

Fig. 3. Compressive strength of concrete with 40% POFA

3.2 Porosity

Concrete porosity testing is done in line with ASTM C-642-97 [12] and involves filling the concrete pores with water to assess how dense the concrete is. The 10.5x10.5 cm concrete porosity test specimens were evaluated at three different curing ages: 3 days, 7 days, and 28 days.

Figure 4 illustrates how all concrete variations with 0% POFA component lost strength over time. The POFA0_SF15 variety has the lowest porosity, coming in at 9.45%. As the concrete's age and other changes rose, the POFA0_SF15 concrete's porosity changed much less. In comparison to concrete without silica fume, which has an 11.57% porosity, POFA0_SF10 concrete has a 9.7% reduced porosity. Similar to POFA0_SF5, this concrete has a 10% lower porosity than the 11.52% porosity of concrete without silica fume. At 28 days old, POFA0_SF0 concrete has a porosity of 12.81 percent. This demonstrates how silica fume helps concrete become denser by filling its pores and reducing the concrete's porosity.

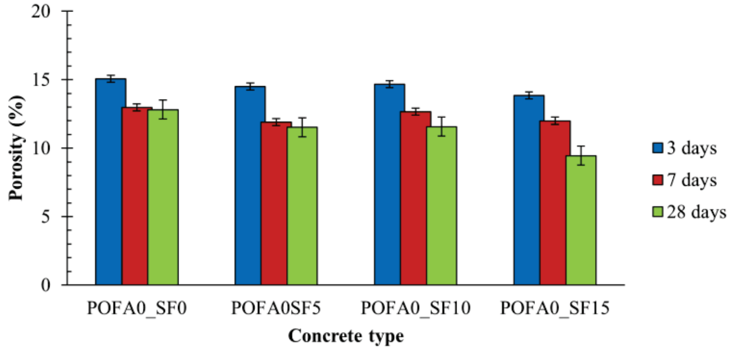

Fig. 4. Porosity of concrete with 0% POFA

Figure 5 compares the porosity of concrete with and without 20% POFA substitution. The porosity of POFA20_SF0 concrete is 10.86%, which is comparable to 20% POFA concrete. The difference between 20% POFA concrete with silica fume and POFA20_SF5 concrete is 15% less at 9.23%. In comparison to 20% POFA concrete without silica fume, which is 9.19%, POFA20_SF10 concrete has a lesser differential of 15.4%. Additionally, the difference between 20% POFA concrete with silica fume and POFA20_SF15 concrete is 13% less, or 9.40%. Overall, 20% POFA replacement in concrete results in less porosity than control concrete. This research is comparable to that done by Kroehong [13], who found that using POFA as a cement alternative can lower concrete's porosity rate.

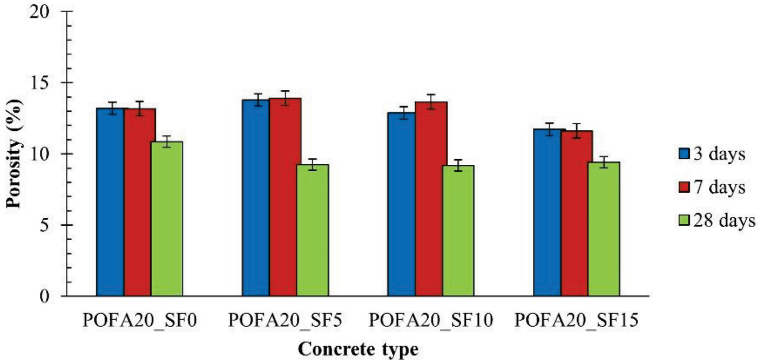

Fig. 5. Porosity of concrete with 20% POFA

Figure 6 demonstrates that concrete with POFA40_SF0 has a 10.44% porosity. In comparison to POFA40_SF0 concrete, POFA40_SF5 concrete has a porosity differential that is 10.37% lower at 0.7%. While the porosity of POFA40_SF10 concrete at age 28 is 11.49%. With a porosity of 9.46% after 28 days, POFA40_SF15 concrete mixtures continue to exhibit significant porosity reduction as they age.

When compared to concrete without silica fume, the use of silica fume additions in concrete mixtures can improve the quality of concrete. When silica fume is added to concrete, the compressive strength and porosity are improved. Concrete mixtures with a 20% POFA replacement and 10% silica fume have the best porosity. The pore number of concrete with 40% POFA replacement differs significantly from the pore number of control concrete, in line with the study of Kroehong [13].

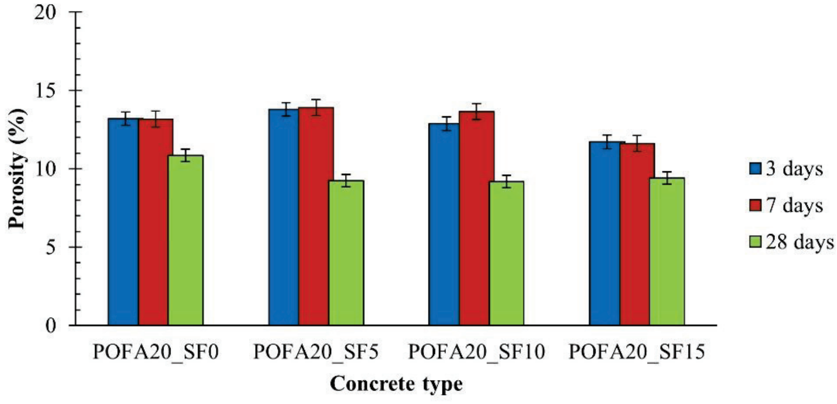

Fig. 6. Porosity of concrete with 40% POFA

4 Conclusion

1. The results show that compressive strength and porosity of blended POFA concrete admixed with micro were influenced by concrete age, micro silica content, and POFA content.
2. The highest strength was shown by concrete without POFA inclusion and silica at 10%. In contrast, the lowest strength was concrete with a POFA of 40% and without micro silica content.
3. Porosity is also reduced by adding up to 10% micro silica without POFA in the mixes

The authors gratefully acknowledge the financial support provided by Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT), Tahun 2023, LPPM Universitas Riau, Pekanbaru, Indonesia, Contract Number 11316/UN19.5.1.3/AL.04.2023.

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