DEVELOPMENT OF NEW GEOPOLYMER MORTAR BY USING SEWAGE ASH

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1. INTRODUCTION

This study investigates the possibility of creating geopolymer mortar by employing sewage ash as a complete replacement for fly ash. Sewage ash is a waste product produced by the combustion of sewage ash, containing silica and alumina, generally known as the source of geo-polymerization in fly ash. The compressive strength of mortar and paste made with sewage ash instead of fly ash is examined in this study. In addition, the effects of molarity of alkaline solution are studied to discover the optimal combination for reaching a 7-day compressive strength.

2. METHODOLOGY

2.1 Material Characteristics

The material properties of the sewage ash were characterized to determine its chemical and physical properties as shown in Table 1 and Table 2. Also, an SEM test was conducted to study the shape of raw sewage ash as shown in Figure 1, following recent works by (Liang et al., 2022).

Table 1. Chemical composition results of raw sewage ash using (EDS).

Constituents	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	Fe_2O_3
%	1.3	4.1	15.3	19.8	32.0	3.2	14.9	1.4	7.5

Table 2. Physical properties of raw sewage ash.

Description	Test value
Color	Brown
Particle density	2.39 g/cm^3
Specific surface area	3549 cm^2/g
Particle size	2~209 μm

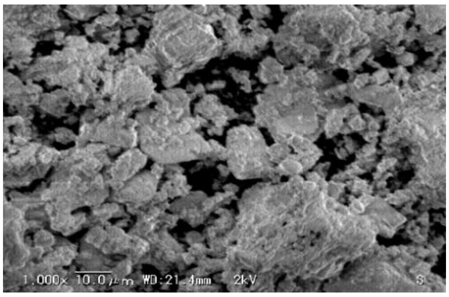

Figure 1. SEM test for raw sewage ash.

2.2 Mix Design and Mixing Condition

Combinations of sewage ash, alkaline solution type, and molarity were used to develop geopolymer mortar specimens as shown in Table 3. The first three trials (S1, S2, S3) involved sewage ash (SA) and natural sand (NS) and intended to determine the necessity of extra water for SA. The mixing time was 4 minutes, with the addition of extra water in the SA specimens. After curing the specimens in an oven at 80°C for 48 hours. The next trials (S5, S6, S7, S8) involved increasing the mixing time, and molarity, and adding silica fume (SF) to the SA. Three-cylinder specimens with 50mm diameter and 100mm height were prepared for each mix proportion.

3. EXPERIMENTAL RESULTS

The uniaxial compressive strength test was conducted at age 7 days. The average compressive strengths were shown together in Table 3. For mix S1, 2, 3, and 4, strength could not be measured due to the failures right after demolding. The fifth trial produced strength by utilizing SA+SF, while the sixth, seventh, and eighth trials used higher molarity with SA and SF to try and achieved a higher compressive strength. The SEM analysis of the hardened specimens shown in Figure 2 showed how the SA was still in its powdery form and that there was no bond between the SA and the AAS. However, the addition of SF to the SA helped in

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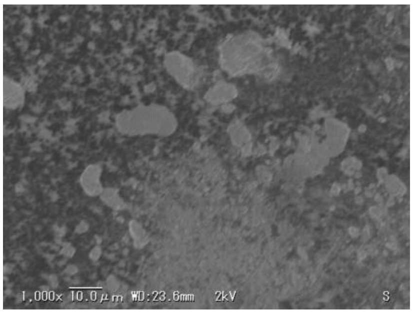
creating a bond and caused geopolymerization between the SA and AAS. The strength was relatively smaller in the following trial by reducing the SF concentration to 30%, as shown in Figure 3. The requisite strength was alternatively reached by utilizing slag in the following trials (S13) through (S15) as Alkaline Activated Material (AAM), instead of geopolymers.

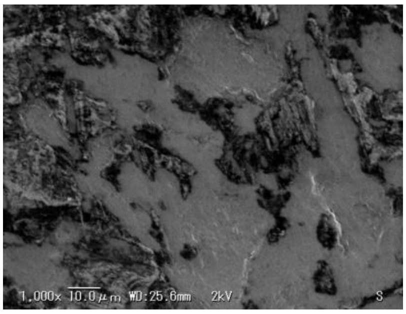
Table 3. Mix details of geopolymer mortar mixes for 1m^3.

MIX ID	Sewage Ash	Silica Fume	Blast furnace Slag	Sand	NaOH	NaOH	Na_2SiO_3	Extra Water	Na_2SiO_3 /NaOH	AA /Binder	Comp. strength
	Kg/m3	Kg/m3	Kg/m3	Kg/m3	M	Kg/m3	Kg/m3	Kg/m3	---	---	(7 days) MPa
S1	665	---	---	1330	8	95	238	---	2.5	0.5	---
S2	495	---	---	990	8	71	177	248	2.5	0.5	---
S3	750	---	---	---	8	214	536	263	2.5	1	---
S4	750	---	---	---	16	214	536	263	2.5	1	---
S5	450	450	---	---	6	154	386	270	2.5	0.6	6.5
S6	450	450	---	---	8	154	386	270	2.5	0.6	10
S7	450	450	---	---	12	154	386	270	2.5	0.6	10.6
S8	450	450	---	---	16	154	386	270	2.5	0.6	11.1
S9	640	275	---	---	6	157	392	275	2.5	0.6	4.3
S10	640	275	---	---	8	157	392	275	2.5	0.6	5.5
S11	640	275	---	---	12	157	392	275	2.5	0.6	7
S12	640	275	---	---	16	157	392	275	2.5	0.6	7.6
S13	740	---	320	---	8	182	454	212	2.5	0.6	9
S14	740	---	320	---	12	182	454	212	2.5	0.6	11
S15	540	---	540	---	12	185	463	216	2.5	0.6	20

*All the specimens were cured in an oven at 80°C for 48 hours.



(a)



(b)

Figure 2. SEM test a) sewage ash (S4), b) sewage ash + silica fume (S8).

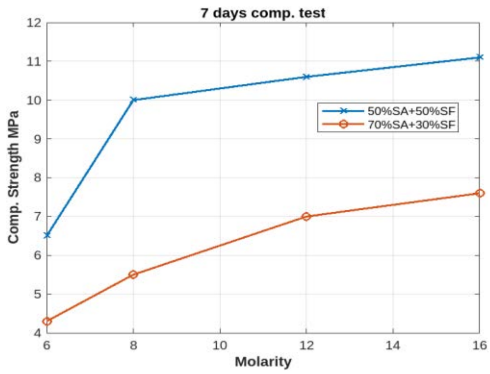


Figure 3. The differences in compressive strength

4. CONCLUSION

1. It can be concluded that the use of sewage ash (SA) in geopolymer mortars and pastes is challenging due to its high-water absorption and the difficulty in achieving proper bonding with other materials.
2. The addition of silica fume (SF) to SA helped in achieving a bond with each other and causing geopolymerization between SA and AAS, resulting in some strength in the specimens.
3. Increasing the molarity of the solution did not result in a significant increase in strength and reducing the SF content led to a decrease in strength. Incorporating slag in the mix did significantly increase the strength of the geopolymer mortar.

Overall, further research and experiment are needed to optimize the use of SA in geopolymer mortars and achieve higher strengths. Also, different materials containing silica such as (sand casting and silica sand) should be investigated as a replacement for natural sand.

REFERENCES

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