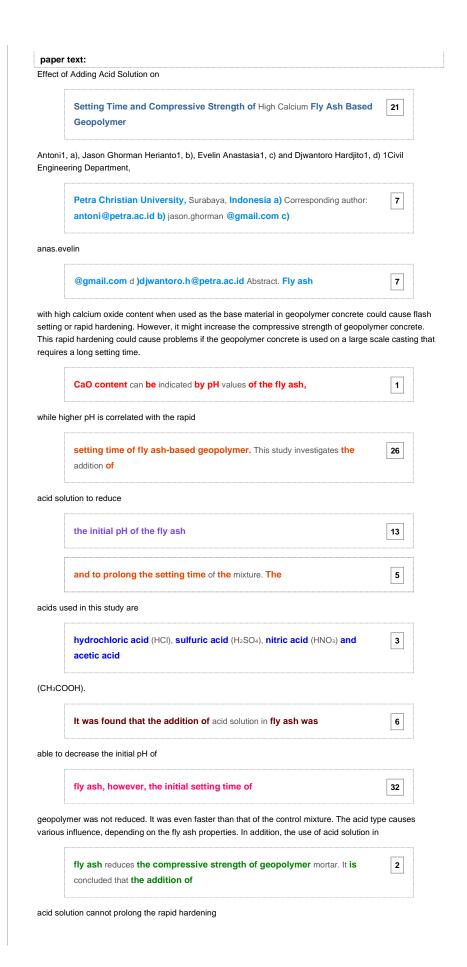
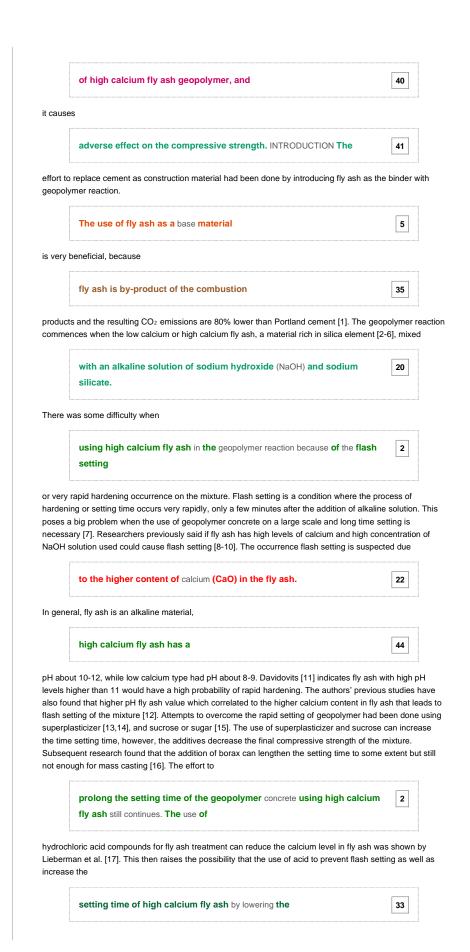
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pH level. Tinnea & Young [18] also found that the addition of citrate acid can slow down the hydration process preventing excessive hardening of conventional concrete. The acid is potentially used as a retarder to slow the hydration process on cement. In subsequent research, the use of citric acid as a hydration process retarder on Portland cement also developed [19]. Other researchers also confirmed that the citric acid could slow the setting time on conventional concrete at very early age [20]. Thus, the addition of various acid solutions to fly ash can cause a decrease in pH value and reduce the free CaO levels in fly ash so

that the setting time can be extended. This research evaluates the effect of

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several acid solutions addition in the high calcium

fly ash to its setting time and compressive strength properties of the geopolymer

mortar. The acids used in this study are

hydrochloric acid (HCl), sulfuric acid (H₂SO₄), nitric acid (HNO₃) and acetic acid

(CH₃COOH). EXPERIMENTAL METHODS Materials Fly ash used is high

calcium fly ash obtained from Paiton Power Plant, Probolinggo, East Java.

This study used two fly ash samples (F1 & F2) taken at different times. The sand used is from Lumajang quarry, East Java, and the gradation is controlled to conform to ASTM C778 [21]. The acids used in the study are 10.5 M hydrochloric acid (HCI), 16.9 M sulfuric acid (H₂SO₄), 16

.3 M nitric acid (HNO3) and 17.2 M acetic acid

(CH₃COOH). The alkali solution

used in this study was sodium hydroxide (NaOH) and sodium silicate Grade 52. The

XRF result and the sieve analysis results are shown

in Table 1. From the XRF test results can be seen that the

fly ash is categorized as type C based on ASTM C311 [22], with the content of $SiO_2 + Al_2O_3 + Fe_2O_3$ more than 50% and CaO levels above 10%.

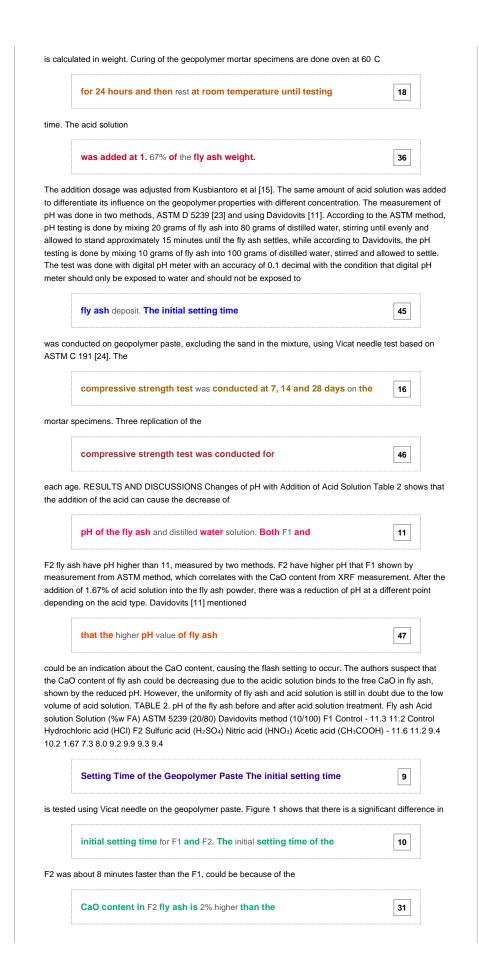
TABLE 1. Chemical and physical properties of the fly ash.

No. Parameter Unit F1 F2 1 SiO₂ % wt 2 Al₂O₃ % wt 3 Fe₂O₃ % wt 4 CaO % wt 5 MgO % wt 6 Na₂O % wt 7 SO₃ % wt 8 K₂O % wt 9 TiO₂ % wt 10 P₂O % wt 11 MnO₂ % wt 12 L O I % wt 13 %Passing sieve #325 % wt 35.46 16.91 15.43 16.98 7.23 2.83 1.72 1.32 0.75 0.26 0.18 0.4 88 Mixture and Testing 34.29 16.62 15.38 18.18 7.52 2.97 1.63 1.35 0.73 0.25 0.17 0.36 92 The composition of mix design for making the geopolymer mortar mixture are as follows; sand

to fly ash ratio of 2, free water to fly ash ratio

of 0.25, the NaOH molarity is calculated to be 8 M for the given free water mass and

ratio of sodium silicate solution to sodium hydroxide solid was 2.5. All ratio



F1 fly ash. The pH of the F2 is also higher than the F1, as shown in Table 2.

With the addition of acid solution in the dry fly ash, the

initial setting time was considerably faster for F1, while the F2 only shown a relative small change. This could be because of the already short initial setting time of the F2. The similar effect of rapid hardening is also shown by Kusbiantoro et al [15] when citric acid was used. He suspected the reaction is due to the formation of C₃A which can cause quick hardening. In conventional concrete, C₃A or tricalcium aluminate reactions result in an acceleration of hydration resulting calcium hydroaluminate (3CaO-Al₂O₃-Ca(OH)₂-nH₂O or hydroxy-AFm), which makes concrete paste harden faster [25]. The addition of acid into the dry F1 fly ash accelerate its initial setting time about 40-60% when compared to the control. While for F2 samples, the addition of acid accelerates about 8% compared to the control specimen. The addition of several type of acids namely

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hydrochloric acid, sulfuric acid, nitric acid, and acetic acid

at 1.67% of fly ash weight, did not produce a longer initial setting time of the geopolymer. This result is similar to the previous studies with the addition of citric acid to the geopolymer paste [15]. And the acceleration of setting time was not aligned with the previous studies on the use of acid in the normal concrete, where the citric acid could act as a hydration process retarder on cement [19] and conventional concrete [18]. Initial setting time (Mins) 18 16 14 12 10 8 6 4 2 Initial setting time (Mins) 18 16 14 12 10 8 6 4 2 Initial setting time (Mins) 18 16 14 12 10 8 6 4 2 0 0 F1 F1HCI F1H₂SO₄ F1HNO₃ F1CH₃ COOH (a) F2 F2HCI F2H₂SO₄ F2HNO₃ F2CH₃ COOH (b) FIGURE 1.

erent acio	l solution,	
for (a	F1 fly ash and (b) F2 fly ash.	1
Comp	ressive Strength of Geopolymer Mortar The increase in ressive strength	12

shown in Fig. 2, the compressive strength of the F2 fly ash is higher than the

F1 fly ash also correlated with the slightly higher CaO

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content in the F2 fly ash. For geopolymer

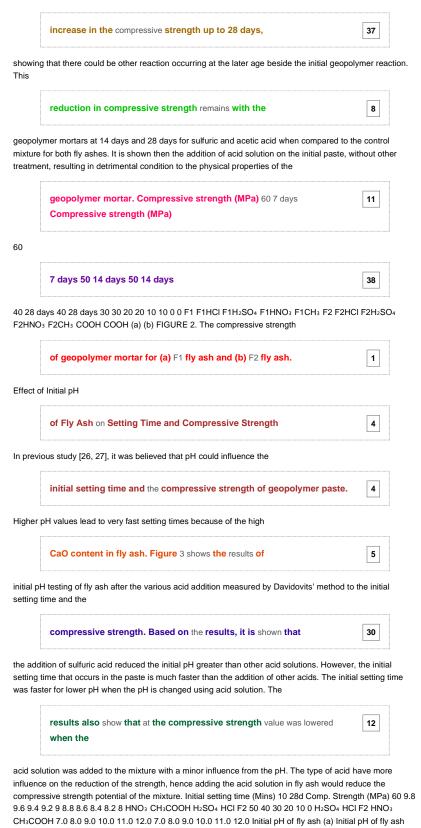
mortar with various acid added initially in the fly ash, the addition of 1.67% of acid solution into the F1 fly ash decreases the result of the compressive strength compared to the control geopolymer mortar. Hydrochloric acid had the highest reduction of strength at 7 days testing compared to other acids, the reduction was about 40% compared with the control mortar. There was an increase of the strength at the later age, showing that reduction could be reversed. This

result is similar to research on the use of citric acid in

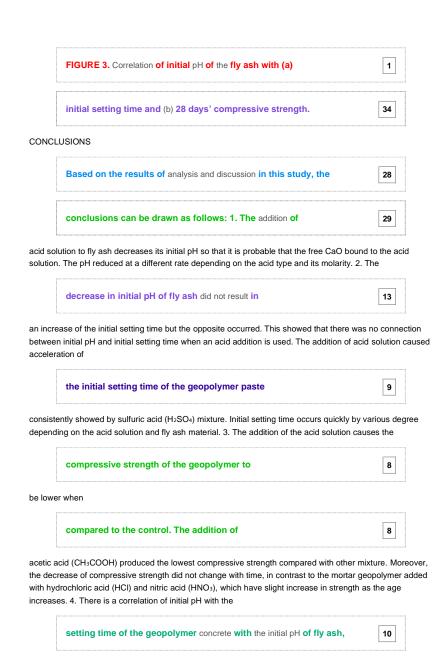
conventional concrete that causes the reduction of

compressive strength of concrete at very early age

[20]. For F2 fly ash, the highest reduction of strength happened on the specimens with acetic acid addition. The specimen did not increase in strength with age on contrary with the specimens with hydrochloric acid. Specimen with the addition of hydrochloric acid and nitric acid still show some



(b)



with lower pH giving the faster setting time. The compressive strength also

influenced by the acid addition however the effect
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