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ADDITION OF SUPERPLASTICIZER ON GEOPOLYMER CONCRETE

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ABSTRACT

It is already known that the Portland Cement process manufacturing produces CO_2 as emission that interfere in environment. Therefore it is necessary to find an alternative materials as a substitute for PC or alternative concrete. Today one of the alternative solution is geopolymer concrete, it is based on fly-ash or other material pozzolanic. By adding some alkali activator in fly-ash would make geopolymer concrete. The addition of high-range water-reducing admixture up to approximately 2% of fly-ash mass have improved the workability of fresh geopolymer concrete.In this study the mixtures of geopolymer binder were made with the ratio of fly-ash and alkali activator were 74%: 26%, molarity of sodium hydroxide was 12 M. Ratio of sodium silicate to sodium hydroxide were varies from 1.5 to 3, the percentage of naphthalene-based superplasticizer (SP) were varies from 1.5 to 3 of fly-ash mass. Tests performed were compressive strength, tensile strength and density. The results showed that the highest compressive strength achieved for the proportion of Na_2SiO_3/NaOH = 2 and for the percentage of SP 1.5, the highest tensile strength achieved for the proportion Na_2SiO_3/NaOH = 2,5 and for the percentage of SP 1.5. The average density of geopolymer was 2400 kg / m^3.

Keyword: geopolymer, pozzolanic material, alkali activator, molarity.

INTRODUCTION

It is already illustrated that the Portland Cement process manufacturing produce CO_2 as emissions that interfere in environment . In manufacturing process one ton of PC produce 0.95 tons of CO_2, represents the sum of the results of the coal burning process and exhaust gases from fuel [1]. Accordingly it is necessary to find an alternative materials as a substitute for PC or alternative concrete. Currently one of the alternative concrete solution is geopolymer , it is based on fly-ash or other material pozzolanic such as metakaolin, blast furnace slag, and others. By adding some alkali activator which is a mixture of sodium silicate (Na_2SiO_3) and sodium hydroxide NaOH in fly-ash would make geopolymer concrete [3]. Problem already known that the initial setting time binder of geopolymer based on some particular of fly-ash were very fast in scale of minutes with poor workability [2] , consequently it is essential to find chemical additive to adjust the time settings. The addition of high-range water-reducing admixture, up to approximately 2% of fly-ash mass, improved the workability of fresh geopolymer concrete with very little effect on the compressive strength of hardened concrete [3]. In this study the mixtures of geopolymer binder were made of fly-ash and alkali activator, with certain molarity of sodium hydroxide. To facilitate the pouring then used superplasticizer. Tests performed were setting time, compressive strength and tensile strength.

RESEARCH CONDUCTED

This geopolymer research was based on fly-ash which was a waste of electricity industry in Paiton , Probolinggo East Java Indonesia. This binder geopolymer was performed with ratio of fly-ash to the alkali activator was 74% to 26%. The proportion of Na_2SiO_3 to NaOH varies from 1,5 to 3 with the molarity of NaOH was 12, moreover the percentage of superplasticizer naphthalene based varied from 1,5 to 3 of fly-ash weight, form of binder specimens were 2 cm in diameter and 4 cm high .The geopolymer concrete specimens were made by adding some aggregate to the binder with the proportion of aggregate to the binder was 75% : 25%, the proportion of fine aggregate to coarse aggregate was 40%:60%. Form of geopolymer concrete specimens were 10 cm in diameter and 20 cm high. All specimens were treated in ambient environment. Tests conducted were setting time, value of compressive strength and tensile strength. Compressive strength tests were conducted at 7, 14, 21, and 28 days.While the tensile stength tests were conducted at 28 days.

EXPERIMENTAL RESULTS

Material analysis chemical analysis of Fly-Ash

The analysis of XRD (X-Ray Diffractometry) and XRF (X-Ray Fluorescence) were applied to determine the chemical compounds and oxides contained in fly-ash, the results are shown in Figure-1 and Table-1.

Table-1. Chemical compounds of Fly-Ash from XRD analysis.

Notation	Mineral	Chemical Formula
q	Quartz = Silicon Oxide	SiO_2
h	Hematite = Iron Oxide	Fe_2O_3
s	Sillimanite = Aluminium Silicate	Al_2SiO_5

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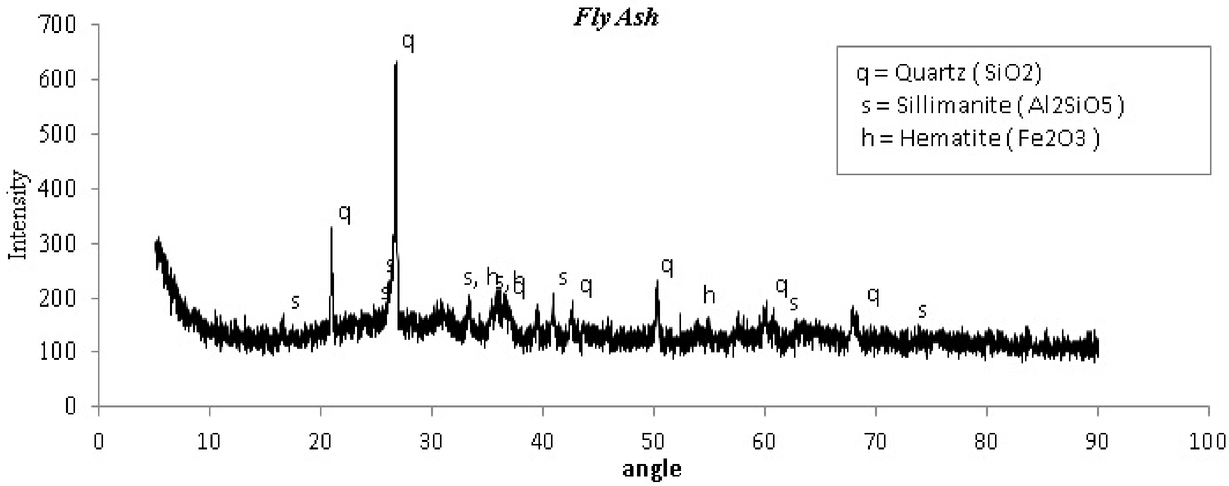

Figure-1. XRD analysis of fly-ash.

Table-2. Oxides contains of Fly-Ash in XRF analysis.

No.	Oxides Contained	Formula	Percentage (%)
1	Silice oxide	SiO2	34.645
2	Aluminium Oxide	Al2O3	22.548
3	Ferric Oxide	Fe2O3	12.522
4	Calcium Oxide	CaO	15.24
5	Magnesium Oxide	MgO	6.82
6	Sulfur Oxide	SO3	1.171
7	Sodium Oxide	Na2O	1.584
8	Kalium Oxide	K2O	1.314
9	Phosphorus Oxide	P2O5	3.229

As shown on the Table-2, the total quantity of oxides (SiO_2 + Fe_2O_3 + Al_2O_3) in fly-ash are not more than 70% however close to 70% (69.715%) , so the material is not classified as pozzolanic material according to ASTM C618-2012. Furthermore the volume of CaO in fly-ash more than 10% , so that fly-ash classified as type C.

Proportion of mixture

Proportion of geopolymer concrete mixtures are shown in Table-3.

Setting time initial setting

All of geopolymer binder mixtures were observed the value of setting time, the results of initial setting are shown in Figure-2.

On Figure-2 indicated that the influence of superplasticizer might say almost no influence against the initial setting time. Conversely, the ratio of $Na_2SiO_{3/}$ NaOH have significantly affects to the initial setting time, the greater the ratio of $Na_2SiO_{3/}$ NaOH the faster the initial setting value. It happens as the increasing ratio of Si / Al, with increasing ratio of Na2SiO3 / NaOH the ratio of Si / Al will increase as well so that the amount of reaction Si-Al is also increase.The important role of sodium silicate as catalyst can be seen , the higher amount of sodium silicate in the mixture deliver the faster setting time [4].

Final setting

All of geopolymer concrete mixtures were investigated the value of final setting time, the results are shown in Figure-3.

Different to the effect of the initial setting, the role of superplasticizer in final setting time seems has effect although the value are relatively small. The more the amount of superplasticizer, the longer the final of setting time. Influence ratio of Na_2SiO_3/ NaOH on the final setting similar to its effect on the initial setting. The greater the ratio $Na_2SiO_{3/}$ NaOH the faster the initial setting value. The role of sodium silicate as catalyst can be seen clearly, the higher amount of sodium silicate in the mixture deliver the faster final setting time [4] . This result has corresponds with previous research, that sodium silicate can accelerate the polymerization reaction [3].
Influence Ratio of Si/Al.

Influence ratio of Si/Al on final setting is shown on Figure-4.

The effect of Si / Al on setting time is evident, the greater the value of Si / Al the faster the final setting. The increasing ratio of Si / Al there is relation to the increasing in volume Na2SiO3. This result in accordance with previous research [4] the higher amount of sodium silicate in the mixture, deliver the faster final setting time.

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Table-3. Materials proportion of geopolymer concrete.

Notation of Specimens	Masse of Concrete	Coarse Aggregate	Fine Aggregate	Fly Ash	Alkali Activator		Superplasticizer
					Na_2SiO_3	NaOH 12 M	
	Kg	Kg	Kg	kg	Kg	kg	gram
B-1.5-1.5	3.454	1.554	1.036	0.639	0.135	0.090	9.585
B-1.5-2	3.454	1.554	1.036	0.639	0.135	0.090	12.780
B-1.5-2.5	3.454	1.554	1.036	0.639	0.135	0.090	15.975
B-1.5-3	3.454	1.554	1.036	0.639	0.135	0.090	19.170
B-2-1.5	3.454	1.554	1.036	0.639	0.150	0.075	9.585
B-2-2	3.454	1.554	1.036	0.639	0.150	0.075	12.780
B-2-2.5	3.454	1.554	1.036	0.639	0.150	0.075	15.975
B-2-3	3.454	1.554	1.036	0.639	0.150	0.075	19.170
B-2.5-1.5	3.454	1.554	1.036	0.639	0.160	0.064	9.585
B-2.5-2	3.454	1.554	1.036	0.639	0.160	0.064	12.780
B-2.5-2.5	3.454	1.554	1.036	0.639	0.160	0.064	15.975
B-2.5-3	3.454	1.554	1.036	0.639	0.160	0.064	19.170
B-3-1.5	3.454	1.554	1.036	0.639	0.168	0.056	9.585
B-3-2	3.454	1.554	1.036	0.639	0.168	0.056	12.780
B-3-2.5	3.454	1.554	1.036	0.639	0.168	0.056	15.975
B-3-3	3.454	1.554	1.036	0.639	0.168	0.056	19.170

Note : Bx-y
x= ratio of NaOH to Na_2SiO_3
y= percentage of superplasticizer

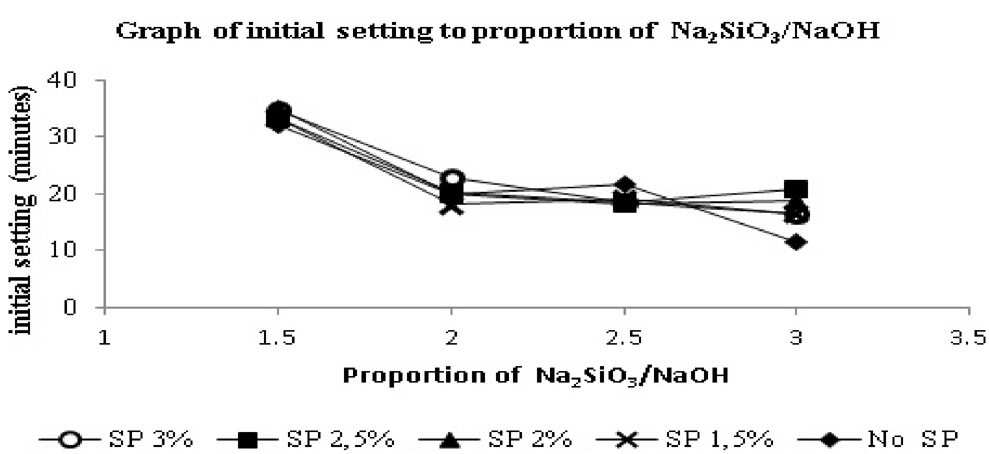


Figure-2. Correlation graphs of initial setting and ratio of Na_2SiO_3/ NaOH.

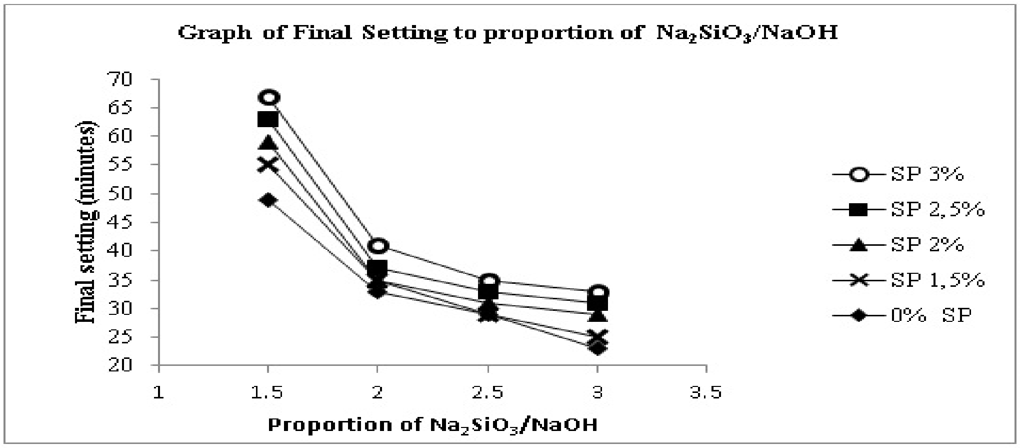


Figure-3. Correlation graphs of final setting and proportion Na_2SiO_3/ NaOH.

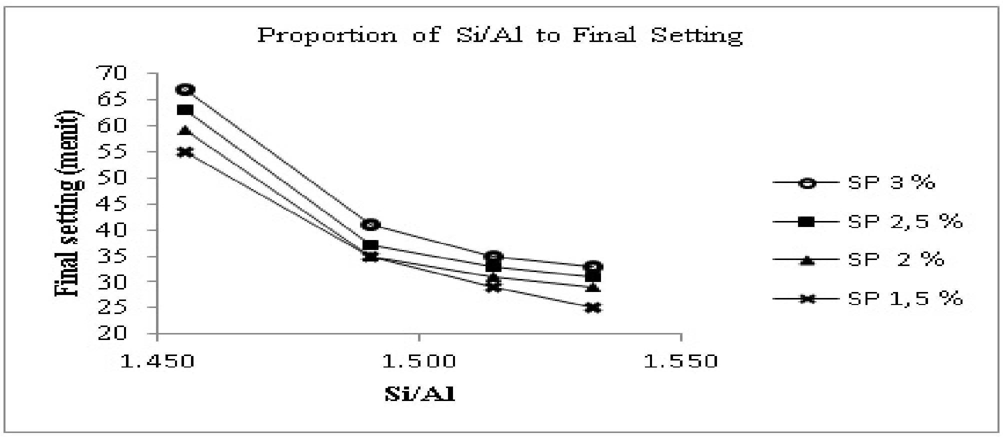
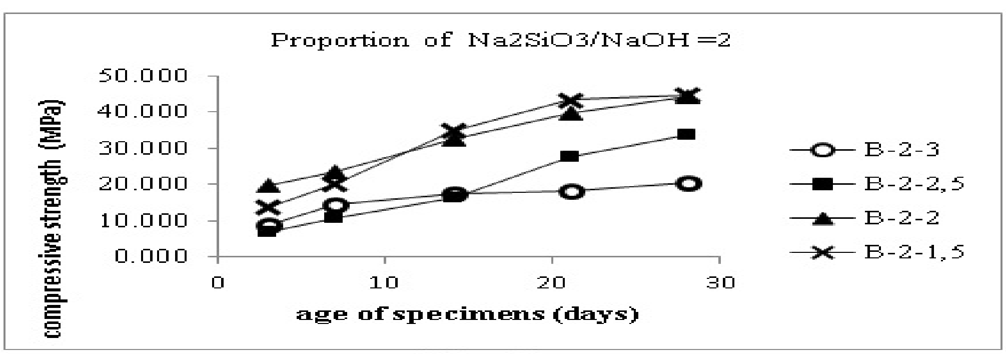


Figure-4. Correlation graphs of final setting and proportion of Si/ Al.

Compressive strength influence of superplasticizer to the compressive strength

Influence percentage of superplasticizer to the geopolymer concrete compressive strength are shown in Figure-5.

As on previous results in this studies, the highest value of compressive strength was obtained on proportion of Na_2SiO_3/ NaOH = 2.



Note : Bx-y
x= ratio of NaOH to Na_2SiO_3
y= percentage of superplasticizer

Figure-5. Correlation graphs of the compressive strength and the age of specimens, on Na_2SiO_3/NaOH =2.

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From the graph shows that the highest value of compressive strength obtained on the mixture of 1.5% superplasticizer. The results almost the same as previous research [5] where the highest value of compressive strength obtained on the mixture of 1% superplasticizer. The addition of superplasticizer decrease the compressive strength. The other research the highest value of compressive strength obtained on the mixture of 1% with the same type of superplasticizer, naphthalene based [6].

Influence of proportion of SI/AL to the compressive strength

Influence of proportion of SI/AL to the compressive strength are shown in Figure-6.

There is correlation among compressive strength and proportion of Si/Al. The maximum compressive strength value occurs in the proportion of Si / Al 1,500. The concentration of silicon in the activating solution of geopolymers has significant effect on compressive strength [8].

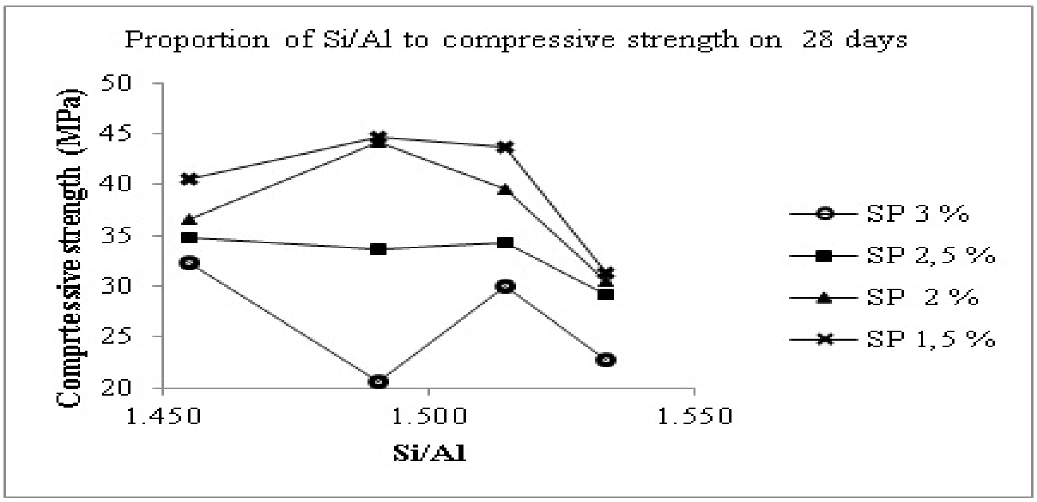

Figure-6. Correlation graphs of compressive strength and proportion of Si/Al.

A mixture of the specimen with the higher content of Si / Al will be given a special meaning exhibited significantly increases in strength [7], the maximum yield of the compressive strength occurs at a ratio of Si / Al was 1.9. The other research indicated that the maximum yield of the compressive strength occurs at a ratio of Si / Al was 2 .[9]

Split tensile strength

All of mixture were observed the value of split tensile strength. The influence percentage of superplasticizer to the geopolymer concrete split tensile strength are shown in Figure-7.

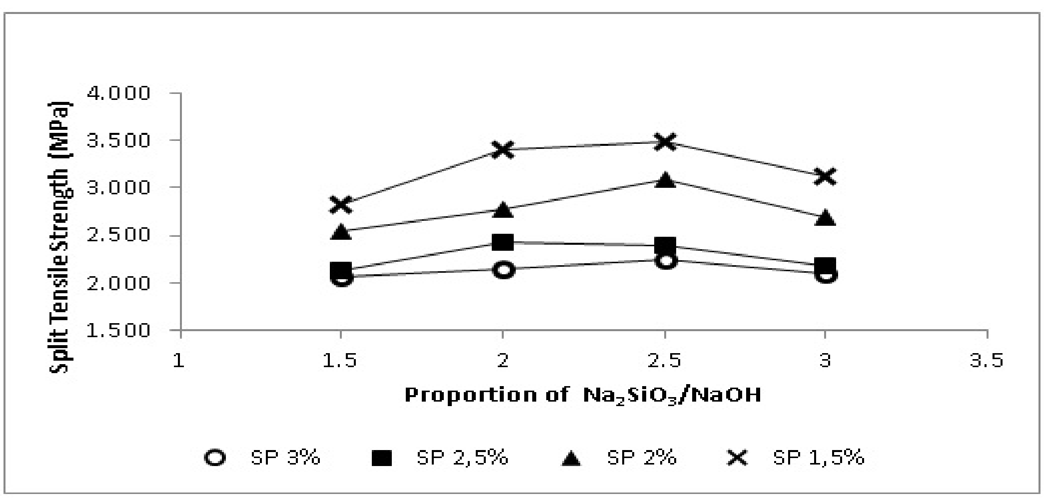

Figure-7. Correlation graphs of split tensile strength and ratio of Na_2SiO_3/ NaOH.

On Figure-7 are illustrated the influence of superplasticizer have significantly affects against the split tensile strength. Conversely, the ratio of Na_2SiO_3/ NaOH have a very small affects to the split tensile strength. The higher value of split tensile strength achieved for presentation of Supeplasticizer = 1,5 with the value of split tensile strength is 3,5 MPa.The result is the same as the effect of Superplasticizer on the compressive strength. Other study show the maximum result of direct tensile strength was 5 MPa [10] in the geopolymer with activator liquid fly ash ratio of 0.40.

Ratio of split tensile strength (ft) to the compressive strength (fc)

Ratio of Split Tensile Strength (ft) to the Compressive Strength (fc) are shown in Figure-8.

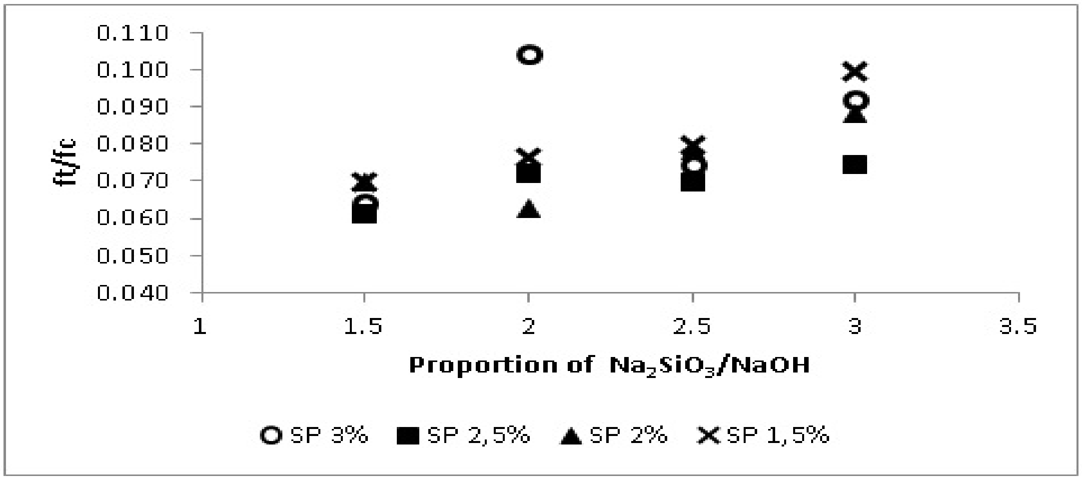

Figure-8. Correlation of ratio of ft/fc and proportion of Na_2SiO_3/ NaOH.

From the Figure-8 indicates that the highest ratio of ft/fc is 1.0, achieved on the proportion of Na_2SiO_3/ NaOH= 3 with activator liquid fly ash ratio of 0,33. Viewed from the previous results of compressive strength, for the ratio Na_2SiO_3/ NaOH = 3 has the lowest value. The other research has the higest ratio ft/fc was 1.4 [10] with activator liquid fly ash ratio of 0.40, this experiments were used Analytical Grade Sodium Hydroxide pellets with 98% purity and Sodium Silicate Solution.

CONCLUSIONS

- The influence of superplasticizer might say almost no influence against the initial setting time, in final setting the superplasticizer seems has effect although the value are quite small. But the effect of Si / Al on setting time is evident, the greater the volume of Si / Al the faster the final setting.
- The highest value of compressive strength obtained on the mixture of 1.5% superplasticizer. And the maximum compressive strength value occurs in the proportion of Si / Al 1,500
- The higher value of split tensile strength achieved for presentations of Superplasticizer = 1,5.

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