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High Initial Concrete Compressive Strength with Variations of Superplasticizer and Silica Fume Additions

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Abstract

Concrete is one of the construction materials resulting from a combination of cement, fine aggregate, coarse aggregate, and water, which are mixed into a solid mass and then can be added with minerals (additives) or chemical additives (admixtures). The purpose of this study is to produce high-quality concrete that is optimum at the early age of the concrete so that the concreting time can be shortened, including by adding superplasticizer as a filler and silica fume as an accelerator. This research method involves making a cylindrical test object with a diameter of 15 cm and a height of 30 cm. Then, the concrete mixture is added with silica fume brand Sika Fume and superplasticizer brand Sika Concrete produced by PT. Sika with 19 variations of the mixture composition; the compressive strength test of the concrete is carried out at 3 days, 7 days, and 28 days. The findings are that 75% of concrete samples using additional materials in the form of silica fume and superplasticizer are quite significant in increasing the initial compressive strength of the concrete by up to 30% both at the age of 3 days, as well as at the age of 7 days and 28 days. The use of additional materials in the form of silica fume and superplasticizer in concrete mixtures with the right levels can generally improve the quality of concrete in its initial compressive strength at the age of 3 days or its workability or fluidity. However, silica fume and superplasticizer materials, when entered into concrete, have mutually influenced performance. The innovation is that high-quality concrete that is optimum at an early age of concrete can be done easily and cheaply using materials that are easily found in the field by combining superplasticizer as a filler and silica fume as an accelerator.

Keywords: Compressive Strength; High Initial; Silica Fume; Superplasticizer.

1. Introduction

Concrete is one of the commonly used construction materials where the basic ingredients are cement, coarse aggregate, fine aggregate, and water, which are mixed in such a way based on estimates that have been calculated to become solid materials such as rocks. Some of the advantages of using concrete as a construction material include being easy to make and work with and using raw materials that are very easy to obtain and resistant to fire and time. The application of concrete making in the field usually uses steel reinforcement, which is then commonly called reinforced concrete. The conventional concrete-making process takes quite a long time compared to other materials and requires formwork to place fresh concrete. Casting is carried out for a minimum of one day which then has to wait for the concrete to be 7 days old which then the formwork can be dismantled and the next work can be carried out.

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The length of time for this work process and waiting for the concrete strength to reach a safe limit to carry out the next work often makes construction projects take longer to work on. Concrete with high early strength is concrete that has a high initial compressive strength at the beginning after the binding process occurs so that it can be completed immediately. This type of concrete is commonly used in the construction of high-rise buildings, precast concrete, concrete roads or toll roads, concreting in cold areas, airports, and underwater buildings that do not require sulfate resistance. Through these problems, an analysis of concrete mixture variations was carried out with the aim of producing a fairly high initial strength with the hope that it can help accelerate the work on construction projects that are based on concrete. Producing concrete with high early strength can speed up the process of dismantling the formwork and can quickly continue the work to the next stage. This study analyzed the compressive strength of concrete consisting of variations of superplasticizer and silica fume. The analysis carried out was in the form of the compressive strength of concrete cylinders at the ages of 3, 7, and 28 days. The total test objects in this study were 30 test objects measuring 15 cm in diameter and 30 cm in height with 10 variations of the mixture. Several studies on silica fume as a material for making concrete have been conducted by Mazloom et al. (2004) [1], who analyzed the effects of using silica fume on the mechanical properties of high-quality concrete. Motahari Karein et al. (2017) [2] studied the size of silica fume on the compressive strength of concrete, where the size made in a wet state is formed like small grains according to each variation. Rostami & Behfarmia (2017) [3] conducted a study on the effect of silica fume on the durability of alkali activators in concrete using slag materials. Through several studies above, it can be concluded that silica fume has the potential to increase the initial compressive strength of concrete.

Concrete with high early compressive strength is basically not a new technology in the construction world, but until now, it has not been through this research, and it is expected to obtain the right composition to obtain concrete with good enough early compressive strength to accelerate construction work. Bhalla et al. (2018) [4] conducted a study on monitoring the early compressive strength of concrete with added silica fume using the wave propagation method; through this study, the compressive strength of concrete at the age of 3 days was 15 MPa. Concrete generally still has empty cavities that affect the compressive strength of concrete. The addition of filler is needed to fill the empty parts. The addition of filler has received attention again, considering that high-quality mineral additives such as fly ash, granulated blast furnace slag, and silica fume are not enough to meet the high demand for concrete production in various regions. Fillers can adapt well to concrete because of their local availability.

Initially reported by Soroka & Setter [5] that fillers have a nucleation effect, accelerating cement hydration and structural formation at an early age. Experimental research has been conducted on the effect of replacing part of the cement mass with silica fume in concrete; the results of the tested concrete are quite satisfactory, making it a good material for buildings and construction and increasing the consistency of concrete up to 55% [6]. The addition of silica fume reduces total porosity and shifts the pore distribution downward [7, 8]. So that the cost of cement consumption and performance improvements can be reduced by replacing cement with silica fume [9]. Further research was conducted to evaluate the impact of fillers on the properties of fresh and hardened concrete [10]. For example, increasing the volume of solids, improving the pore structure, and reducing total porosity, thereby increasing long-term strength [11], tensile strength, splitting tensile strength, and modulus of elasticity can be increased [12]. As a substitute for cement, it reduces bleeding and segregation, which reduces water requirements. In addition to its chemical contribution, fly ash often has a compacting effect on the structure of the cement paste, leading to the limitation of the possibility of ion exchange responsible for ettringite precipitation [13]. It is claimed that the compressive strength is not significantly affected by fillers up to 15% cement replacement [14].

As far as durability is concerned, fillers increase the carbonation rate of concrete [15] but reduce the chloride diffusion coefficient [16], while others state that the increase in chloride ion penetration occurs due to the replacement of cement with LF [17]. However, other researchers found that a number of fillers replacing Portland cement, namely up to 15% by mass, did not significantly affect the chloride penetration resistance. It was concluded that the available research on concrete durability influenced by fillers is still controversial [18, 19]. Based on the description above, there is still a gap in the results of the studies that have been presented. Malhotra et al. (1989) [20] determined the effect of silica fume on the behavior of concrete at high temperatures. Tests were carried out on eight different concrete mixtures; four W/C values were tested: 0.23, 0.35, 0.5, and 0.71. For each W/C, two concretes were studied with and without silica fume. Silica fume was not used to replace cement but was added at a level of 8% of the cement mass. The sand was natural sand (Ottawa Valley).

The aggregate (crushed) had a maximum diameter of 19 mm. The authors did not determine the mineralogical properties of this aggregate. A sulfonated naphthalene formaldehyde condensate superplasticizer was used in all mixtures. The focus of the analysis was on concrete with W/C ratios of 0.35 and 0.23 and whose resistance was greater than 50 MPa. The resistance of these two types of concrete was determined after 28 days of wet curing, ranging from 53 to 87 MPa. The test specimens subjected to high temperatures were cylinders 102 × 203 mm in the case of compression tests. The specimens were previously left in wet curing for 7 days and then at T = 21°C and 50% RH for 21 days. The specimens were subjected to temperatures of 150, 300, and 450 °C, respectively. The specimens were maintained at these temperatures. The addition of silica fume weakens the interlocking effect and reduces friction but can form an interparticle bridging effect between cement grains. Superplasticizers can not only inhibit the aggregation of cement grains but also reduce the bridging effect of silica fume [19].

Based on the description above, it is clear. In the explanation of the research above, it turns out that there has been a combination of superplasticizer as a filler and silica fume, so to fill the gap, further research is needed to emphasize the collaboration of the functions of these materials to obtain the optimum composition to produce high-quality concrete at the early age of work. The compressive strength of concrete will increase with the increasing age of the concrete. The strength of the concrete will increase rapidly (linearly) until the age of 28 days, but after that, the increase will be small. The compressive strength of concrete in certain cases will increase for several years in advance. Usually, the design strength of concrete is calculated at the age of 28 days. Compressive strength is one of the main performances of concrete. Compressive strength is the ability of concrete to receive a unit area of compressive force. Although there is a small tensile stress in concrete, it is assumed that all compressive stress is supported by the concrete. The compressive strength of concrete is the magnitude of the load per unit area, which causes the concrete test object to be destroyed when loaded with a certain compressive force, which is produced by a press machine [21, 22]. The value of the compressive strength is obtained from the result of dividing the maximum load from the compression test results by the cross-sectional area of the cylindrical test object as written in Equation 1.

$$Concrete\ compressive\ strength = \frac{P}{A}\left(\frac{Kg}{cm^2}\right) \tag{1}$$

with P is maximum load (kg), A is cross-sectional area (cm^2).

Concrete compressive strength is represented by the maximum stress fc' with units of kg/cm^2 or MPa. The value of concrete compressive strength is generally relatively higher compared to its tensile strength, therefore to review the quality of concrete, usually only its compressive strength is reviewed roughly [23]. Based on its compressive strength, concrete can be divided into several types as shown in Table 1.

Table 1. Several types of concrete according to compressive strength

Types of concrete	Compressive strength
Simple concrete	<10 MPa
Normal concrete	15 – 30 MPa
Prestressed concrete	30 – 40 MPa
High compressive strength concrete	40 – 80 MPa
Very high compressive strength concrete	>80 MPa

According to Pertiwi (2011) [24] the magnitude of the concrete compressive strength is influenced by a number of factors, including the following.

- Water cement factor: The relationship between the water-cement factor and the compressive strength of concrete, in general, is that the lower the water-cement factor value, the higher the compressive strength of the concrete. However, in reality, at a certain water cement factor value, the lower the concrete is, the more difficult it is to compact. Thus, there is an optimal water cement factor value that produces maximum compressive strength.
- The type of cement and its quality affect the average strength and ultimate strength of the concrete.
- Type and relief of the aggregate surface: The reality shows that the use of crushed stone aggregate will produce concrete with greater compressive strength than natural aggregate.
- Efficiency of curing: Loss of strength of up to 40% can occur if drying occurs prematurely. Curing is very important in fieldwork and in the manufacture of test objects.
- Temperature: In general, the speed of concrete hardening increases with increasing temperature. At freezing point, the compressive strength will remain low for a long time.
- Age under normal conditions: The strength of concrete increases with age, depending on the type of cement. For example, cement with a high alumina content produces concrete that is strong enough to break in 24 hours, the same as ordinary Portland cement in 28 days. Hardening continues slowly for several years.

2. Research Method

This research consists of several stages. The experimental work begins with preparing the materials used in the experiment, determining the composition of the concrete mixture, casting, demolding, and curing the test specimens, and then testing the test specimens. The data obtained from the experimental work are then analyzed to convey conclusions. Figure 1 illustrates the workflow of this research.

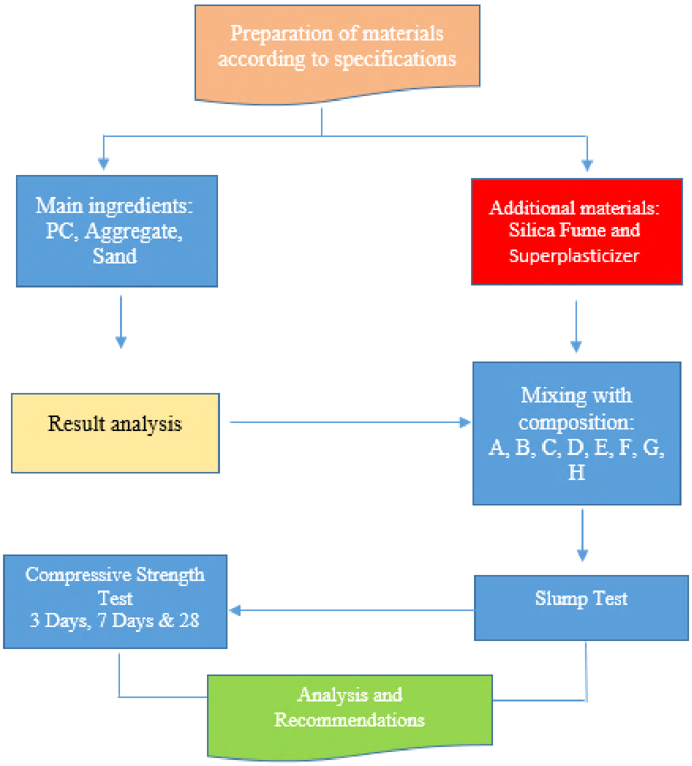

Figure 1. Research flow diagram

Research Tools and Materials

The main materials used in the research are described below (Figure 2):

- Portland Pozzolan Cement (PCC) with the Gresik brand in 40 kg packaging which functions as an adhesive between aggregates.
- Fine aggregate in the form of LumAjang sand, Lumajang, East Java, which was taken at the Construction Materials Technology Laboratory, Civil Engineering Study Program, Faculty of Engineering, Muhammadiyah University of Jember.
- Coarse aggregate in the form of Panti gravel, Jember, East Java, which was taken at the Construction Materials Technology Laboratory, Civil Engineering Study Program, Faculty of Engineering, Muhammadiyah University of Jember.
- Clean water taken from the Construction Materials Technology Laboratory, Civil Engineering Department, Faculty of Engineering, Muhammadiyah University of Jember.

(a) (b) (c)

Figure 2. Materials (a) Fine Aggregate, (b) Coarse Aggregate, and (c) Cement

The additional materials used in the study are described in the following description, including additional materials such as cement substitutes and chemical additives (Figure 3), including:

- Additional materials in the form of silica fume, Sika Fume brand, produced by PT. Sika which functions as a filler (increases the compressive strength of concrete) and replaces part of the cement.
- Chemical additives in the form of superplasticizer, Sika Concrete brand, produced by PT. Sika which functions as an accelerator (accelerates concrete bonding and hardens concrete).

While the tools used in this study from material inspection to testing of test objects, with the following description:

- A measuring cup with a maximum capacity of 1000 ml to measure the volume of water and an Erlenmeyer flask with the Pyrex brand, for checking the specific gravity,
- Ohauss brand scales with an accuracy of ± 0.1 grams, to determine the weight of the concrete ingredients,
- Sieve and sieve machine, to determine the gradation of fine aggregates then Oven, to check the ingredients to be used in the concrete mixture,
- Shovel, trowel, and tray, to accommodate and stir and pour the concrete mixture into the mold,
- Molen machine to mix and stir the test object mixture with a larger volume,
- Abrams cone, to test the slump value of concrete,
- Cylindrical concrete mold with a size of 15 cm × 30 cm,
- EMBETE brand concrete compression test machine, used to test and determine the value.

(a) (b)

Figure 3. Additive Materials (a) Sika Fume (b) Sika Concrete Addictive

3. Research Implementation

The research design was carried out in the laboratory using cylindrical test objects with a diameter of 15 cm and a diameter of 30 cm with 10 variations of concrete mixtures. The components varied in this study were Additive additives and admixtures which can be seen in Table 2. The implementation of the study began with data collection, material procurement, material inspection, making mix design and then making test objects which were carried out at the Construction Materials Technology Laboratory, Civil Engineering Study Program, Faculty of Engineering, Muhammadiyah University of Jember. The method used in this study was an experimental method, namely a method carried out by experiment. Testing of fine aggregates and coarse aggregates was carried out to achieve the specified results.

Table 2. Components of Additional Material Variations

No.	Code	Additional materials	
		Sika Fume (%)	Sika Concrete (%)
1	A	0	0
2	B	2.5	0,5
3	C	5	0,5
4	D	7.5	0,5
5	E	10	0,5
6	F	12.5	0,5
7	G	15	0,5
8	H	2.5	1
9	I	5	1
10	J	7.5	1
11	K	10	1
12	L	12.5	1
13	M	15	1
14	N	2.5	1.5
15	O	5	1.5
16	P	7.5	1.5
17	Q	10	1.5
18	R	12.5	1.5
19	S	15	1.5

Steps in calculating normal concrete mix design based on SNI 03-2834-2000 [25], for mix design calculation analysis can be seen in Table 3.

Table 3. Concrete mix composition

Code	Cement (kg)	Sand Lumajang (kg)	Coral Panti (kg)	Water (liters)	Additive Content	
					Sika Concrete (liter)	Sika Fume (kg)
A	3.20	4.70	3.84	1.28	0.00	0
B	3.12	4.70	3.84	1.09	0.02	0.08
C	3.04	4.70	3.84	1.09	0.02	0.16
D	2.96	4.70	3.84	1.09	0.02	0.24
E	2.88	4.70	3.84	1.09	0.02	0.32
F	2.80	4.70	3.84	1.09	0.02	0.399
G	2.72	4.70	3.84	1.09	0.02	0.479
H	3.12	4.70	3.84	1.09	0.03	0.08
I	3.04	4.70	3.84	1.09	0.03	0.16
J	2.96	4.70	3.84	1.09	0.03	0.24
K	2.88	4.70	3.84	1.09	0.03	0.32
L	2.80	4.70	3.84	1.09	0.03	0.399
M	2.72	4.70	3.84	1.09	0.03	0.479
N	3.12	4.70	3.84	1.09	0.05	0.08
O	3.04	4.70	3.84	1.09	0.05	0.16
P	2.96	4.70	3.84	1.09	0.05	0.24
Q	2.88	4.70	3.84	1.09	0.05	0.32
R	2.80	4.70	3.84	1.09	0.05	0.399
S	2.72	4.70	3.84	1.09	0.05	0.479

4. Result and Discussion

4.1. Results of Aggregate Properties Examination

Examination of fine aggregate properties was carried out before making the mix design, the results of the fine aggregate examination can be seen in Table 4 and Figure 4. The tests carried out were in the form of mud content, grain gradation, and fine modulus observed carefully, whether in dry, wet, or SSD conditions. Examination of fine aggregate properties was carried out before making the mix design, the results of the fine aggregate examination can be seen in Table 4. The tests carried out were in the form of mud content, grain gradation, fine modulus of grains, specific gravity, water absorption, unit weight, and water content. This examination was also compared with previous research by Ikhsan et al. (2016) [26]. Based on these results, it was concluded that there was no significant difference from previous research.

Table 4. Results of fine aggregate examination

No	Types of aggregate testing	Unit	Result	
			Test	Ikhsan et al. [26]
1	Mud level	%	0.63	4.53
2	Grain Gradation	-	Zona 2	Zona 2
3	Specific gravity	-	2.78	2.58
4	Water Absorption	%	5.7	0.26
5	Volume Weight	g/cm^3	2.03	1.31
6	Water Content	%	4.8	4.57

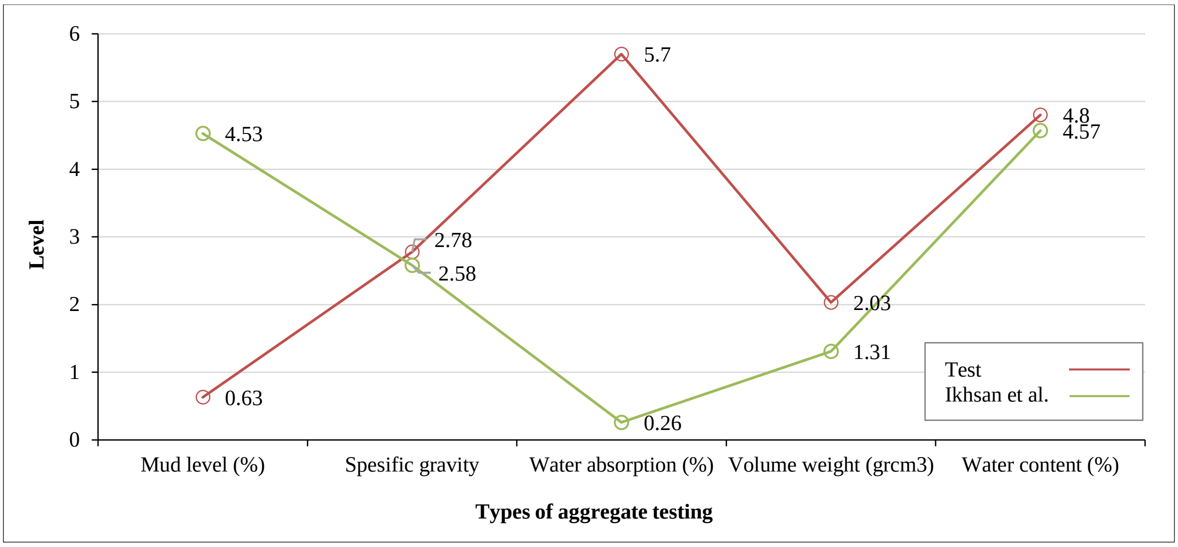

Figure 4. Results of fine aggregate material assessment

A coarse aggregate examination was carried out to determine the characteristics of the material; the aggregate used came from Panti, Jember. In this examination, the values of mud content, aggregate wear, specific gravity, water absorption, unit weight, and water content were obtained. The results of the examination were compared with previous tests, as in Table 5 and Figure 5. There was a significant difference in the aggregate wear value where the examination obtained a value of 33.33% while in the previous study, a value of 21.36% was obtained. This shows that the quality of the aggregate in the previous study was better than in this study. While the mud content obtained had almost the same value, both values did not meet the specified mud content limit standard of 1%. From the two aggregates whose characteristics were analyzed, it can be concluded that this material is still solid to be used as a material for making concrete with high early compressive strength; only the mud content in the coarse aggregate does not meet the specified requirements. To overcome this problem, it is necessary to clean the coarse aggregate first before use. In addition, the condition of the material before being tested should be carefully observed, whether it is in a dry or wet condition.

Table 5. Results of coarse aggregate examination

No	Types of aggregate testing	Unit	Result	
			Test	Ikhsan et al. [26]
1.	Mud level	%	1	1.75
2.	Grain Gradation	gr/cm^3	2.08	2.63
3.	Specific gravity	%	0.8	4.47
4.	Water Absorption	gr/cm^3	2.06	1.55
5.	Volume Weight	%	0.9	0.55

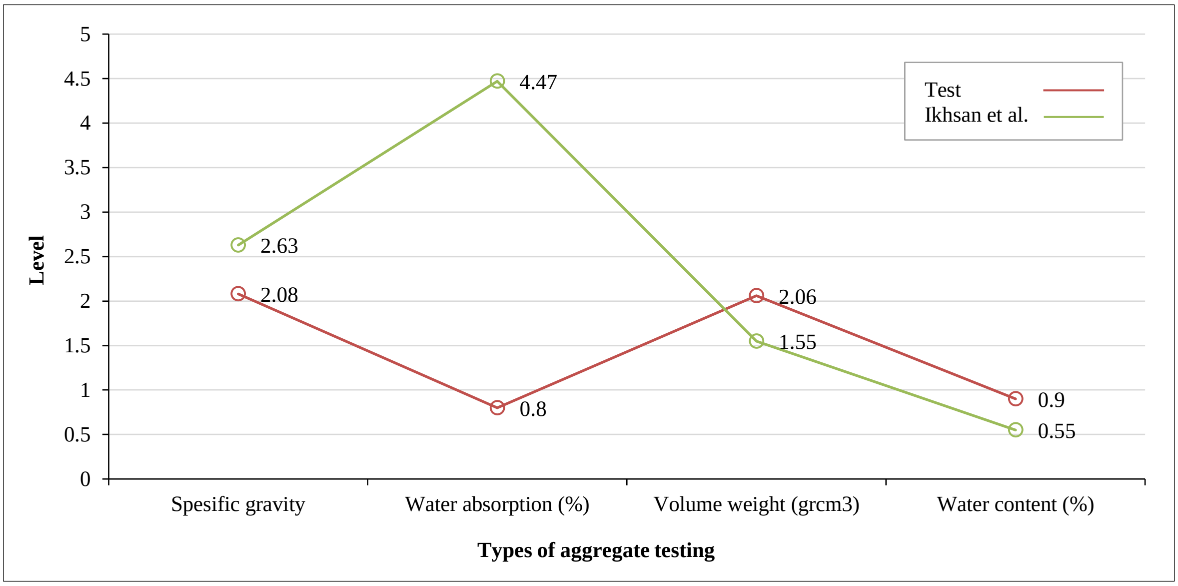

Figure 5. Results of coarse aggregate material assessment

4.2. Slump Inspection Results

Slump inspection is carried out to determine the level of ease of processing, each variation has a different slump value (Figure 6). Figure 7 shows that the slump value in 19 samples ranges from 6 - 16 cm. The smallest slump value of 6.0 cm was obtained by a test object with code P with a composition of 7.5% Silica Fume and 1.5% Superplasticizer, while the largest slump value of 16 cm was obtained by a test object with code I with a composition of 5% Silica Fume and 1% Superplasticizer. The average slump value is 9.3 cm, this indicates that the water content used in this study is sufficient.

(a) (b) (c)

Figure 6. Mixing test specimens (a) Fresh Concrete, (b) Slump test, and (c) Molding and curing

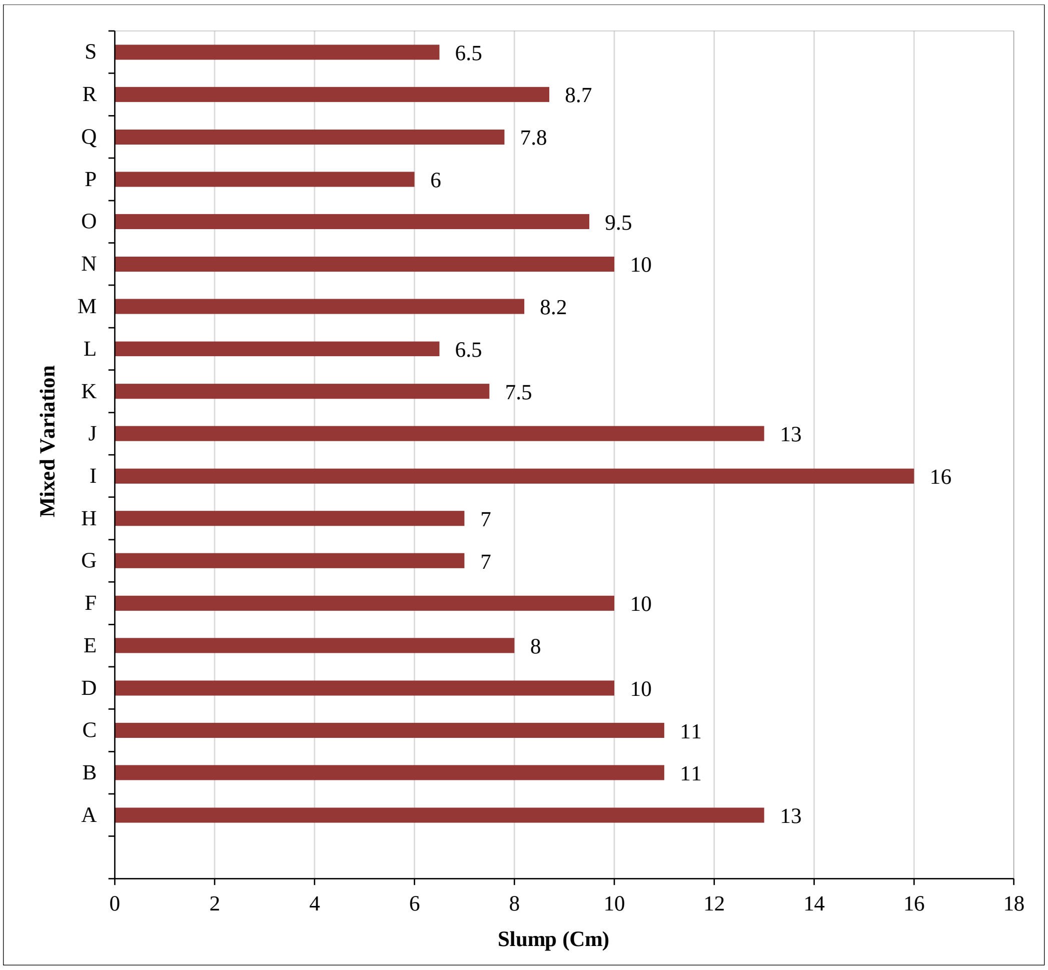

Figure 7. Results of slump value examination

4.3. Compressive Strength Test Results

Initial concrete compressive strength test was conducted at 3 days old, after which testing was conducted at 7 days and 28 days old (Figure 8). Table 6 shows the results of concrete compressive strength at 3 days old, Concrete A was 18.16 MPa which is normal concrete, while the addition of 5% to 12.5% silica fume tends to increase the compressive strength of concrete except for Concrete D, Beron J, and Concrete O samples, the value is less than Concrete A. Even in the Concrete D sample, the compressive strength value is very low at 12.22 MPa even though the composition of silica fume is 7.5% but the Superplasticizer is still 0.5%. The highest concrete strength was obtained in the Concrete S sample at 26.13 MPa.

(a) (b) (c)

Figure 6. Compressive strength testing (a) Compression testing machine, (b) Test specimen before testing, and (c) Test specimen after testing

Table 6. Average concrete compressive strength results based on age

No	Code	Additional materials		Fc' Average By Age (MPa)		
		Sika Fume (%)	Sika Concrete (%)	3 Day	7 Day	28 Day
1	A	0	0	18.16	29.19	41.18
2	B	2.5	0,5	17.14	24.10	37.73
3	C	5	0,5	25.23	26.76	49.55
4	D	7.5	0,5	12.22	21.89	39.88
5	E	10	0,5	21.66	22.00	51.08
6	F	12.5	0,5	16.46	33.60	40.11
7	G	15	0,5	21.95	27.21	29.41
8	H	2.5	1	22.46	33.88	36.94
9	I	5	1	22.68	34.90	42.20
10	J	7.5	1	16.74	21.27	38.29
11	K	10	1	21.04	39.88	55.26
12	L	12.5	1	21.66	33.60	47.29
13	M	15	1	15.67	37.96	38.63
14	N	2.5	1.5	21.49	33.03	54.30
15	O	5	1.5	18.16	39.14	45.48
16	P	7.5	1.5	23.87	48.87	43.39
17	Q	10	1.5	23.53	35.92	43.56
18	R	12.5	1.5	26.02	40.73	48.14
19	S	15	1.5	26.13	39.88	44.52

At the age of 7 days, normal concrete obtained a compressive strength of 29.19 MPa. Meanwhile, in the Concrete D sample, the compressive strength of the concrete increased significantly to 21.89 MPa, higher than Concrete J which had the lowest compressive strength value of 21.27 MPa. The highest compressive strength of concrete was the Concrete P sample with a compressive strength value of 48.87 MPa, higher than the Concrete S sample of 39.88 MPa. Meanwhile, at the age of 28 days, the compressive strength value of the concrete had increased above the Normal Concrete Sample A, but there were still 6 samples that were lower, even the Concrete G Sample had a fairly low compressive strength value of 29.41 MPa. From these results, it can be concluded that in general the addition of sika fume and sika concrete materials has an impact on improving the quality of concrete since the age of 3 days, 7 days and is very significant when the concrete is 28 days old.

Based on Figure 9 which connects each variation with the compressive strength of 3-day-old concrete, shows a trend graph that the addition of silica fume and Superplasticizer materials has an impact on increasing the quality of early concrete even though there are 5 samples that do not follow the trend, namely Concrete Sample D, Concrete F, Concrete J. Concrete M and Concrete O. If in percentage from 19 Samples there are about 25% do not follow the trend. In concrete J there is a possibility that the compressive strength of the concrete is very low because the water content is too high with a slump value of 13 cm, while in concrete M there is a possibility that the compressive strength of the concrete is very low because the water content is too low with a slump value of 8 cm so that Concrete Sample J and Concrete M slump values deviate somewhat from the average slump of around 9.3 cm. So if the 2 samples are corrected by getting a slump that is close to the average, the possibility of the initial concrete compressive strength will be higher and follow the trend. So after re-correction with 19 Samples, there are about 15% not following the trend.

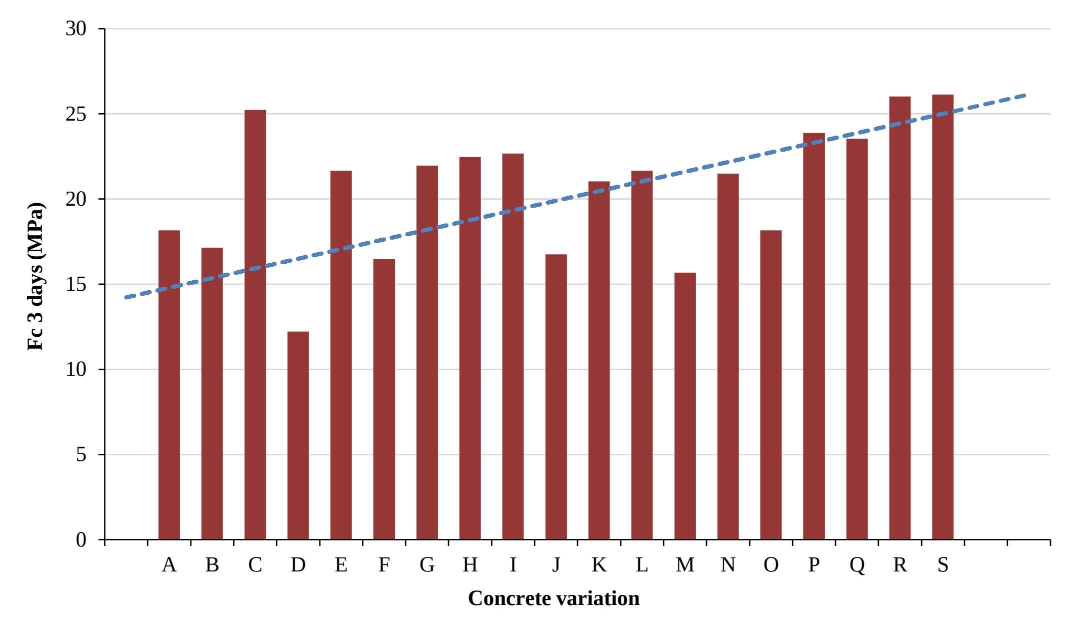

Figure 7. Results of 3-day concrete compressive strength

The trend of concrete compressive strength at the age of 3 days, 7 days, and 28 days is presented in Figure 10. Figure 10 shows that at the age of 28 days, the concrete compressive strength shows results that are not much different in each variation. In general, the trend of 16 samples is close to normal concrete, while 3 samples are rather low at the age of 7 days but increase at the age of 28 days. Based on the graph, it is very clear that the effect of the addition is actually seen at the age of 7 days with a higher variation compared to the age of 3 days and 28 days. There is even a sample of Concrete G that does not show any significant change in the quality of the concrete either at the age of 7 days or at the age of 28 days. This is likely because the concrete slump is quite low, 7 cm less than the average, so it affects the concrete mixing process at the age of 7 days, hardening but not perfectly mixed.

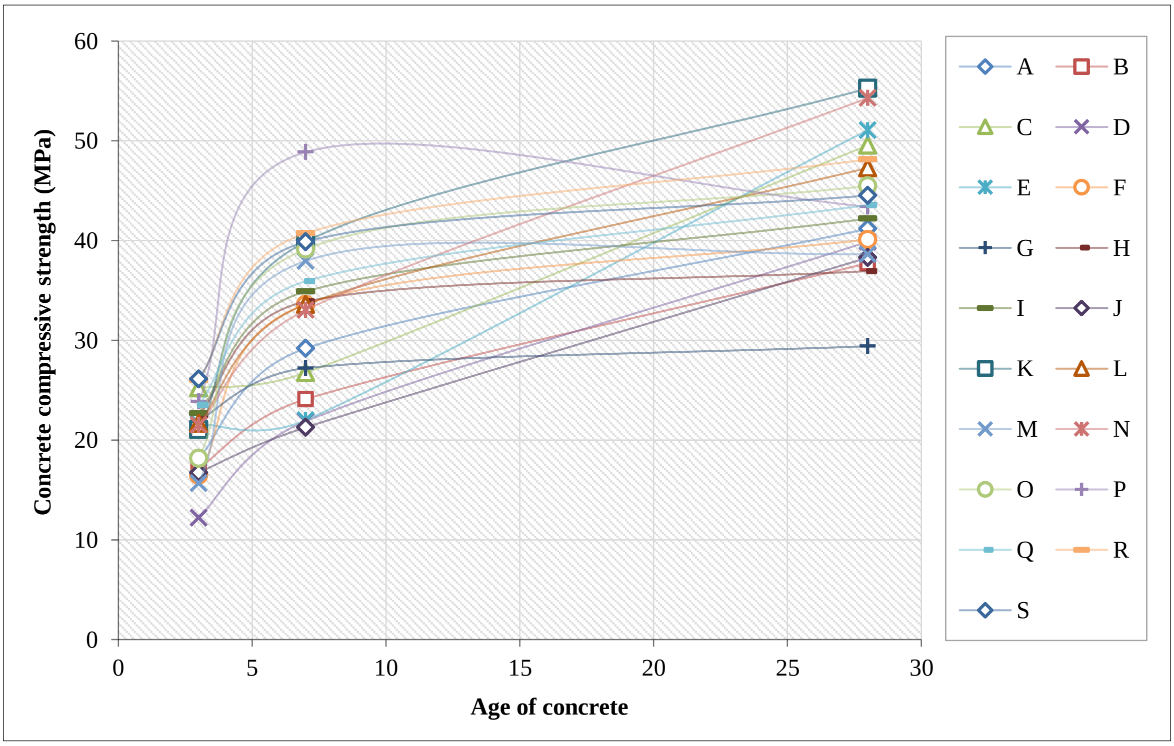

Figure 8. Relationship between curing time and concrete compressive strength

To determine the optimum level of silica fume, a regression analysis was carried out on the concrete compressive strength value at the age of 3 days. The results of the regression analysis can be seen in Figure 11, which is a relationship in the form of a polynomial. From Figure 10, the concrete compressive strength increases with the use of 0% to 5% Silica fume, but with the use of silica fume> 5%, the compressive strength results decrease and then increase again with the use of between 10-12%. However, a more in-depth analysis is needed, because some concrete samples have slump values that are less than the average, and some are higher than the average. In addition, the mixing technique and mixing pressure are also determinants in obtaining the extent of the influence of silica fume. Moreover, the silica fume given is quite small so it also has an effect. The addition of silica fume weakens the interlocking effect and reduces friction but can form a bridge effect between particles between cement grains. Superplasticizers can not only inhibit the aggregation of cement grains but also reduce the bridging effect of Silica Fume [19]. However, in this study, there is a Superplastizer factor that certainly affects the performance of silica fume. So based on these results, it shows that Superplastizer also affects the performance of silica fume. It is possible that at a concentration of Superplastizer that is not too large, it affects the function of silica fume but it is very significant when the Superplastizer concentration is greater than silica fume, the function of silica fume is reduced. Moreover, Superplastizer also increases the volume of solids, improves pore structure, and reduces total porosity, thereby increasing long-term strength [11].

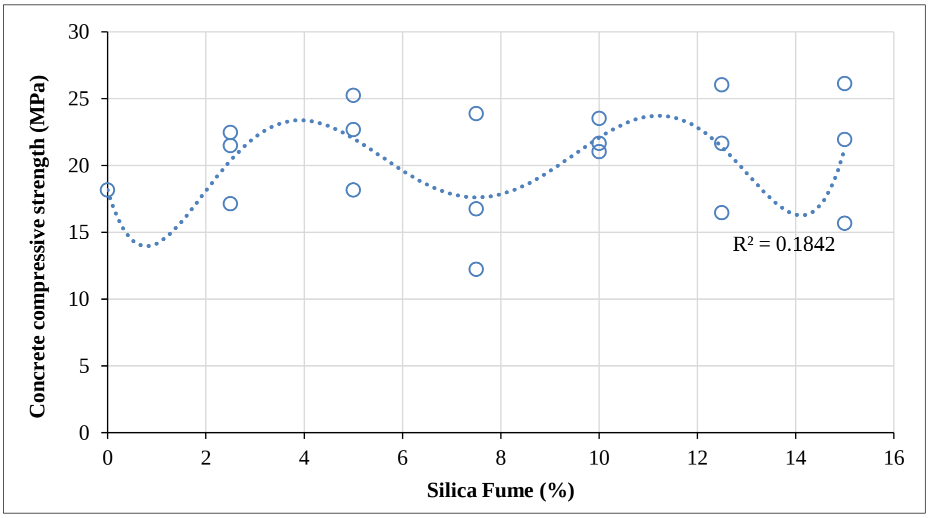

Figure 9. Relationship between Silica Fume content and 3-day concrete compressive strength

The results of the regression analysis of the relationship between concrete compressive strength and superplasticizer can be seen in Figure 12. Based on polynomial analysis. Based on Figure 12, the initial compressive strength of concrete increases with the use of 0.5% to 1% superplasticizer, with details in the mixture of 0.5 to 1% not significant but above 1% to 1.5%, it can be concluded that the content of superplasticizer that can be used to increase the initial compressive strength of concrete in this study is 1.5%. In addition to the addition of these materials, a study is also needed if geopolymer concrete materials are used [27, 28] while still following the National Standardization Agency on Procedures for Making Normal Concrete Mix Plans from the Ministry of Public Works (SNI) [25]. So these results have shown information that the most significant superplasticizer affects the high quality of the early age of concrete. However, it needs to be studied again by adding more variations of silica fume to obtain more significant results in the future.

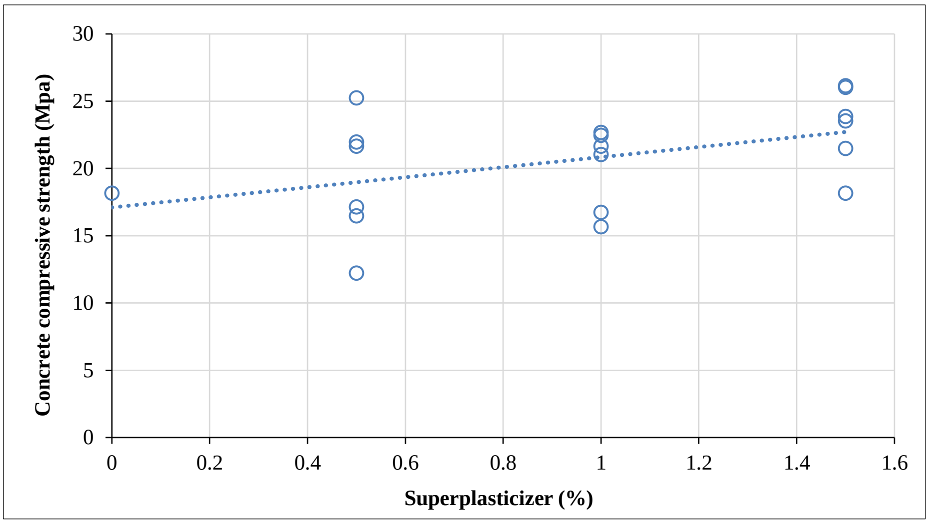

Figure 10. Relationship between Superplasticizer and 3-day concrete compressive strength

5. Conclusion

In general, after conducting a concrete compressive strength test, it was obtained that 75% of concrete samples using additional materials in the form of silica fume and superplasticizer were quite significantly able to increase the initial concrete compressive strength quality by up to 30% both at 3-day concrete age as well as at 7-day and 28-day concrete ages. The use of additional materials in the form of silica fume and superplasticizer in a concrete mixture with the right content can generally improve the quality of concrete in its initial compressive strength at 3 days and its workability or fluidity. However, silica fume and superplasticizer materials, when entered into concrete, have mutually influenced performance. The use of silica fume that is not too large greatly supports the function of the superplasticizer to form high-quality initial concrete, but if the composition of silica fume is added even more, it can reduce the performance of the superplasticizer. The decrease in the initial concrete quality is not solely a factor of silica fume, but there is an influence of the water mixture on the concrete composition because some concrete samples have very low and very high slumps, which affect the performance of the concrete. So in the future, it is necessary to conduct further studies with the determination of uniform slump, and uniform mixing so that we get a fixed variable so that the factors that influence the initial concrete compressive strength can be obtained including the relationship between silica fume and superplasticizer can be expressed as an empirical equation that can be used for the purposes of early high-quality concrete construction work in the future.

Suggestions in this study should try to conduct testing at the age of 3 days of concrete, by maintaining the composition of 5% silica fume and superplasticizer added to 2%, then the number of test samples is increased by 2 times with the slump value made uniform before the implementation of the initial concrete compressive strength test.

6. Declarations

6.1. Author Contributions

Conceptualization, N.S.R. and E.A.; methodology, E.A.; software, N.S.R.; validation, E.A. and N.A.M.; formal analysis, N.S.R.; investigation, E.A.; resources, N.A.M.; data curation, N.A.M.; writing—original draft preparation, N.S.R.; writing—review and editing, N.S.R.; visualization, E.A.; supervision, E.A.; project administration, N.A.M.; funding acquisition, N.S.R. All authors have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available in the article.

6.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

6.4. Conflicts of Interest

The authors declare no conflict of interest.

7. References

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