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The use of coarse aggregate from fly ash and its effect on the mechanical properties of concrete

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Abstract

The amount of fly ash waste is increasing, causing environmental and storage problems. One solution is to utilize the fly ash as an artificial aggregate. This research focuses on getting the right formula for mixing fly ash, cement, and superplasticizer (SP). The tests carried out were compressive strength at 3, 14, 28, and 56 days. The results showed that the best composition with a ratio of cement: fly ash of 1:4 added with a superplasticizer of 1.2% by weight of the mixture resulted in a compressive strength of 79 MPa at 56 days of age.

Keywords: Fly ash; Cement; Superplasticizer; Compressive strength

1. Introduction

Currently infrastructure development continues to increase so that the need for natural aggregates is increasing, as a result the availability of natural aggregates is dwindling. For this reason, innovation is needed by utilizing industrial waste materials such as fly ash. Based on data, as much as 150-170 million tons globally, while in Indonesia it is estimated that the amount of waste reaches 8.2 million tons [1]. Researchers are trying to utilize the waste into aggregates that are sustainable as a substitute for cement and aggregate [2-5].

Fly ash can be used as an artificial aggregate because the chemical composition of cement and fly ash is almost the same, especially in terms of the percentage composition of SiO2 which is the main filler in fly ash of 39.90% and in cement of 19.69%. SiO2 can affect the mortar hardening process. The presence of these ingredients can increase the compressive strength by 15% to 18.2% of the control mortar at 28 days [6-8]. This is due to the pozzolanic reaction from the SiO2 fly ash content which helps fill in the gaps in the bonding process in the mortar mix because it has micro-sized particles [9-11].

Artificial aggregates from fly ash with the addition of superplasticizer (SP) have high mechanical properties and durability with compressive strengths of 25-83.5 MPa [12-16]. Meanwhile, the addition of 100% fly ash and SP increased the compressive strength by 4.97 at 28 days and 31.32% at 90 days [17] Other researchers also tested the effectiveness of artificial aggregates using fly ash on the mechanical properties of concrete using fly ash. 90% ash and 10% cement obtain a compressive strength of 45 MPa [18].

In addition, the use of Superplasticizer (SP) can increase the ability by 32% and increase the compressive strength by 50% compared to the control paste and shows a lower loss of fluidity [19-21].

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The performance of lightweight aggregate concrete made from fly ash has yet to find a composition that has good strength. The research that will be carried out is different from previous research. In this research, they are still looking for the best artificial aggregate composition by mixing fly ash, cement, water and added additives. by using the method of making light aggregate, namely making it a cube test object.

2. Material and methods

2.1. Material

In this test using Type 1 Portland cement material according to ASTM C150 [22] from PT. Adhimix RMC, fly ash and a mixture of drugs or additives, namely superplasticizer (SP) 0.6% mixture from PT. John Idetama Teknik. This test is to determine the effect of artificial fly ash aggregate on compressive strength at the age of 3, 14, 28 and 56 days. The proportions of the test specimens are shown in Table 2. FSAC and FSBC are control concrete with the proportion of mixed cement, fly ash with w/w 0.35 and 0.22. FSA1-FSA3 are concrete with a mixture of cement, fly ash and 0.6% superplasticizer. FSB1-FSB2 uses a mixture of cement, fly ash, and 1.2-1.8% superplasticizer.

Table 1 Chemical composition of cement and fly ash

Composition	Fly Ash	Cement
SiO2	54.90	10:60 p.m
Al2O3	25.80	4.30
Fe2O3	6.90	2.50
CaO	8.70	64.40
MgO	1.80	2.10
SO2	0.60	2.30
Na2O & K2O	0.60	0.60

Table 2 Mix fly ash paste design

No	TestItem Code	W/B	Composition			
			Cement: Fly Ash		Super Plasticizer (SP)	Water
1	FSAC	0.35	1000	4000	0	1750
2	FSA1	0.3	1000	4000	30	1470
4	FSA2	0.25	1000	4000	30	1220
5	FSA3	0.2	1000	4000	30	970
6	FSBC	0.22	1000	4000	0	1100
7	FSB1	0.176	1000	4000	60	820
8	FSB2	0.154	1000	4000	90	680

2.2. Method

The first step is to make the test object according to the mix design as shown in Table 2, then a test flow is carried out to measure the thickness of the paste mixture using a tool made in the shape of a D30 circle. The test used the method by filling 100 ml of the paste sample into the funnel, after which the time for the paste to decrease was calculated using a stopwatch.

Then perform a compressive strength test using a 50x50x50 mm specimen at the age of 3, 14, 28, and 56 days according to ASTM C109 [23]. After that, Curing (soaked in water) is carried out according to ASTM C192 [24].

3. Results and discussion

3.1. Flow Test

The results of the flow test can be seen in Table 3. FSA1 has the fastest settling time with a travel time of 2.65 seconds because the specimen results are more fluid than the other samples, while the flow test with the longest settling time occurs in the FSB2 sample with a time of 137, 24 seconds.

The results of the settling time of the FSBC specimen could not be measured because the mixture was too wet and very dense so there was no decrease in the flow test, so SP was added to the sample to improve flow properties (workability), the liquefaction effect was caused by the reaction that occurred between the cement particles and the SP. [25–27].

Table 3 Characteristics of the test results of the fly ash aggregate mixture

Test Object Code	Diameter of Test flow Test 100 ml (mm)	Flow Test Drop Time 100 ml (s)	Compressive Strength (Mpa)			
			3	14	28	56
FSAC	110	3.71	2.0	4,2	5.0	10.50
FSA1	225	2.65	4.0	4.0	8.0	14.70
FSA2	330	12.90	5.0	25.0	35.0	33.50
FSA3	250	12,28	21.0	14.0	12,3	18.90
FSBC	-	-	9.30	32,30	19,44	33,30
FSB1	155	133.80	12,1	49,7	24.5	79.00
FSB2	145	137,24	9,6	45,3	27,2	38,60

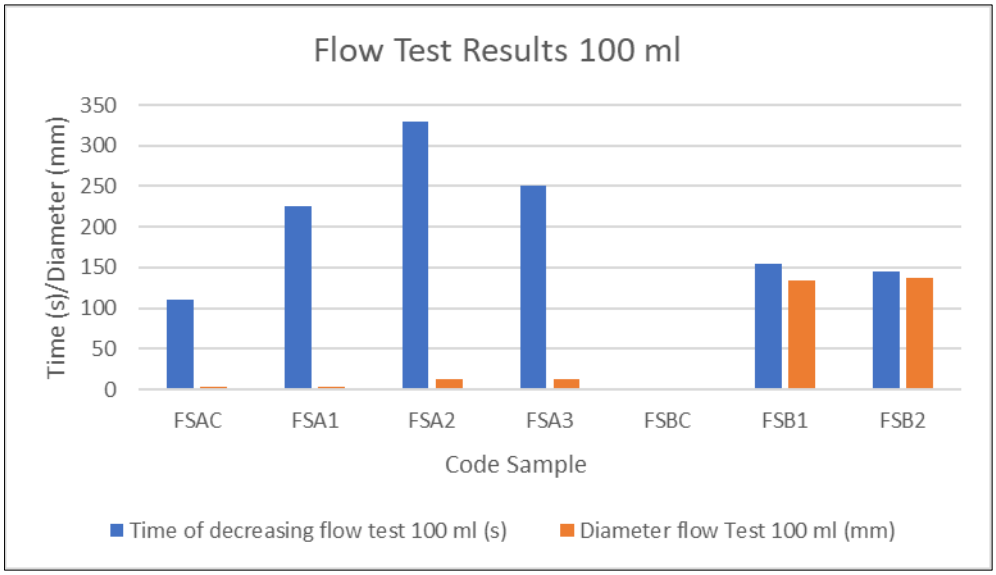

Figure 1 Flow Test Time 100 ml

3.2. Compressive Strength

Based on the characteristics of the test results for the fly ash aggregate mixture (Table 3), it shows that the time for decreasing the flow test is related to the results of the compressive strength test. The results of the compressive strength on the FSA test object code on the FSAC specimen increased with age, at 3 days old with a flow test of 3.71 seconds, the compressive strength was 2 MPa, 4.2 MPa at 14 days, 5 MPa at 28 days, and increased at

56 days by 10.5 MPa. In the FSA1 specimen, the compressive strength increased at 3 days of age with a flow test value of 2.65 seconds of 4 MPa, at 14 days of age it was 4 MPa, at 28 days it increased by 8 MPa, and at 56 days it was 14.70 MPa , FSA2 increased up to 28 days of age with a flow test of 12.90 seconds at 35 MPa and decreased at 56 days of age at 33.5 MPa. Based on these data, the FSA2 specimen experienced the highest increase in strength exceeding 100% compared to the FSAC control specimen. In the FSA3 specimen with flow test results of 12.28 seconds the results showed a decrease until 28 days old, but at 56 days the compressive strength increased by 18.90 MPa. This is because when the w/w is reduced it results in the artificial aggregate mixture being too viscous so that it has a poor bond.

Meanwhile, in the FSB test object code, the compressive strength of FSBC at 3 days of age was 9.30 MPa, at 14 days of age it was 32.30 MPa, at 28 days it decreased by 19.44 MPa, and at 56 days it experienced an increase. of 33.30 MPa. In FSB1 with a flow test of 133.80 seconds, it has a compressive strength value at 3 days of age of 12.1 MPa, at 14 days of 49.7 MPa, at 28 days of age of 24.5 MPa, and increases at 56 days of age of 79 MPa. In FSB2 aged 28 days with a value of 27.2 MPa with a flow test of 137.24 seconds, FSB2 experienced an increase of 38.60 MPa at 56 days of age. FSB1 sample has the best aggregate composition of all mixtures by reducing w/w to 0.176 with an addition of 1.2%. This is in accordance with the results of research conducted by researchers, the more SP used and the use of fly ash will greatly affect the increase in compressive strength values when balanced with the appropriate water composition [28-30]. Based on the results, this artificial aggregate can affect the mechanical properties because in previous studies the value of compressive strength can be increased even by replacing natural coarse aggregate with lightweight aggregate in the concrete mix and making the water-cement ratio lower than normal natural aggregate [17].

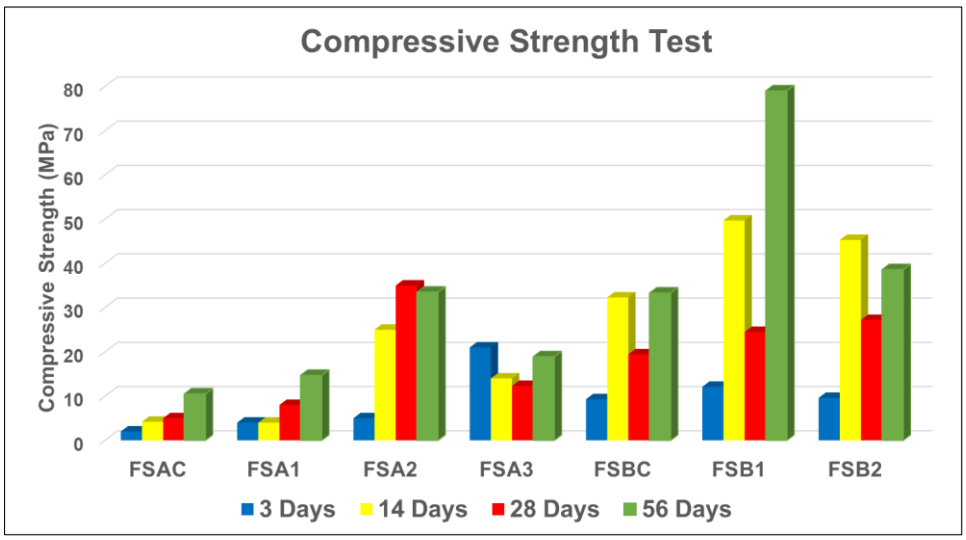

Figure 2 Compressive Strength Chart

4. Conclusion

In the results of the compressive strength test it was found that at 56 days of age 79 MPa was the best aggregate composition in the FSB1 sample by reducing w/w to 0.17 and adding SP usage of 1.2%.

The use of superplasticizer (SP) in the paste mixture greatly affects the flow properties (workability) because there is a reaction between the cement and the superplasticizer (SP), the result is that the control specimens get a higher drop in flow test compared to the paste mixture which adds superplasticizer (SP). The flow test with compressive strength greatly affects the mechanical properties, the thicker the concrete mix, the compressive strength will increase.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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