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Analysis of the Effect of Fly Ash as Filler on the Compressive Strength of High Strength Self-Compacting Concrete

Ellen Joan Kumaat[1], Rizki Andika Mahmud[2], Reky Stenly Windah[3]
[1,2,3] Sam Ratulangi University, Manado, Indonesia

ABSTRACT: High Strength Self Compacting Concrete is a concrete innovation with the advantage of having high workability and high concrete quality. In this research, fly ash was used as a filler. Tests carried out by using a fly ash with the percentage of 1%, and conducting a slump flow test with a curing time of 14 days. The same percentage of fly ash was also tested using three types of slump tests, namely the slump flow test, l box test and v funnel test with a curing time of 28 days. The specimens are cylindrical with dimensions of 100 mm and 200 mm. The research results with a curing time of 14 days qualified for Self-Compacting Concrete according to EFNARC with a slump flow test value of 700 mm and qualified for High Strength Concrete with an average compressive strength value of 62.14 MPa. The results of the study with a curing time of 28 days obtained Slump Flow Test values of 719 mm, L Box test of 1 cm and V funnel of 19.99 seconds with an average compressive strength of 44.36 MPa at 28 days.

KEYWORDS: High Strength Self-Compacting Concrete, Fly Ash, Slump, Compressive Strength

1. INTRODUCTION

1.1. Background

High Strength Self-Compacting Concrete is a concrete innovation that combines two types of concrete, namely High Strength Concrete and Self-Compacting Concrete. To obtain High Strength Self Compacting Concrete (HSSCC), additional materials are needed, namely superplasticizer and use of a large cement composition in the concrete mixture. With a certain composition, the strength of concrete can be increased and high-quality concrete with good workability can be created [7][9]. HSCC use a high amount of the cement which has an impact on production costs.

To overcome this problem, other materials are needed that can reduce HSSCC production costs without reducing strength and workability. Fly ash can be used as an additive in concrete to reduce the high amount of cement used. Fly ash can be used as a filler so that it can also take advantage of factory waste. This research was conducted to find the effect of compressive strength by using fly ash as filler.

1.2. Formulation of the problem

This research was conducted to analyze the effect of compressive strength by using fly ash as a filler so that it can reduce production costs without reducing the performance of High Strength Self-Compacting Concrete.

1.3. Problem Statement

The limitations of the problems of this research are as follows:

1. Basic composition of concrete materials: (a). local cement, coarse aggregate, and fine aggregate (b). Additives: superplasticizer and fly ash from local electric steam power plant.
2. The percentage of fly ash used is 1%
3. The test object is a cylinder with a diameter of 10 cm and a height of 20 cm.
4. Curing time 14 days and 28 days.

1.4. Goals of the research

This research was conducted to analyze the effect experienced by High Strength Self-Compacting Concrete by using fly ash as filler on the compressive strength.

1.5. Definitions

One of the innovations from concrete is Self-Compacting Concrete (SCC). Self-Compacting Concrete is concrete that can fill empty cavities in concrete which are usually overcome with a vibrator. In this case, the use of SCC can reduce the number of workers, shorten processing time, and reduce noise due to using a compactor. SCC will save pumping and compaction energy so that the concrete has been designed to be more environmentally friendly [10][16]. SCC can compact into every corner of the building structure and can fill the desired surface height evenly (self-leveling) without experiencing bleeding and segregation [6].

For the application of SCC itself, it is necessary to add materials that reduce water use such as superplasticizers. In addition, SCC also requires fine materials that function as lubricants so that they can increase their flowability and workability, and can support the properties of SCC which can fill cavities in concrete.

Another innovation of concrete, namely High Strength Concrete. High Strength Concrete is defined as concrete which has a greater required compressive strength equal to 41.4 MPa. The compressive strength required to determine the proportion of high strength concrete mix can be selected for 28 days. To achieve the required compressive strength, the mixture must be proportioned in such a way that the average compressive strength from field test results is higher than the required compressive strength [14]. Factors that influence the creation of high-strength concrete include material quality, cement water factor, density, and aggregate gradation [5][11].

1.6. Fly Ash

Fly ash is the residue of coal combustion, which is in the form of fine particles and is an inorganic material formed from changes in mineral materials due to the coal combustion process. The use of fly ash material as a concrete forming material is based on the properties of this material which are similar with the properties of cement.

Physically, the fly ash material is similar with cement in terms of the fineness of the grains. According to ACI, fly ash has quite fine grains, which pass through the sieve No. 325 (45 milli micron) 5-27% with a specific gravity between 2.15-2.6 and blackish gray in color. The main components of fly ash in coal are SiO_2, Al_2O_3, Fe_2O_3, and CaO[8].

Based on chemical content, fly ash according to ASTM C168-12a is classified as follows:

Table 1: Chemical Properties of Fly Ash

	Class		
	N	F	C
Silicon dioxide (SiO_2) plus aluminum oxide (Al_2O_3) plus iron oxide (Fe_2O_3), min, %	70	70	50
Sulfur trioxide (SO_3), max, %	4	5	5
Moisture content, max, %	3	3	3
Loss on ignition, max, %	10	6	6

Fly ash is not as good as cement to replace the properties of cement which has the main function as a binder of material in concrete, but fly ash as an additive can increase the compressive strength of concrete. Because fly ash is more appropriate to function as a filler or filler. Where the pores filled with fly ash will increase the impermeability of the concrete which will be directly proportional to the compressive strength of the concrete [6]. The use of fly ash in concrete mixtures cannot completely replace the function of cement as a binder [5].

Fly ash can be used to increase the slump value when applied to Self-Compacting Concrete. By using fly ash in the concrete mixture, it can improve the rheological properties of SCC and reduce the hydration heat of cement so that it can reduce the potential for cracking [1].

2. RESEARCH PROCEDURE

2.1. Compressive strength test (SNI 1974:2011)

Based on SNI 1974:2011 the calculation of the compressive strength of concrete is based on the formula:

$$fc' = \frac{P}{A} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:

fc' = Compressive strength [MPa]

P = Maximum applied load [N]

A = Cross-sectional area [mm^2]

The compressive strength of concrete which is obtained from the comparison between the axial compressive force and the cross-sectional area of the specimen.

2.2. Slump Flow Test (EFNARC 2002)

Testing with Slump Cone is carried out to determine how much the ability of the concrete mixture to fill the space (filling ability). This can be seen from the diameter of the concrete mix circle to measure the filling ability of the concrete mix. Limitations in the Slump Cone test equipment, the concrete mix is categorized as SCC, the minimum limit for slump flow is 65 cm and the maximum limit is 80 cm [4].

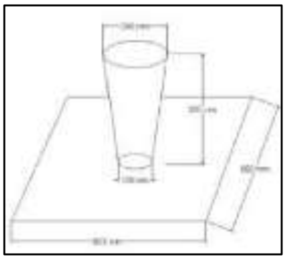

Fig.1. Slump Flow Test

2.3. L Box Test (EFNARC 2002)

L-Box is used to test the ability of concrete in terms of passing ability. This test assesses the extent to which concrete flow can be blocked by reinforcement. Limitations in the L-Box test equipment, concrete mixtures that are categorized as SCC must be able to meet the H2/H1 requirements between 0.8-1.0 mm [4].

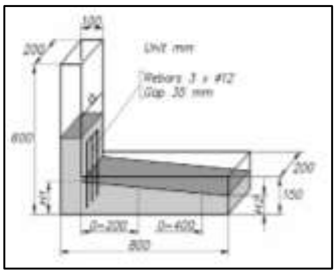

Fig.2. L Box Test

2.4. *V Funnel Test*

Testing using the V-Funnel is useful for measuring the flowability of the concrete mix, where the ability of the concrete mix to fill space (filling ability) can be seen. In addition, testing using the V-Funnel can be used to determine the ability of the concrete mix to resist segregation. The limit for this test is 8-12 second [4].

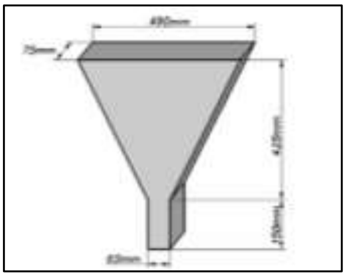

Fig.3. V Funnel Test

3. MATERIAL USED

3.1. Material Inspection

To get better quality concrete, it is necessary to check the aggregate to be used. The following are the results of the aggregate inspection carried out at the Materials Engineering Laboratory, Faculty of Engineering, Sam Ratulangi University, Manado:

Table 2: Mechanical properties of coarse aggregate

Items	Value
Fine Modulus	7,449
Bulk Specific Gravity Oven Dry	2,635
Bulk Specific Gravity Saturated Surface Dry	2,657
Apparent Specific Gravity	2,687
Maximum Absorption, %	0,86%
Unit Weight (Compaction Method), g/cm3	1,491
Unit Weight (Loose Method), g/cm3	1,376
Water Content, %	0,482
Abrasion Value, %	17,17

Table 3: Mechanical properties of the fine aggregate

Items	Value
Fine Modulus	3,419
Bulk Specific Gravity Oven Dry	2,037
Bulk Specific Gravity Saturated Surface Dry	2,283
Apparent Specific Gravity	2,703
Maximum Absorption, %	0,121
Unit Weight (Compaction Method), g/cm3	1,287
Unit Weight (Loose Method), gr/cm3	1,198
Water Content, %	9,697
Sludge Content, %	1,133
Sludge Percentage, %	3,461

3.2. Fly Ash

The fly ash that will be used is fly ash that passes sieve no 200. A content check has also been carried out on the fly ash used using the E 965 Oxide test which was carried out at the Central Mineral and Advanced Materials Laboratory, State University of Malang.

Table 4: Chemical properties of the fly ash

Compound	Value	Compound	Value
Al_2O_3	8,50%	Fe_2O_3	37,32%
SiO_2	19,40%	NiO	0,02%
P_2O_5	0,20%	CuO	0,04%
So_3	9,00%	SrO	0,55%
K_2O	1,10%	MoO_3	4,20%
CaO	17,20%	BaO	0,27%
TiO_2	1,10%	Eu_2O_3	0,41%
V_2O_5	0,04%	Yb_2O_3	0,02%
Cr_2O3	0,08%	Re_2O_7	0,27%
MnO	0,43%		

4. RESULTS AND DISCUSSION

4.1. Trial Mix Results

Trial mix with various treatments including the order and time of mixing. This is done to meet the requirements of High Strength Concrete according to SNI and Self-Compacting Concrete according to EFNARC. As a first step, a slump test is carried out on fresh concrete before reviewing it for compressive strength. The slump test refers to EFNARC by conducting a Slump Flow Test, L Box Test and V Funnel Test.

Table 5. Slump Flow Test, L Box Test, and V Funnel Test of Trial Mix Results

Specimens	Slump Flow Value	L Box Value	V Funnel Value
	mm	mm	seconds
Trial Mix 1	540	1,375	30
Trial Mix 2	700	1,180	77,06
Trial Mix 3	790	-	-
Trial Mix 4	850	1,018	12,38
Trial Mix 5	605	-	24,7
Trial Mix 6	582	-	-
Trial Mix 7	600	-	-
Trial Mix 8	662	1,117	-
Trial Mix 9	688	1,022	24,54

In the implementation of slump testing there are several problems, one of them is the testing time. Sufficient time is required to carry out three tests on fresh concrete. However, fresh concrete hardens quickly due to the use of superplasticizers in the mix. In addition, the testing tools used sometimes have problems.

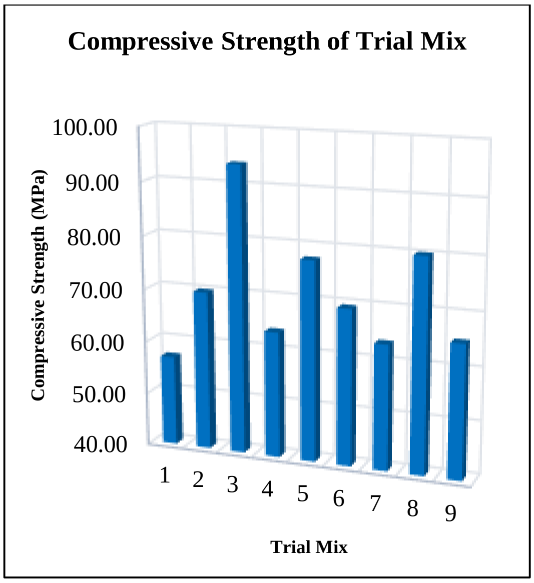

Fig.4. Results of Average Compressive Strength of Trial Mix

After obtaining the values of the slump flow test, l box test and v funnel test, proceed with casting in the cylinder molds that have been provided. The specimens were cured for 7 days and then their compressive strength was tested. the average value of the compressive strength test results is presented in figure 4.

4.2. Compressive Strength Results with Fly Ash as Filler

The mix design used to apply fly ash with a percentage of 1% is trial mix 9. A test object for curing 14 days is made using a slump flow test. The result of the slump flow test was 700 mm with the resulting compressive strength of 62.14 MPa. In the process of making test specimens, there is a change in the mix design caused by an increase in water demand. This is because the use of fly ash causes clumping in fresh concrete. So that 50ml was added to each sample to overcome clumping.

Table 6. Results Compressive Strength Test of Test Objects with Fly Ash as Filler

Specimens	Value of Compressive Strength (MPa)
FA 1% 14 - KT1	61,27
FA 1% 14 - KT2	63,14
FA 1% 14 - KT3	62,00

After examining the compressive strength using fly ash percentages of 1% with curing time of 14 days, the research was continued with tests for making objects for a curing time of 28 days using the same mix design. However, in this study three types of slump tests were carried out, namely the Slump Flow Test, the L Box Test and the V Funnel Test.

Table 7. Results Slump Test of Test Objects with Fly Ash as Filler

Testing Object	Value
Slump Flow Test	719 mm
L Box Test	1,00 cm
V Funnel Test	19,99 seconds

After three types of slump testing, the specimens were cured for 28 days before being tested for their compressive strength. After being cured and tested for compressive strength, an average compressive strength of 44.36 MPa was obtained

Table 8. Results of Compressive Strength of Test Objects with Fly Ash as Filler

Specimens	Value of Compressive Strength (MPa)
FA 1% 28 -KT1	39,24
FA 1% 28 -KT2	46,77
FA 1% 28 -KT3	47,23
FA 1% 28 -KT4	45,51
FA 1% 28 -KT5	43,05

4.3 Discussion of Compressive Strength Analysis

From the results of the research conducted, it could be seen that using of fly ash has an effect to the compressive strength of concrete. When the cement starts hydration, fly ash serves as a nucleation site for hydration products. Fly ash increases the initial hydration rate of C3S. Fly ash itself can enter the spaces between cement grains in the same way that sand fills the gaps between coarse aggregate particles and cement. The use of fly ash causes compaction of the pore structure resulting in an increase in cement strength. Fly ash fills the micropores in the paste as a filling effect, resulting in an improvement in the mechanical properties of the concrete.

5 CONCLUSION

The results of the analysis and discussion of using fly ash as filler on the compressive strength of high strength self-compacting concrete, that have been carried out are as follows:

1. The use of fly ash as a filler for the mix design causes the mixture to agglomerate so that the water requirement increases and affects the compressive strength of the resulting concrete.
2. The resulting compressive strength of high strength self-compacting concrete with a curing time of 14 days resulted in a slump flow test value of 700 mm with a compressive strength of 62.14 MPa.

3. The compressive strength value of concrete using the percentage of 1% fly ash filler with a curing time of 28 days obtains a slump flow test value of 719 mm, a l box test value of 1 mm, a funnel v test value of 19.99 seconds and produces a compressive strength of 44.36 MPa.

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