

The utilization of fly ash in mix proportion of self-consolidation concrete

M Solikin, K O M Oraibi and Y Nurchasanah

Civil Engineering Department Universitas Muhammadiyah Surakarta, Jl. Ahmad Yani
Tromol Pos 1 Pabelan Surakarta 57162

msolikin@ums.ac.id

Abstract. The application of Self-Consolidation concrete is needed for casting the concrete element with close-fitting reinforcement. This study was conducted to examine the effect of fly ash utilization on Self-Consolidation concrete properties and also to discover the optimum amount of fly ash as partially cement substitution in increasing mechanical properties of Self-Consolidation concrete. To coop with the problem three different mix design of Self-Consolidation concrete specimens were prepared to accomplish the laboratory experimental program. The mix proportion variation of fly ash replacement is 0%, 15% and 35% from cement weight. The specimens were prepared to test the properties of Self-Consolidation concrete, i.e.: slump flow test, flexural strength test, compressive strength test, and modulus of elasticity. Except slump flow test that was conducted for fresh concrete, the other tests were conducted after 28 days of curing time. After finishing testing programs, it is found that the utilization 15% of fly ash in production of Self-Consolidation concrete improve flexural strength of concrete whereas only a slightly decrease in compressive strength was found.

1. Introduction

One of development in concrete technology is called Self-Consolidation Concrete (SCC) which was developed by [1]. This genre of concrete can flow under its own weight to fill up the formwork and no external vibration is needed to compact it. Even though the fresh concrete is highly workable that flow easily trough restricted section, there is no segregation and bleeding effect to the concrete. In addition, homogeneity of fresh concrete should be maintained to ensure there is no change in quality during transportation.

There are two properties need to be balance in Self-Consolidation concrete i.e. deformability and stability that makes the concrete can be used for casting narrow concrete element or congested reinforcement condition without any external vibration. At the end of the process, a dense and homogeneous concrete will be produce and it has similar mechanical properties and durability as normal vibrated concrete.

Similar to normal concrete, the binder of Self-Consolidation concrete can be combined by using pozzolanic material. One of widely used pozzolanic material that can be used as partially cement replacement is fly ash [2]. Fly ash is non-combustible mineral material, a residual product of coal burned process in power plant which rise with flue gas and collected in dust collection system [3].

The fly ash that has spherical shape is beneficial to increase concrete workability as it would reduce the friction between the particle when it is used as partially cement replacement in Self-Consolidation



concrete. Moreover, previous researcher also reported the positive effect of fly ash to reduce bleeding, reduce w/c ratio, and reduce heat hydration. At early stage the strength development of fly ash concrete is lower rather than normal concrete, however after longer period its strength could be higher rather than normal concrete. In addition to the advantage in improving mechanical properties, the reduce of cement consumption will reduce the production of green-house gas into the atmosphere [4-7].

A massive research about the application of fly ash in concrete as cementitious material, as fine aggregate replacement or as additional material has been conducted started in 1930's [8]. However, it needs a continuous study about the utilization of fly ash in Self-Consolidation concrete especially when the fly ash is produce from a local power plant. In addition, the compatibility of fly ash with other concrete ingredients such as superplasticizer and local aggregate need to be tested.

Therefore, this paper will report the mechanical properties of Self-Consolidation concrete by utilization of fly ash as partially cement replacement. The variation of fly ash replacement is design between 15 – 35% from cement content. The mechanical properties test consists of slump flow test, compressive strength test, and flexural strength test.

2. Research methodology

2.1. Material

The material to produce Self-Consolidation concrete in this research consist of cement, fly ash, fine aggregate and coarse aggregate which came from reliable sources were tested to ensure the quality of the material. According to ASTM standard for testing material, fine aggregate properties i.e. specific gravity, absorption and sand equivalent and also coarse aggregate properties i.e. abrasion test, absorption and specific gravity meet the standard as concrete material. In addition, the fly ash which is employed in this experimental program belongs to class F in which the over-all content of $\text{SiO}_2 + \text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3$ more than 70%.

2.2. Mix design

Following the material test, a concrete mix design was prepared with total binder of 442 kg to possibly produce a 40 MPa design strength. Basically, the mix proportion of Self-Consolidation concrete is similar to normal concrete. However, some consideration must be taken i.e. the usage of superplasticizer is compulsory to enable the fresh concrete flow by its weight. Moreover, the content of fine aggregate is around 50% - 60% from total of aggregate, to reduce friction effect from the coarse aggregate.

Table 1. Mix design of concrete.

Mix type	Coarse aggregate (kg/m ³)	Fine aggregate (kg/m ³)	Water (kg/m ³)	Fly ash (kg/m ³)	Cement (kg/m ³)	Sp (% by weight of cement)	w/c
A (0)	866	884	208	0.0	442.0	2% (8.84 kg)	0.47
B (15)	866	884	208	66.3	375.7	2% (7.51 kg)	0.47
C (35)	866	884	208	154.7	287.3	2% (5.75 kg)	0.47

The mix design for this research in table 1 shows three concrete mix designs with different fly ash content i.e. 0%, 15% and 35%. Table 1 shows the reduction of cement content along with the increase of fly ash content. In addition, the mix proportion used 50.5% of fine aggregate to the total of aggregate used. Although 0.47 w/c was used, 2% of superplasticizer by the weight of cement was used to increase the workability of fresh concrete.

After preparing the mix proportion, a series of specimen was casted in regard to the appropriate experimental program. The specimens were removed from the mould after one day of casting and continued by immersing in water for curing process for 28 days. Table 2 shows the matrix of specimen for the experiment which shows the dimension and number of specimens.

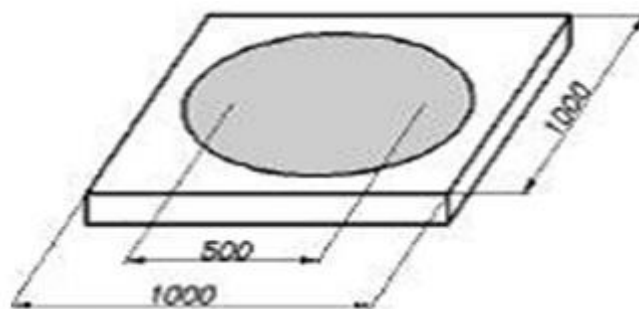
Table 2. Specimens for experimental program.

No	Testing program	Specimen	Number of specimen		
			A	B	C
1	Compressive strength	Cube 15 x 15 x 15 cm	3	3	3
2	Flexural strength	beam 15 x 15 x 50 cm	3	3	3

3. Result and discussion

3.1. Slump flow test

Slump flow test was conducted to measure the workability and flowability of fresh concrete to check whether the concrete meet the criteria of Self-Consolidation concrete. The test was carried on by filling fresh concrete into a slump cone and lift up vertically to let the fresh concrete spread on a flat surface. The next step of test is measuring two perpendicular diameter of the fresh concrete to find out the average diameter of slump flow. Based on ASTM C 1611 the slump flow of self-consolidating concrete in the laboratory or the field, the requirement diameter of slump flow test is 500 – 700 mm. The slump flow test illustration is shown in figure 1.

**Figure 1.** Slump flow test illustration [9].

The observed result as shown in table 3, the diameter of slump flow was increased following the increase of fly ash as partial cement substitution. Similar trend on increasing the slump flow as the amount of fly ash substitution increased also reported by [10-12]. The phenomena closed related to the spherical shape of fly ash.

Table 3. Diameter of slump flow (mm).

Fly Ash substitution	Slump Flow	Average
0 %	571.0	598.0
	625.0	
15 %	613.0	610.3
	658.0	
35 %	687.0	655.0
	640.0	

3.2. Concrete compressive strength test

Concrete compressive strength test was conducted on a concrete cylinder which has 15 cm of diameter and 30 cm of height to find out the strength of the concrete cylinder. The test was carried out after curing the specimen for 28 days and the strength can be found using deploying the formula in which the maximum load was divided by area of cylinder.

Compressive strength test result after curing process for 28 days shows a slightly reduction in compressive strength as the increase of fly ash amount, i.e.: 30.62 MPa for control concrete to 29.37 MPa for 15% of fly ash amount. However significant decrease of strength to 23.06 MPa is found when the amount of fly ash was increased to 35%, as revealed in table 4.

Table 4. Concrete compressive strength (28 days of curing).

Fly Ash	Compressive Strength
0%	30.62 MPa
15%	29.37 MPa
35%	23.06 MPa

Therefore, the concrete compressive strength result is significantly affected by percentage used of fly ash, in which highest compressive strength is belongs to normal Self-Consolidation concrete without Fly Ash in comparison to SCC modified with 15% and 35% of fly ash as partially cement substitution. Similar report was published by [13] who reported that the increase of fly ash used as substitution of cement lead to the lower of concrete compressive strength. The lower the compressive strength is possibly caused by the more the fly ash used the less the C_3A from cement content, a substance which responsible to the early strength of concrete [14]. However, the decrease of strength not too far as besides react with cement hydration product, some fly ash act as filler in concrete which can fill cavities in the concrete to make the concrete product more solid.

Previous researcher such as [15] reported, that fly ash concrete can produce high strength concrete, however it has similar result that the more of fly ash used the lower the compressive strength. In the research the decrease of compressive strength test is from 53.17 MPa at 10% of fly ash used to 39.25 MPa at 50% after 28 days of curing period.

The optimum amount of fly ash used in concrete production was reported by previous researcher, in which fly ash can be used until 30 % of fly ash in increasing self-consolidation concrete compressive strength. However, after the optimum amount of Fly Ash, the compressive strength of SCC is decrease following the increase in Fly Ash content. The difference result in optimum amount of Fly Ash content from this research is possibly affected by the difference content of binder and different w/c ratio. Previous research employs 550 kg/m³ of total binder with w/c of 0.42 whereas in this research used less binder of 440 kg/m³ and higher w/c of 0.47.

3.3. Flexural strength test

Flexural test investigates maximum bending load on a concrete beam with the dimension of 15 x 15 cm and clear span of 45 cm. The test is important to analyze the flexural behavior of concrete and to ensure the design mix proportion meet the ductility criteria of concrete. The flexural strength test was conducted based on ASTM C 78, a methods and procedures for unreinforced concrete bending test. The results of flexural strength are presented in table 5.

Table 5. Flexural strength test result (28 days of curing).

Fly ash	Flexural strength (Kg/cm ²)	Flexural Strength (MPa)
0 %	53.9	5.4
15 %	57.1	5.7
35 %	52.8	5.3

The flexural strength test result shows the effect of fly ash content to the flexural strength, which has slightly different trend from concrete compressive strength. The employment of 15% of fly ash is slightly increase the flexural strength, however addition fly ash content of 35% decrease the flexural

strength. The fact of slightly flexural strength improvement at 15% of fly ash utilization is possible affected by the use of optimum content of fly ash in improving concrete compressive strength. However, the increase of fly ash content to 35% decrease the flexural strength. Early research conducted in 2011 by [16] reported the same trend of flexural strength result and obtained similarly result, that optimum content of fly ash to improve flexural strength is 15%.

4. Conclusion

After analyzing the result of experimental program on Self-Consolidation concrete with fly ash as partially cement replacement, it can be concluded that the utilization of fly ash is beneficial to improve the fresh concrete properties of Self-Consolidation concrete in which the more the use of fly ash the better the slump flow result. In addition, it is recommended to use 15% fly ash as cement replacement as optimum amount related to compressive strength and flexural strength of concrete.

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