Properties of High Strength Concrete Applied on Semarang - Bawen Highway

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Abstract. To fulfill the needs of highway construction then a high quality concrete is expected to be produced by a short time and high workability, therefore the addition of additive chemicals needs to be conducted. The objective of the study was to find out the properties of high quality concrete including slump value, compressive strength, flexural strength, elasticity modulus and stress-strain diagrams with the addition of fly ash and superplasticizer. There were five types of mixtures were made in this study with a fas (cement water factor) was 0,41 and an additional 15% of fly ash and a varied superplasticizer of 0%, 0.5%, 1%, 2% towards the weight/volume and cement/water. Test samples of cylinders and prisms or beams were tested in the laboratory at 1, 3, 7, 14, and 28 days. The test results were then compared with the test results made without additional additives.

Based on the result of this research, it can be concluded that the increase of slump value due to the addition of 15% fly ash is 0.53 cm of the base slump value. The use of superplasticizer causes the weight of the type to be greater. The optimum dose of superplasticizer is 1.2%, it is still in the usage level according to the F-type admixture brochure (water reducing, high-range admixture) such as 0.6% -1.5%. All mixture types which use addition materials for flexural strength (fr'=45kg/cm²) can be achieved at 3 days.

Keywords: fly ash, high strength concrete, superplasticizer

1. Introduction

Road construction is currently required with high flexural strength concrete which need short time to reach the expected strength fr'=45kg/cm² (Bina Marga, 2010), therefore high strength concrete is required a high quality concrete. High quality concrete based on SNI 03-6468-2000 (Planning Procedure of High-Strength Mixed Concrete with Portland Cement and Fly Ash) is defined as a concrete which has required compressive strength greater or equal to 41.4 MPa.

Good quality in concrete mix with addition material aim to change one or more properties of concrete material in fresh and after hard condition (Alex Kurniawand, et al, 2011). The use of addition inappropriate material will cause damage from the concrete mixture itself (Henny Lydiasari, 2009). Fly ash is one of the addition materials that can be used in the manufacture of concrete. Fly ash is the rest of the coal burning process that is at the base of furnace called bottom ash. The quality of fly ash depends on the perfection of the process of the burning (Paul Nugraha and Antono, 2007).

According to Surya Sebayang (2010) the use of fly ash is able to make the mixture of concrete into cohesive and does not occur segregation on concrete mortar. Gunavant K. Kate and Pranesh B. Magazine (2013) conducted research by adding fly ash as a replacement for cement with a minimum grade of 10% and a maximum of 70%. This study concludes that the shrinkage of high strength concrete increases with the increase in fly ash content and the workability of high strength concrete improve with the increase in fly ash content. (Ghais, 2014) by using 10% fly ash addition enhanced the compressive strength of concrete in 28 days period, and the workability is increased by 53.8%. Serta Kaolin replacement reduce both the strength and workability of concrete. Arka Saha, Dr. Et al (2014) conducted addition Indian Fly Ash by 0 to 40% of the content of cement in the mixture and compressive strengths of concrete have been evaluated at 7, 28 and 90 days age. The research concluded that the contribution of fly ash in improving strength of concrete increased with increase in
replacement levels beyond 28 days. The average ratio of fly ash concrete strength between 7 and 28 days has been observed as 0.61 whereas gain in strengths from 28 to 90 days is about 20%.

In addition, according to ASTM C494 / C 494M - 99a, added material is divided into seven types, among type f (Water reducing high range admixture)/superplasticizer. The use of superplasticizer or high range water reducer aims to control and produce optimum slump value in fresh concrete, so that good concrete casting performance can be produced (A Pujianto, 2010). The dose accuracy of superplasticizer addition generally need to be proven by making trial mixes with some dose addition of superplasticizer to get optimum result in eligible laceration planned.

Based on the description of the admixture usage above, then by different doses will analyze the optimum proportion estimation and analyze the workability level, the mechanical behavior (compressive strength and flexural strength) of the concrete and the time required to achieve the strength of $f_{r}=45 \text{ kg/cm}^2$.

2. Methodology / Experimental

2.1 Variation of Mixed Proportions

The variation of the materials addition number and the number of samples for the compressive strength and flexural strength could be seen in table 1 and table 2 below. The number of minimum samples was 3 pieces for each type, age and condition of the test, this was in accordance with SNI 03-2493-1991 (Method of manufacture and maintenance of concrete sample in laboratory).

| Samples Code | Concrete Quality (MPa) | Fly Ash (%) | Superplasticizer (%) | Test Age | The Number of Samples |
|--------------|------------------------|-------------|----------------------|----------|-----------------------|
| UCS#0        | 41,4                   | -           | -                    | 3 7 14 28 | 3 3 3 3 |
| UCS#1        | 41,4                   | 15          | -                    | 3 7 14 28 | 3 3 3 3 |
| UCS#2        | 41,4                   | 15          | 0,5                  | 3 7 14 28 | 3 3 3 3 |
| UCS#3        | 41,4                   | 15          | 1,0                  | 3 7 14 28 | 3 3 3 3 |
| UCS#4        | 41,4                   | 15          | 2,0                  | 3 7 14 28 | 3 3 3 3 |
| $\sum N$     |                        |             |                      | 60       | 60                    |
Table 2. Variations and number of flexural strength sample

| Samples Code | Concrete Quality (MPa) | Fly Ash (%) | Superplasticizer (%) | Test Age | The Number of Samples |
|--------------|------------------------|-------------|----------------------|----------|-----------------------|
| FR#0         | 4,7                    | -           | -                    | 3        | 3                     |
|              |                        |             |                      | 7        | 3                     |
|              |                        |             |                      | 14       | 3                     |
|              |                        |             |                      | 28       | 3                     |
| FR#1         | 4,7                    | 15          | -                    | 3        | 3                     |
|              |                        |             |                      | 7        | 3                     |
|              |                        |             |                      | 14       | 3                     |
|              |                        |             |                      | 28       | 3                     |
| FR#2         | 4,7                    | 15          | 0.5                  | 3        | 3                     |
|              |                        |             |                      | 7        | 3                     |
|              |                        |             |                      | 14       | 3                     |
|              |                        |             |                      | 28       | 3                     |
| FR#3         | 4,7                    | 15          | 1.0                  | 3        | 3                     |
|              |                        |             |                      | 7        | 3                     |
|              |                        |             |                      | 14       | 3                     |
|              |                        |             |                      | 28       | 3                     |
| FR#4         | 4,7                    | 15          | 2.0                  | 3        | 3                     |
|              |                        |             |                      | 7        | 3                     |
|              |                        |             |                      | 14       | 3                     |
|              |                        |             |                      | 28       | 3                     |
| ΣN           |                        |             |                      |          | 60                    |

2.2 Material
The materials used for the manufacture of concrete are mostly imported from outside of the water-cooling batching plant, the materials used in the manufacture of the concrete were:
1. Coarse aggregates of broken stone 10-20 and 20-30 from Gringsing
2. Fine aggregate using Munitlan sand
3. Cement portland type I, Semen Gresik
4. Water used is water wells
5. Addition Material of Fly Ash mineral from PLTU Jepara
6. Addition Material of admixture type-F (water reducing, high range admixtures)

The aggregate properties used and tested in the laboratory is shown in table 3 as follows:

Table 3. Aggregate properties

| The Properties of Material | Method                                | Material Type               |
|----------------------------|---------------------------------------|----------------------------|
|                            |                                       | Aggregate Coarse 10-20     |
|                            |                                       | Aggregate Coarse 20-30     |
|                            |                                       | Aggregate Fine             |
| Sieve Analysis             | SNI 03-1968-1990                      | 2,68                       |
| Specific Weight (Bulk)     | SNI 03-1969-1990                      | 2,63                       |
| Specific Weight (SSD)      | SNI 03-1969-1990                      | 2,67                       |
| Water Absorption           | SNI 03-1969-1990                      | 1,51                       |
| Content Weight SSD Solid   | SNI 03-4804-1998                      | 1,30                       |
| Content Weight of SSD Friable | SNI 03-4804-1998           | 1,29                       |
| The Wear of Concrete Aggregate | SNI 03-2417-1991          | 1,20                       |
| Fine Aggregate Durability  | SNI 03-3407-1994                    | 16,30                      |
| Through the Filter No.200  | SNI 03-4142-1996                    | 14,10                      |
| Fineness Modulus           |                                       | 16,10                      |

| Through the Filter No.200  | SNI 03-4142-1996                    | 14,10                      |
| Fineness Modulus           |                                       | 16,10                      |
2.3 Design of Mixed Proportions

By the data test of aggregate properties that have been implemented, it could be made a mixed proportion based on SNI03-6468-2000 (Procedure of Planning of Concrete Strength Concrete with Portland Cement and Fly Ash), the result is shown in table 4.

| Table 4. Mixed proportions |
|---------------------------|
| **Samples Code** | **Quality of Concrete (fc' (MPa))** | **Volume of Concrete (m³)** | **FAS** | **Material Needs** |
| | | | | **Water (kg)** | **PC (kg)** | **Coarse Aggregate (kg)** | **Fine Aggregate (kg)** | **Fly Ash (kg)** | **SP (kg)** |
| UCS#0 | FR#0 | 41,4 | 1 | 0,41 | 224,00 | 547,00 | 972,00 | 624,00 | - | - |
| UCS#1 | FR#1 | 224,00 | 464,95 | 972,00 | 608,27 | 82,05 | - | - |
| UCS#2 | FR#2 | 221,72 | 464,95 | 972,00 | 608,27 | 82,05 | 2,735 |
| UCS#3 | FR#3 | 219,44 | 464,95 | 972,00 | 608,27 | 82,05 | 5,470 |
| UCS#4 | FR#4 | 214,88 | 464,95 | 972,00 | 608,27 | 82,05 | 10,940 |

2.4 Method of the Test

There were three sample tests in this research such as Slump tests, compressive strength of concrete test and flexural strength of concrete test. Slump test was conducted with the steps imposed on SNI 03-1972-1990, concrete compressive strength test conducted in accordance with SNI 03-1904-1990, and test of flexural strength of concrete was carried out in accordance with SNI 03-4431-2997.

3. Result and Discussion

3.1 Workability

One of parameters to measure the level of ease of concrete to work was the slump value. The result of research by adding fly ash and variation of superplasticizer addition, it was obtained a slump value of concrete as in table 5 following:

| Table 5. Concrete slump value |
|-----------------------------|
| **Mixture Type** | **Faktor Air Semen/ Cement Water Factor (FAS)** | **Fly Ash (% Weight of PC)** | **Superplasticizer (% Weight of PC)** | **Slump Value (cm)** |
| #0 | 0,41 | - | - | 4,8 |
| #1 | 0,41 | 15 | - | 5,3 |
| #2 | 0,41 | 15 | 0,5 | 9,2 |
| #3 | 0,41 | 15 | 1,0 | 12,2 |
| #4 | 0,41 | 15 | 2,0 | 18,1 |

From the table above, it can be showed that mixed type # 1 with the addition 15% fly ash of the basic mixture type # 0 (without addition material usage) causes the slump raising to 5,3cm from 4.8cm, it is caused by the smoothness and shape of fly ash particles that cannot improve the workability yet.

Workability can also be seen from the table of the density concrete. From table 6, It appears that the higher the addition of superplasticizer, then the type of concrete weight becomes larger, because the higher superplasticizer addition of concrete slump also becomes higher, so it is easier to work.
Table 6. Concrete weight of each mixed concrete

| Mixture Type | Faktor Air Semen/Cement Water Factor (FAS) | Fly Ash (% weight PC) | Superplasticizer (% weight PC) | Concrete Weight (Ton/m³) |
|--------------|-----------------------------------------|-----------------------|-----------------------------|-------------------------|
| #0           | 0.41                                    | -                     | -                           | 2,416                   |
| #1           | 0.41                                    | 15                    | -                           | 2,418                   |
| #2           | 0.41                                    | 15                    | 0.5                         | 2,425                   |
| #3           | 0.41                                    | 15                    | 1.0                         | 2,432                   |
| #4           | 0.41                                    | 15                    | 2.0                         | 2,436                   |

3.2 Mechanical Properties of Concrete

3.2.1 Compressive Strength Concrete Test Result. The results of the compressive strength test of the average concrete are shown in graph 1 form below:

![Figure 1. Chart of concrete compressive strength test results](image1)

Based on the result, concrete compressive strength test at age 28 days, it can be seen that the quality of concrete is still under the concrete quality target of f'c = 51.06 Mpa. The use of the material generally decreases the compressive strength of the concrete, either at an early age or at 28 days of age. From the five mixtures, the strongest value of the compressive strength test results at 28 days was mixed type #3 (mixture with additional 15% fly ash and 1.0% superplasticizer) was 43.85 Mpa.

Compressive Strength of Concrete test results and slump were then made in the chart between the compressive strength of concrete from various ages with slump of various proportions of mixture.

![Figure 2. Chart between the slump and the compressive strength test of various ages](image2)
Based on the chart the above, the relationship between slump and concrete compressive strength, it can be seen that mixed type # 4 (using 2% superplasticizer) had a compressive strength that at 28 days was the lowest result such as 40.29 MPa. It can be concluded that the use of superplasticizer should be understood the dose, because the excessive use will cause the mortar was difficult to hardened and the lost the strength.

3.2.2 **Flexural Strength Concrete Test Result of Mixed Type.** The results of the average concrete flexural strength test are shown in chart 1 below:

![Figure 3. Concrete flexural strength test chart](image)

From the results of the flexural strength test, all mixtures which used addition materials have a higher flexural strength at the beginning of the process than the original mixed type # 0 (mixture without added any addition material), which occurred at 28 days, all flexural strength was under the base mixed type # 0. The amount of flexural strength for mixed type # 0 was equal $f_r = 64.83 \text{ kg/cm}^3$. It can be concluded that the use of added materials was useful for obtaining flexural strength in the early ages.

The result of concrete flexural strength test and slump then made a chart between the flexural strength of concrete from various age with slump of mixed proportion, as in figure 4 below:

![Figure 4. Bar chart between slump and flexural test of various ages](image)

From the figure 4 above, it can be seen that the use of added superplasticizer of mixture type # 4 was 2% is apparently flexural strength becomes greater, in other hand, the compressive strength decreased.
3.2.3 Estimated Optimum Superplasticizer Level. From the 28-day concrete compressive strength test on mixed type # 2, mixed type # 3 and mixed type # 4, it is estimated that optimum use of superplasticizer is 1,2 as can be seen in figure 5 below:

![Figure 5. Estimated optimum superplasticizer level](image)

4. Conclusion
Based on the results of research and the discussion of high quality concrete, it can be concluded some conclusions as follows:

1) The use of added materials 15% fly ash causes the slump value to be higher so that the concrete the more crumpled and easier to work. The increase in slump value of the addition of 15% fly ash is 0.53cm from the base slump value.

2) The use of superplasticizer causes the weight of the type becomes greater so that the the more crumpled concrete and easier to work. The results of the consecutive weight values are # 0 = 2,416; # 1 = 2,418; # 3 = 2,432 and # 4 = 2,436.

3) It is estimated that the optimum dose of superplasticizer is 1.2%, it is still in the usage dosage according to the F-type admixture brochure (water reducing, high range admixture) that is 0.6% - 1.5%.

4) All types of mixtures which use addition materials for flexural strength fr’= 45kg/cm² can be achieved at 3 days.

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