Optimization of superplasticizer MasterGlenium SKY 8614 with added materials fly ash, steel slag, and silica fume for high strength concrete

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Abstract. Indonesia as a developing country continues build various infrastructures such as high storey building, bridge, highway, or fly over. Most of the construction project in Indonesia use concrete as the main material. Various problems arise as the ongoing developments such as reduced the natural resources to market demand require the concrete can be used one day after the project completion. The research is trying to solve this problem. The use of fly ash as substitute material to reduce the amount of cement use due to its chemical properties of silica and alumina, the use of steel slag instead of 50% coarse aggregate, and use of silica fume so greatly affect the compressive strength of concrete. The result of concrete compressive strength in 3 samples from first mix design with code AR were 29.16 MPa, 29.72 MPa, and 30.12 MPa. Fly ash, steel slag, and silica fume can increase the compressive strength which is much higher than design compressive strength of 15 MPa and with this mix design only use 51% of total cement requirement with normal mix design of ACI method.

1. Introduction

Development in the construction in Indonesia currently is heavy conducted. More than 60% construction project either from the simplest to the complicated project use concrete as the main construction material. Increasing the lower middle class by 56.5% from 240 million populations can be sure the development will be continuing to grow [1]. The purpose of self-development is to make people prosperous. Without realizing there is problem arising from uncontrolled development is reduction the natural resources that is the impact of massive development that occurred at this time. To solve this problem, so need for innovation. In this study the authors have conducted research on high quality concrete SCC concrete that can be hardened and can be used within 1 day. Concrete consisting of a mixture of cement, fine aggregate, coarse aggregate, and water is a material that cannot be separated in the world of construction.

Conventional concrete is considered less effective because in the process required a vibrator to compress fresh concrete. SCC is also otherwise called as High-Fluidity Concrete, Self-Levelling Concrete and Self-Consolidating Concrete. This concrete has a very good ability to flow inside the formwork in which there is a reinforcing steel relying on the effect of gravity force with a maintained homogeneity [2]. As a solution of the problem, is currently being developed concrete SCC (Self Compacting Concrete) that is self-flowing and self-compacted concrete, to support SCC's work is required also Admixture
material that is Superplasticizer, in this opportunity using MasterGlenium SKY 8614 from BASF, added is required to meet the flow ability requirements.

Then, SCC development needs to be balanced with innovation to save natural resources. The cement production process mostly uses fossil fuels that are likely to cause a greenhouse effect. The residual ash from the cement production process is also directly mixed with the free air which makes it pollution for the environment. It should be noted that 1 ton of cement produces 1 ton of carbon dioxide as well, and cement production also accounts for 7% of overall CO2 generated from various sources. That factor causes many innovations to reduce the amount of cement use in making SCC concrete. Some researchers have done research on the issue, such as the addition of materials as cementitious to reduce the amount of cement and increase the compressive strength of concrete.

Based on the above background, then the problem that became the focus of this research is what is the most optimal material for Superplasticizer MasterGlenium SKY 8614? How do other additives influence the compressive strength of the concrete? While the purpose of this research is to know the optimal added material for Superplasticizer MasterGlenium SKY 8614 and to know the effect of fly ash, steel slag and silica fume combined with Superplasticizer MasterGlenium SKY 8614 to the compressive strength of concrete. The benefits of this research are expected to become the potential developer material of steel slag, silica fume, and fly ash as added materials of SCC concrete construction and can be a solution of construction problems in buildings that will soon be used within 1 day.

2. Research methods
In the first stage of preparation based on study results, literature studies, preparations include materials and equipment to be used in the manufacture of test specimens. The sources of data from primary and secondary data. Primary data in this study was obtained through interviews and consultations with experts who are competent in their field. Secondary data in this study secondary data obtained from the observation and test samples of test specimens, and reference library related to this research. Some of the things observed and tested in this study are:

- Workability of Concrete Mixed Workability, this test is done by Slump Test.
- Compressive Test, this test is done on all samples after all samples reaches age of 24 hours.

In the second stage, the material characteristics and physical test were tested on each material used. This test used the ASTM C 40 assay standard for the ASTM C 127 as a mild aggregate assay test for specific gravity and absorbance tests on coarse aggregate ASTM C 128 for specific gravity and absorption tests on fine aggregate ASTM C 136 for fine aggregate filtration analysis and coarse aggregate.

In the third stage, batching is done with mix design composition 1 with AR code (Superplasticizer MasterGlenium SKY 8614, silica fume, slag steel, sand, gravel, cement, and water), mix design 2 with BS code (Superplasticizer MasterGlenium SKY 8614, fly ash, Slag of steel, sand, gravel, cement, and water). Mix design 3 with CT code (Superplasticizer MasterGlenium SKY 8614, fly ash, silica fume, sand, gravel, cement, and water), mix design 4 with DU code (Superplasticizer MasterGlenium SKY 8614, fly ash, silica fume, slag steel, sand, Gravel, cement, and water) and mix design 5 with the EV code (Superplasticizer MasterGlenium SKY 8614, steel slag, sand, gravel, cement, and water). Each mix design will be made into 3 specimens. Prior to printing into a 15 x 30 cm cylindrical test specimen, each of the fresh concrete results of each mix design is performed slump flow test which refers to the EFNARC testing standard (fresh concrete requirement is to have 55-85 cm slump flow). After the hardened concrete can be done capping (ASTM C 617 Standard) with sulfur material on each hardened concrete so that the surface of the concrete becomes flat [3 – 7].

In the fourth stage, the test of compressive strength of cylindrical concrete on each test specimen is 15 specimens. In the fifth stage data analysis and discussion of all test results that have been done on each specimen. In the sixth stage the conclusion of all test results, analysis and report writing.
2.1. Materials
Steel slag is the waste material from steel casting in the form of waste and has not maximized its use. Silica fume is a delicate pozzolan material, where the composition is mostly produced from the high blast furnace or the rest of the silicon or silicon iron alloy production. The use of silica fume in a concrete mix is intended to produce concrete with increasing strength from day to day. Superplasticizer is an added material used in the manufacture of SCC concrete intended to achieve its flow ability. The PCC (Portland Composite Cement) on this occasion uses a brand of Three Wheels of type I. The cement is often used for buildings in general, in addition to having lower hydration heat during the cooling process compared to other types of portland, the work will be easier and produce surface concrete is denser and smooth (SNI 157064-2004). Aggregates Larrad's (1990) study results show that the maximum grain size provides concrete evidence to make high quality concrete should not be more than 15 mm [8] List of materials are used in this research shown in table 1.

Table 1. Materials data.

| No. | Materials     | Density (gr/cm³) | Explanation               |
|-----|---------------|------------------|---------------------------|
| 1   | Cement        | 3.15             | Tiga Roda tipe PCC         |
| 2   | Sand          | 2.60             | Merapi                    |
| 3   | Coarse        | 2.65             | Kulon Progo               |
| 4   | Steel slag    | 3.60             | Ceper Klaten              |
| 5   | Silica fume   | 2.20             | SikaFume, PT. Sika        |
| 6   | Fly ash       | 2.15             | PT. Varia Usaha Beton      |
| 7   | Superplasticizer |           | Brosur PT. BASF           |

2.2. Mix design
AR code is used as designation for mix design type 1, BS code is used as designation for mix design type 2, CT code is used as designation for mix design type 3, DU code is used as designation for mix design type 4, and EV code is used as designation for mix design type 5. The above materials use fly ash 15% of cementitious, silica fume 10% of cementitious, superplasticizer 1.5% of cementitious, 50% steel slag of total coarse aggregate, fine aggregate ratio: coarse aggregate = 49:51. The concrete strength of the concrete plan is 15 MPa within 1 day. Mix design using American Concrete Institute (ACI) method, with strong press 15 MPa plan in 1 day and f'c 75 MPa in 28 days. As a result of normal concrete mix design, total cement requirement of 800 kg/m³, gravel 672 kg/m³, sand 650 kg/m³, water 0.206 m³. Then modified to mix design modification with cementitious deduction of 27.25% of cement content, to obtain total cement requirement of 550 kg/m³, silica fume 5.5% from cementitious of 32 kg/m³. The mix design is shown in table 2.

Table 2. Mix design.

| No. | Material   | Mix Design Code (Needs 3 cylinder) | Unit |
|-----|------------|-----------------------------------|------|
|     |            | AR  | BS  | CT  | DU  | EV  |      |
| 1   | Cement     | 8.7 | 7.9 | 6.9 | 6.9 | 9.2 | kg   |
| 2   | Silica fume| 0.5 | -   | 0.9 | 0.9 | -   | kg   |
| 3   | Fly ash    | -   | 1.4 | 1.4 | 1.4 | -   | kg   |
| 4   | Water      | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | liter|
| 5   | Superplasticizer | 0.2 | 0.1 | 0.2 | 0.2 | 0.1 | liter|
| 6   | Sand       | 12  | 13  | 12  | 12  | 13  | kg   |
| 7   | Gravel     | 6.2 | 6.7 | 13  | 6.5 | 6.8 | kg   |
| 8   | Steel Slag | 6.2 | 6.7 | -   | 6.5 | 6.8 | kg   |
3. Result of concrete cylindrical pressure test

The cylindrical concrete was tested for compressive strength at the age of 1 day (24 hours) with a compressive strength test machine. The following is the result of the cylinder concrete compressive test can be seen in the table 3.

Table 3. Result of concrete pressure test.

| Mix Design Code | 1   | 2   | 3   | Average(MPa) |
|-----------------|-----|-----|-----|--------------|
| AR              | 29.14 | 29.71 | 30.10 | 29.65        |
| BS              | 19.24 | 22.07 | 20.27 | 20.53        |
| CT              | 4.00  | 4.44  | 4.44  | 4.27         |
| DU              | 4.30  | 4.10  | 3.40  | 3.93         |
| EV              | 26.60 | 23.80 | 30.60 | 27.00        |

4. Discussion

The result of compressive strength test is shown in figure 1 (a) AR concrete mix design (b) BS concrete mix design (c) CT concrete mix design (d) DU concrete mix design and (e) EV concrete mix design. Figure 2 shows the comparison result of all mix design and figure 3 shows the graph of concrete optimum compressive strength.

The results of compressive strength test of AR concrete mix design, AR1 cylinder has a compressive strength of 29.14 MPa, AR2 cylinder has a compressive strength of 29.71 MPa, and the AR3 cylinder has a compressive strength of 30.10 MPa. The average of AR concrete compressive strength is 29.65 MPa at 1 day (24 hours).

The results of compressive strength test from concrete BS design mix, BS1 cylinder have compressive strength of 19.24 MPa, BS2 cylinder have compressive strength 20.27 MPa, and BS3 cylinder have compressive strength equal to 22.07 MPa. The average of concrete strength of BS is 20.53 MPa at 1 day (24 hours).

The results of compressive strength test from concrete mix design CT, CT1 cylinder has a compressive strength of 4.00 MPa, cylinder CT2 has a compressive strength of 4.44 MPa, and CT3 cylinder has a compressive strength of 4.44 MPa. The average of compressive strength of CT concrete is 4.27 MPa at 1 day (24 hours).

The results of compressive strength test from DU concrete mix design, DU1 cylinder have compressive strength equal to 3.4 MPa, cylinder DU2 have compressive strength 4.1 MPa, and cylinder DU3 have compressive strength equal to 4.3 MPa. The average of concrete compressive strength of DU is 3.93 MPa at 1 day (24 hours).

The results of the compressive strength test of EV concrete mix design, EV1 cylinder has a compressive strength of 23.8 MPa, EV2 cylinder has a compressive strength of 26.6 MPa, and EV3 cylinder has a compressive strength of 30.6 MPa. The average of compressive strength of EV concrete is 27.00 MPa at 1 day (24 hours).

AR concrete has the highest average compressive strength compared to other mixed concrete that is 29.65 MPa in the age of 1 day (24 hours). Recommended additives for the SKY 8614 Superplasticizer MasterGlenium are silica fume and steel slag.

From the results of the compressive strength shown in the table 3 that the addition of Superplasticizer and fly ash is not effective in increasing the compressive strength of the concrete mixture. The use of steel slaags that have high hardness characteristics can support increased compressive strength.
Figure 1. The result of compressive strength test.
5. Conclusion
From the results and discussion can be concluded that the optimal added materials for Superplasticizer MasterGlenium SKY 8614 is silica fume and steel slag. And the addition of added materials will be optimum using silica fume with 5.5% content of cementitious, steel slag of 50% of the total coarse aggregate.

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