Utility of local quartz powder and silica fume to produce high early strength of self compacting high strength concrete.

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Abstract. Generally concrete needs 7 to 14 days to reach minimum adequate compressive strength. Sometimes it is needed to get high early compressive strength of concrete for some reason. This research conduct an experimental program to make high early strength of self compacting concrete which is using local quartz powder and silica fume. Twenty one cylinder specimens were made and tested to get the compressive strength at age of 1 day, 3 days, 7 days, 14 days, 21 days, and 28 days. While the modulus elasticity of concrete were tested only at the age of 28 days. The cylinder specimen was using standard size of (150 × 300) mm2. The experimental program shows that the average compressive strength of concrete in 1 day, 3 days, 7 days, 14 days, 21 days, and 28 days were 10.00 MPa, 27.16 MPa, 36.41 MPa, 40.93 MPa, 50.36 MPa, and 48.66 MPa, respectively. While the average modulus elasticity of the concrete at the age of 28 days was 18,703.45 MPa.

1. Introduction
Concrete becomes famous materials for building construction in the past decades up to now. If the cast in situ concrete is using for material of building construction, the age of the concrete to reach the maximum compressive strength is very important. Generally, the concrete needs 28 days to reach the maximum compressive strength. Normally, concrete needs 7 to 14 days to achieve minimum compressive strength of 0.7 to 0.85 fc′ as a minimum strength. If the minimum strength can be achieved, the scaffolding and formwork can be removed and the work can be proceed to the next step. It can be said that the project of building construction needs high early strength of concrete to make a faster project construction.

Experimental study to produce high early strength of concrete were conducted by Soni et al. [1]. This study is using plasticizer to achieve high early strength and the results showed that the concrete could get 40% high early strenght using the plasticizer. Yasin et al. [2] used local materials of calcite stone from Tuban East-Java and sand from Bengawan Solo River, Bojonegoro East-Java to produce high early strength of concrete. The results showed that the high early strength of concrete can be achieved using the local materials. However, both studies were not intended for high early strength of self compacting concrete.

In several decades ago up to now, self compacting compacting concrete was developed to solve the problem for complex form work of concrete structure such as thin element of structure or curved element of structure, especially in the element of structures which has congested reinforcement [3, 4]. So that, to get a high early strength of self compacting concrete using local quartz powder and silica fume, this research was conducted.
2. Experimental

2.1 Materials

Portland Pozzolana Cement (PPC) used in this project. Portland Pozzolana Cement is a hydraulic cement consisting of a homogeneous mixture between portland cement with fine pozzolan, which is produced by grinding portland cement and clinker pozzolan together, or mix evenly with portland cement powder with pozzolan powder, or a combination of grinding and mixing, where the levels of pozzolan are 6% to 40% of the mass of Portland cement. Crushed stone with size of 0.5 – 1 cm used as coarse aggregates. The crushed stone is taken from local material in Yogyakarta Province. Quartz sand is taken from Bangka Belitung. In addition, nano quartz which has the finer mesh was also used as filler. The quartz sand with size 0.3– 0.8 mm used as fine aggregates and additional quartz powder which has 200 meshes is also used as additional filler in the concrete. Silica Fume used in this project to encourage the pozzolana activity to begin earlier and continuing the hydration process of concrete so the concrete keep gaining its strength as conducted by Laura et. al. [5]. HRWR (High Range Water Reducer) is used in this research to improve the workability of the concrete in low water to cement ratio.

2.2 Mix Design and Specimens

Several trial and errors of mix design were conducted to carry out the optimum mix design. The mixing was done by several steps. Before getting the optimum design, the initial mix design followed the mix design proposed by Ma and Dietz [6], where the concrete uses the full quartz sand and quartz powder. However, the workability of concrete was not good due to the low water cement ratio. Therefore, the mix design was changed and increased the water to cement ratio by 0.01 and balanced with proper the use of SPC until it forms a homogenous mixture. After the last trial, the optimum mix design of self compacting high strength concrete was gotten.

All the dry materials were mixed for around 2 minutes, and then added by water and HRWR slowly by periods until it forms a homogenous mixture of concrete. After that, the setting time and behavior of the mixtures were studied within one day. The cylinder specimens were cured into the water to keep the moistures of the specimens. The mix design of the self compacting high strength concrete is shown in Table 1.

| No | Properties                          | Amount (kg) |
|----|------------------------------------|-------------|
| 1  | Cement                             | 510         |
| 2  | Silica Fume                        | 76.5        |
| 3  | Water (WCR 0.35)                   | 178.5       |
| 4  | Total Aggregates                   | 1443.3      |
| 5  | Fine Aggregates (Quartz Sand)      | 485.52      |
| 6  | Quartz Powder                      | 208.08      |
| 7  | Coarse Aggregates                  | 749.7       |

Twenty one cylinder specimens with the size of (150x300) mm² were made and tested in this study. The testing’s of concrete were conducted at 1 day, 3 days, 7 days, 14 days, 21 days, and 28 days. In addition, the specimen at age of 28 days was also tested to investigate the modulus of elasticity of the concrete.
2.3 Testing Specimen

The requirement test for self compacting concrete (SCC) were slump flow test and L-Shape box test. These testing were conducted in this study to carry out the filling ability and passing ability of the fresh concrete mixture EFNARC [7]. The slump flow test was depicted in Figure 1.

![Figure 1. Slump flow test](image1)

The L-shape box testing is using the standard L-shape box size as shown in Figure 2.

![Figure 2. L-Shape box test](image2)

Universal Testing Machine (UTM) with the capacity of 30,000 kgf as shown in the figure 3 was used to conduct the compressive strength and modulus of elasticity testing of concrete.
3. Results and Discussions

3.1 Slump flow and L-shape box test

Slump flow test result of the concrete can be seen in Table 2. The slump flow results of the self compacting concrete were in the range of EFNARC requirement. The requirement for the slump flow is 600 to 800 mm, the result of slump flow of this research were in the range of EFNARC requirement.

Table 2. Slump flow test result

|          | Mixing for testing of 1 Day | Mixing for testing of 3 Day | Mixing for testing of 7 Day | Mixing for testing of 14 Day | Mixing for testing of 21 Day | Mixing for testing of 28 Day | EFNARC       |
|----------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|--------------|
| Flow 1   | 680 mm                      | 670 mm                      | 680 mm                      | 690 mm                      | 700 mm                      | 680 mm                      | 600 up to 800 mm |
| Flow 2   | 680 mm                      | 680 mm                      | 680 mm                      | 680 mm                      | 750 mm                      | 680 mm                      |               |
| Flow 3   | 690 mm                      | 650 mm                      | 650 mm                      | 700 mm                      | 720 mm                      | 650 mm                      |               |
| Flow 4   | 700 mm                      | 680 mm                      | 630 mm                      | 700 mm                      | 720 mm                      | 630 mm                      |               |
| Average  | 688 mm                      | 670 mm                      | 660 mm                      | 693 mm                      | 723 mm                      | 660 mm                      |               |
| T50      | 4 sec.                      | 4 sec.                      | 5 sec.                      | 3 sec.                      | 3 sec.                      | 5 sec.                      | 2-5 sec       |

Another testing of fresh concrete in this study was L-shape box test. The result of L-shape box test was shown in Table 3. It can be seen that the result of L-shape box test of the concrete follows the requirement of EFNARC. The requirement of L-shape box test for self compacting concrete according to EFNARC was in the range of 0.8 to 1.0. The result of L-shape box test of this research was in the range of 0.8 to 1.0. So, it can be said that the concrete of this study can be classified as self compacting concrete.

Table 3. L-shape box test result

|          | Mixing for testing of 1 Day | Mixing for testing of 3 Day | Mixing for testing of 7 Day | Mixing for testing of 14 Day | Mixing for testing of 21 Day | Mixing for testing of 28 Day | EFNARC       |
|----------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|--------------|
| Blocking Ratio | 0.83                      | 0.86                      | 0.842                      | 0.87                      | 0.82                      | 0.86                      | 0.8<H<1      |
The testing of the concrete was conducted at the age of concrete of 1 day, 3 days, and 7 days to investigate the early strength of the concrete and also for the concrete at the 14 days, 21 days, and 28 days to investigate the development strength of the concrete. The compressive strength result of the concrete can be seen in Table 4, while the development of the compressive strength can be seen in Figure 4. It can be seen from Table 4 and Figure 4 that the average compressive strength at the early strength at 1 day; 3 days; and 7 days were 10.00 MPa; 27.16 MPa; and 36.41 MPa, respectively. The compressive strength at 1 day was not so satisfied due to the quality of quartz sand which was taken from local material. The quartz sand from local material was not as good as the super fine grains size.

While the compressive strength at 14 days; 21 days; and 28 days were 40.93 MPa; 50.36 MPa; and 48.66 MPa, respectively. The concrete which has a compressive strength more than 41.4 MPa can be categorized as high strength concrete [8]. So, it can be said that the self-compacting concrete in this research can be classified as high strength concrete, because the compressive strength of the concrete at 21 days and 28 days had the value more than 41.4 MPa.

| Table 4. The compressive strength test result |
| Age | Specimen | Load (kN) | Strength (MPa) | Average (MPa) |
|-----|----------|-----------|----------------|---------------|
| 1 Day | 1 | 120 | 6.79 | 10.00 |
| | 2 | 200 | 11.32 | |
| | 3 | 210 | 11.88 | |
| 3 Days | 1 | 450 | 25.46 | |
| | 2 | 510 | 28.86 | 27.16 |
| | 3 | 480 | 27.16 | |
| 7 Days | 1 | 650 | 36.78 | |
| | 2 | 590 | 33.39 | 36.41 |
| | 3 | 690 | 39.05 | |
| 14 Days | 1 | 680 | 38.48 | |
| | 2 | 700 | 39.61 | 40.93 |
| | 3 | 790 | 44.7 | |
| 21 Days | 1 | 870 | 49.23 | |
| | 2 | 920 | 52.06 | 50.36 |
| | 3 | 880 | 49.8 | |
| 28 Days | 1 | 790 | 44.71 | |
| | 2 | 880 | 49.8 | 48.66 |
| | 3 | 910 | 51.49 | |
Figure 4. The development strength of concrete

The modulus of elasticity of the concrete was conducted when the concrete has reached 28 days. The modulus of elasticity of the concrete was depicted in Table 5. It can be seen from Table 5 that the average of modulus of elasticity was 18,703.45 MPa. The modulus of elasticity of self-compacting concrete in this research has the value less than the normal concrete which usually has the modulus elasticity more than 20,000 MPa. This indicated that the self-compacting concrete in this study was not as stiff as the normal concrete.

Table 5. The modulus of elasticity.

| Cylinder | Modulus of elasticity (MPa) | Average (MPa) |
|----------|-----------------------------|---------------|
| 1        | 17,512.87                   |               |
| 2        | 19,525.82                   | 18,703.45     |
| 3        | 19,071.68                   |               |

4. Conclusion

Based on the result of experiments program, several conclusions can be drawn as follow:

1. The fresh properties testing of self compacting high early strength of concrete fulfils the requirements of Self Compacting Concrete. It is indicated by the average of slump flow and L-Shape Box testing in 1 day; 3 days; 7 days; 14 days; 21 days; and 28 days.
2. The early strength of self compacting high strength concrete in one day, three days, and seven days were 10 MPa; 27.16 MPa; and 36.41 MPa, respectively. This indicated that the early high strength of self compacting concrete which is more than 20 MPa can be achieved at three days.
3. The compressive strength of self compacting concrete in 14 days; 21 days; and 28 days were 40.93MPa; 50.36 MPa; and 48.66 MPa, respectively. The compressive strength of the self-compacting concrete at 21 days and 28 days had the value more than 41.4 MPa. It means that the self compacting concrete in this research can be classified as high strength concrete.
Acknowledgments
The Authors are wishing to acknowledge to the head and staff of the Laboratory of Structures and Materials, Department of Civil Engineering, Faculty of Engineering, Universitas Atma jaya Yogyakarta for the facilities, so the research can be conducted.

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