Enhancing Slump Flow, Specific Gravity, and Compressive Strength Material Properties of Self Compacting Concrete (SCC) with Glass Waste Powder

D Noorzyafiqi1, E Srisunarsih1, T L A Sucipto1, B Siswanto1
1 Building Engineering of Education Department, Faculty of Teacher Training and Education, Universitas Sebelas Maret, Indonesia, Jl Ir Sutami 36A Surakarta, Jawa Tengah, Indonesia.

Email: dnoorzyafiqi28@student.uns.ac.id

Abstract: Self Compacting Concrete (SCC) is the latest and advanced technology in the field of concrete technology. SCC is an innovative type of concrete, one of which has properties flowable. In this study, one of the innovations in the use of glass bottles as a substitute some cement for SCC. This research was conducted to determine the effect of glass waste powder as partial substitute for cement on slump flow, specific gravity, and the compressive strength of concrete aged 14 days SCC. The mix design used was Okumura's Simple Mix Design [1], water-to-powder ratio 0.35, and dosage superplasticizer 1%. Variation of glass waste powder 0%, 5%, 10%, 15%, 20%, 25%, and 30% of the weight of cement, the size of the waste glass powder is through the filter no. 100 and stuck in the filter no. 200. The test object in this study uses a cylinder with diameter 15 cm and height 30 cm. The flowability test is carried out when the concrete is fresh. For hard concrete, specific gravity and compressive strength tests are carried out at the age of 14 days. The result of replacing glass waste powder as a substitute for some cement has a significant effect on the slump flow value of 85%. Slump flow in fresh concrete mixture with various glass waste powder 5%, 10%, 15%, and 20% reach the standard [2]. Replacement of glass waste powder as a substitute for part of cement has a significant effect on the specific gravity concrete amounting to 69.6%. Specific gravity concrete in this study fulfills the requirements for structural normal specific gravity[3]. On the compressive strength of concrete aged 14 days, glass waste powder has a significant effect of 86.2%. Compressive strength has a maximum compressive strength of 35.322 MPa, with an optimal percentage of glass waste powder as a substitute for partial cement is 10.464%.

Keywords: self compacting concrete, glass waste powder, slump flow, specific gravity, compressive strength

1 Introduction

The increasing demand for high quality concrete also results in environmental problems caused by the manufacture of a concrete mixture, namely cement. Environmental problems are also found in the cement industry. The process of producing cement raw materials into cement requires burning coal which produces carbon dioxide emissions in relatively large quantities for increased global warming. Cement production accounts for 7% of all human CO2 emissions [4]. To reduce this impact, researchers have attempted to make partial substitution of cement with pozzolanic or other cementitious materials, without significantly reducing the quality of the resulting concrete. One of the efforts to overcome this problem is to use glass powder waste as powder and at the same time reduce the use of cement in self-compacting concrete. Large amounts of glass waste originating from industry and households are a source of environmental problems. Utilization of waste glass for reuse is one of the right waste handling solutions. Glass powder is expected to function as a filler and binder because it has the potential as a self-compacting concrete pozzolanic material is a form of concrete mixture that has a small pore volume in the concrete, thereby minimizing the trapped air in fresh concrete [9]. Based on the name, SCC can be defined as a concrete mixture which has the characteristics of being able to solidify itself without
using a vibrator. Self-compacting concrete has the ability to flow, fill space, and pass through the reinforcement density barrier without segregation.

2 Theoretical Foundation

2.1 Self Compacting Concrete

Self Compacting Concrete is a concrete that has high flowability and filling ability so that it can flow and solidify independently without requiring compaction or vibration. The fresh SCC mixture has a more fluid characteristic. This mixture is able to compact, fill, and flow at every corner or gap of reinforced concrete structures whose work is difficult to reach. Fresh SCC concrete also has more cohesive properties and has resistance to bleeding and segregation. [1].

Mix design SCC three main requirements must be achieved: 1) the ability to flow (flowability); 2) the ability to pass (passing ability); and 3) the ability to prevent aggregate segregation [1].

| Parameters tested                  | Test Equipment | Measured parameters             |
|------------------------------------|----------------|---------------------------------|
| Flowability/Filling Ability        | Slump Flow     | Total Spread                    |
|                                    | Kajima Box     | Visual Filling                  |
|                                    | L-box          | Passing ratio                   |
|                                    | U-box          | Height difference               |
|                                    | J-ring         | Step height, total flow         |
|                                    | Kajima box     | Visual passing ability          |
|                                    | V-funnel       | Flow time                       |
|                                    | O-funnel       | Flow time                       |
|                                    | Orimet         | Flow time                       |
| Viscoisty/Flowability             |                |                                 |
| Segregation Resistance            |                |                                 |

Table 2.2. Test parameters and methods for evaluation SCC

| No. | Testing SCC       | Range       |
|-----|-------------------|-------------|
| 1   | Diameter Slump Flow | Min. 550 mm |
| 2   | V-Funnel          | 8-15 second |
| 3   | L-Shaped Box (H2/H1) | > 0.8      |
| 4   | w/p ratio         | 0.25 – 0.40 |
| 5   | Compressive Strength | 26.4 MPa   |
| 6   | Density           | 2200 Kg/m³ |

2.2 Self-Compacting Concrete Composer Materials

The constituent materials of SCC are cement, glass waste powder, fine aggregate, coarse aggregate, admixture (superplasticizer), and water. The fine aggregate used is in accordance with the provisions of SK-SNI-T-15-1990-03 and the coarse aggregate used is in accordance with the provisions of SK-SNI-03-2461-2002 and is the same as the provisions for the aggregate used in making normal concrete in general.

2.2.1 Portland Cement

Portland Pozzolan cement is a hydraulic cement consisting of a homogeneous mixture of portland cement and fine pozzolan, which is produced by grinding the clinker of portland cement and pozzolan together, [5]. The four most important elements in cement are: a. Trikalsium silikat (\(C_3S\)) atau 3CaO.SiO3 b. Dikalsium silikat (\(C_2S\)) atau 2CaO.SiO2 c. Trikalsium aluminat (\(C_3A\)) atau 3CaO.Al2O3 d. Tetrakalsium aluminoferit (\(C_4AF\)) atau 4CaO.Al2O3.FeO2.
2.2.2 Glass
Glass is one of the products of the chemical industry which is a combination of various non-volatile inorganic oxides, resulting from the decomposition and smelting of alkaline and alkaline earth compounds, sand and various other constituents [6]. Glass powder has advantages over other pore filling materials [6], that’s is:
- Has properties zero water absorption,
- The hardness of the glass makes the concrete resistant to abrasion which only a small amount of natural aggregate can achieve,
- Glass Powder improve the content of fresh concrete so that high strength can be achieved without the use of a superplasticizer,
- Glass Powder Good glass powder has pozzolanic properties so that it can function as a substitute for cement and filler.
Chemical content in glass powder [6]

| Ingredient | Content (%) |
|------------|-------------|
| SiO2       | 61.72       |
| A12O3      | 3.45        |
| Fe2O3      | 0.18        |
| CaO        | 0.59        |

2.2.3 Superplasticizer
Superplasticizer is an additional material in concrete either in the form of powder or liquid which functions to modify the characteristics of the mortar or the concrete. The addition of superplasticizer will increase the slump value even higher with the same water cement factor. Superplasticizer is a soluble macromolecule, which is hundreds of times larger than a water molecule (Gani, 1997).
The superplasticizer product used is the Console SS-74N.

2.4 Mix Design SCC
Mix design planning and concrete quality planning for SCC based on Self Compacting Concrete. The specifications include; The use of coarse aggregate is a maximum of 50% of the volume of solid aggregate, the use of fine aggregate is adjusted to the volume range of 45% - 55% of the total volume of the mixture. The water binder factor is set from 0.30 to 0.55[7].

| Material         | Dosage Against Weight (Kg/m3) | Dosage Against Volume (L/m3) |
|------------------|-------------------------------|------------------------------|
| Binder           | 380 – 600                     | -                            |
| Water            | 150 – 210                     | 150 – 210                    |
| Coarse Aggregate | 750 – 1000                    | 270 – 360                    |
| Fine Aggregate   | The use of fine aggregate is 45% - 55% by weight | |
| FAS              | 0.30 – 0.55                   | 0.85 – 1.10                  |

2.5 Testing SCC
2.5.1 Testing Slump Flow
Slump Flow used to determine the stiffness of the mixture fresh concrete. The stiffness in a concrete mixture shows how much water is used. Slump flow used to test the flowability of self compacting concrete so that it can be seen the ability of concrete to fill the empty space.
The slump flow diameter must be between 500 mm and 850 mm according to the standard ACI (American Concrete Institute) No. 237R[2].

2.5.2 Specific Gravity Testing
Specific gravity of concrete or what is commonly referred to as weight is the weight of the unit volume of concrete. Density is calculated by dividing the total concrete weight (Kg) by the absolute total volume (m$^3$). The theoretical unit of theoretical density is Kg/m$^3$. Concrete specific gravity must be fulfilled 2200 Kg/m$^3$ – 2500 Kg/m$^3$ according to the standard SNI 03-2834-2000 [3].

2.5.3 Compressive Strength Testing
This test is in accordance with SNI 03-1974-2011 and is carried out when the concrete reaches 14 days of age which is converted to 28 days of age. The concrete size used is cylindrical concrete which has a diameter of 15 cm and a height of 30 cm. The test is carried out by dividing the compressive load (N) obtained by the cross-sectional area of the test object (mm$^2$). The theoretical unit of compressive strength, namely N/mm$^2$ atau MPa [8].

3 Research Methodology

3.1 Material Testing
The characteristics of the fine and coarse aggregates are tested first. The results of the fine aggregate characteristics examination are as follows:

| Type          | Sand | - |
|---------------|------|---|
| Max size      | 4.75 mm | - |
| Modulus of fineness | 2.67 | SK SNI 1970-2008 |
| Bulk specific gravity | 2.5 | SK SNI 1970-2008 |
| Max absorption | 2.9 | - |
| Water dosage  | 2.86 | SNI 03-1971-2011 |
| Mud dosage    | 5.28 | SNI-1970-2008 |

The results of the examination of coarse aggregate characteristics are as follows:

| Type          | Stone | - |
|---------------|-------|---|
| Max size      | 19 mm | - |
| Modulus of fineness | 6.69 | ASTM C-33 |
| Bulk spesifik gravity | 2.51 | SNI 03-1968-2008 |
| Max absorsption | 2.2 | - |
| Abrasion      | 21.27 | SNI-2417-2008 |

3.2 Glass Powder Making
Glass powder produced from glass bottles from used goods collectors. Bottles are broken and mashed using a Los Angeles machine. The size of the glass powder granules used is through sieve no. 100 and held by sieve no. 200.

3.3 Parameters for Making Test Objects
1. Manufacture of cylindrical specimens with a diameter of 15 cm and a height of 30 cm.
2. Testing of compressive strength at the age of 14 days.
3. Compressive strength Plan 30 MPa age conversion of 14 days to 28 days.
4. variations of the glass powder mixture used as a cement substitute is 7 (0%, 5%, 10%, 15%,
20%, 25% and 30%) each variation using 4 samples.
5. Slump flow test of any concrete mix variations.
6. Compressive strength testing by using a press test machine (compression test machine).
7. Specific gravity testing by using digital scales.
8. Superplasticizer used by Console SS-74N with dosage 1%.

3.4 Composition of Concrete Mixture

| No. | Glass waste powder variations | GWP (kg) | Cement (kg) | Fine Agg (kg) | Coarse Agg (kg) | Water (L) | Superplasticizer (L) |
|-----|-------------------------------|---------|-------------|--------------|----------------|-----------|---------------------|
| 1   | Normal                        | 0       | 12.19       | 21.29        | 17.9          | 4.27      | 0.122               |
| 2   | 5%                            | 0.61    | 21.12       | 21.2         | 17.91         | 4.27      | 0.116               |
| 3   | 10%                           | 1.22    | 21.12       | 21.12        | 17.85         | 4.27      | 0.110               |
| 4   | 15%                           | 1.83    | 21.03       | 21.03        | 17.77         | 4.27      | 0.104               |
| 5   | 20%                           | 2.44    | 20.94       | 20.94        | 17.70         | 4.27      | 0.097               |
| 6   | 25%                           | 3.05    | 20.85       | 20.85        | 17.63         | 4.27      | 0.091               |
| 7   | 30%                           | 3.66    | 20.76       | 20.76        | 17.55         | 4.27      | 0.085               |
|     | Total                         | 12.81   | 147.19      | 147.19       | 124.32        | 29.89     | 0.785               |

3.5 Self Compacting Concrete Testing

3.5.1 Slump Flow Testing

Enough fresh concrete mixture is taken from the mixer and then put into the Abrams cone. The slump flow diameter must be between 500 mm and 850 mm according to the standard ACI (American Concrete Institute) No. 237R-07.

![Slump Flow Test tool](Figure 1. Slump Flow Test tool.)

3.5.2 Specific Gravity Testing

Specific gravity is calculated by dividing the total weight of concrete (Kg) by the total absolute volume (m³). The theoretical unit of theoretical density is Kg / m³. Concrete density must qualify 2200 Kg/m³ – 2500 Kg/m³ [3].

\[
BJ = \frac{\text{Weight}}{\text{Volume}}
\]

\[
BJ = \text{Specific Gravity (Kg/m³)}
\]

Weight (Kg)
Volume (m³)
3.5.3 Compressive Strength Testing
This test is in accordance with SNI 03-1974-2011 and is carried out when the concrete reaches 14 days of age which is converted to 28 days of age [8].

\[ f'c = \frac{P}{A} \times \text{Conversion Factor} \]

Explanation:
- \( f'c \) = Compressive strength (MPa)
- \( P \) = Compressive load (N)
- \( A \) = the cross-sectional area of the test object (mm²)

4 Result and Discussion

4.1 Result of Slump Flow Testing
Slump Flow Testing or it can be called Flowability when the fresh concrete has been completed by pouring the fresh concrete mixture into the Abrams cone without any compaction. In the Slump Flow test, the results can be seen from the maximum distribution achieved by each mixture. The Slump Flow test was carried out 3 times for each variation of the fresh concrete sample.

| Variation Glass Waste Powder (%) | Slump Flow (mm) |
|----------------------------------|-----------------|
| 0                                | 567             |
| 5                                | 570             |
| 10                               | 596             |
| 15                               | 603             |
| 20                               | 536             |
| 25                               | 493             |
| 30                               | 417             |

Figure 2. Slump flow chart
Based on the calculation table of the equation above, with variations of glass waste powder as a partial replacement for cement, 5%, 10%, 15%, and 20%, the flowability of fresh concrete has increased from control concrete and meets the requirements for fresh concrete according to the provisions. For the percentage of 25%, and 30% decreased flowability.

In the process of making and testing the test object, it can be seen that different physical and visual differences for each percentage of glass waste powder, physically the fineness of cement and glass waste powder are different. The increased flowability of fresh concrete due to the use of glass in the mortar is a chemical reaction that takes place between silica particles from glass grains and alkaline particles from cement grains in the pores of the mortar or often called the alkali-silica reaction (ASR) [9] so that cement and glass experience a reaction and reach an optimal point which causes the flowability of fresh concrete to increase. For the fineness of cement is finer than that of glass waste powder, this can be a cause of decreased flowability of fresh concrete due to the texture of the fineness of glass which is rougher than cement, because the increasing percentage of use of glass waste powder from mortar bonds or mixed bonds in the concrete mix decreases, glass, as a pozzolanic material where the glass content is a material containing silica or its alumina compounds, which do not have binding properties like cement. This is because the glass waste powder is pozzolanic or a pozzolanic material because it contains SiO2 which acts as a filler and binder in concrete which is able to fill or occupy cavities in concrete [11]. By decreasing the bonding in the concrete mixture it causes the fatigue level and the flowability of the concrete decreases. And in the process of making test objects using superplastilicer liquid which has properties as a water reducer or as a reduction in water use. Meanwhile, the nature of glass waste powder does not absorb water (zero water absorption) can fill the cavities in the concrete maximally so that the concrete is watertight [6]. Even though glass does not absorb water, water is still needed to coat the remaining glass powder so that the more the percentage of glass waste powder increases, the water used will also increase.

### 4.2 Result of Specific Gravity SCC

| Variation Glass Waste Powder (%) | Specific Gravity (kg/m³) |
|---------------------------------|-------------------------|
| 0                               | 2270.88                 |
| 5                               | 2293.51                 |
| 10                              | 2310.25                 |
| 15                              | 2376.01                 |
| 20                              | 2264.52                 |
| 25                              | 2260.51                 |
| 30                              | 2211.72                 |
Figure 3. Specific gravity chart

Based on the calculation table of the equation above, with a variety of glass waste powder as a partial replacement for cement, 5%, 10%, 15%, 20% and 25% of the specific gravity concrete has increased from control concrete. For a percentage of 30% decreased specific gravity. This is because the specific gravity of cement is greater than that of glass. The increasing percentage of variation of glass waste powder as a substitute for part of the cement as the test object, the specific gravity and weight of the concrete increased and decreased. The greater the percentage of use of the glass concrete waste powder, the greater the cavity in the concrete. This effect occurs because the glass waste powder has character zero water absorption can fill the cavities in the concrete maximally so that the concrete is watertight [6]. So that the concrete experiences hydration which causes air bubbles in the concrete mixture. This is because water is composed of Hydrogen and Oxygen. With the nature of glass that does not absorb water, the moisture content in fresh concrete increases and causes pores or cavities when the concrete dries.

4.3 Result of Compressive Strength
Testing of the compressive strength of concrete is carried out using a compression test machine. Tests are carried out when the concrete is 14 days old, then converted to 28 days based on the concrete conversion table (PB, 1989: 16). The average compressive strength of concrete can be seen in table 7 below:
Table 4.3. Results of Compressive Strength

| Variation Glass Waste Powder (%) | Compressive Strength of 14 days (MPa) | Compressive Strength of 28 days (MPa) |
|----------------------------------|---------------------------------------|---------------------------------------|
| 0                                | 29.190                                | 33.17                                 |
| 5                                | 33.650                                | 38.24                                 |
| 10                               | 35.310                                | 40.13                                 |
| 10.464                           | 35.322                                | 40.14                                 |
| 15                               | 34.170                                | 38.83                                 |
| 20                               | 30.230                                | 34.35                                 |
| 25                               | 23.490                                | 26.69                                 |
| 30                               | 13.950                                | 15.85                                 |

Based on the calculation table of the equation above, with variations of glass waste powder as a partial replacement for cement, 5%, 10%, 15%, and 20%, the compressive strength of concrete has increased from control concrete. For the percentage of 25%, and 30% decreased compressive strength. In the testing process, it can be seen physically and visually the test objects have different characteristics. The increase in the compressive strength of the glass powder waste concrete itself is due to the high silica content in the glass. Glass powder is expected to function as a substitute for cement because it has the potential as a pozzolanic material with a large amount of silica (SiO2), Na2O and CaO in the glass, which is more than 70% so that it produces strength that exceeds the plan and can reduce the cost of making concrete [10]. The decrease in the strength of concrete that occurs is due to the fact that glass has zero water absorption and the hardness of the glass makes concrete resistant to abrasion, which only a little natural aggregate can achieve. [6]. Glass has hard properties but cannot absorb water so that the increasing percentage of glass use decreases the strength of the concrete, on the other hand glass does not have properties that can bind like cement so that the adhesion in the concrete mixture decreases along with the increasing variety of glass waste powder as a partial substitute. cement. The more the percentage of the use of glass waste powder, the more brittle and lighter the concrete. This is directly proportional to the initial tests carried out, namely the flowability of fresh concrete and concrete density. Where the greater the flowability and density of the concrete, the greater the compressive strength to be achieved and the opposite.

\[ Y_c = -0.056X^2 + 1.172X + 29.190 \]
5 Conclusion

5.1 Slump Flow Concrete
The variation in the use of glass waste powder as a substitute for some cement has a significant effect of 85% on the flowability of fresh concrete. Variations in the use of glass waste powder as a partial substitute for cement with the percentage of 5%, 10%, 15%, and 20% reach the standard SCC flowability standard.

5.2 Specific Gravity Concrete
The variation of the use of kaa waste powder as a partial substitute for cement has a significant effect of 69.6% on the specific gravity of concrete. All specific gravity values in this study reach the normal concrete specific gravity standard, so it can be said that the concrete can be used for structural concrete work.

5.3 Compressive Strength Concrete
The variation of the use of glass waste powder as a substitute for some cement had a significant effect of 86.2% on the compressive strength of 14-day-old concrete. The variation of the use of glass waste powder as a substitute for part of cement against the compressive strength of 14 days obtained a maximum compressive strength of 35.322 MPa with the optimal percentage of using glass waste powder which is 10.464%.

References

[1] Okamura, H., and Ouzi, M., 2003. Self compacting concrete, Journal of advanced concrete technology Vol. 1 No. 1 April 2003, Japan Concrete Institute.

[2] American Concrete Institute (ACI) 237R (2007). Self-Consolidating Concrete. Most Recent Current. Publisher.

[3] Standar Nasional Indonesia. (2000). SNI 03-2834-2000. Specific Gravity Testing.

[4] Damtoft, J.S., Lukasik, J., Herfort, D., Sorrentino, D. and Gartner, E.M. 2008. Sustainable development and climate change initiatives, Cement and Concrete Research, 38(2), 115.

[5] Standar Nasional Indonesia. (2004). SNI 15-20-490-2004. Portland Cement.

[6] Syafi’urroziq, A., Purnomo, Y. C. S., & Krisnawati, L. D. (2018). Utilization of Glass Powder from Clear Glass Type with Thickness of 3-4 mm As Added Material in Brick Making. Journal of Technology Management and Civil Engineering, 1(1).

[7] European Federation of National Associations Representing for Concrete (EFNARC) “Specification and guidelines for self-compacting concrete”, Februari 2002.

[8] Standar Nasional Indonesia. (2011). 03-1974-2011. Compressive Strength Testing.

[9] Simanullang, R. (2017). Effect of Mixing Glass Powder As A Partial Substitute for Cement Against Strong Normal Concrete Press. (Doctoral dissertation, UNIMED)

[10] Ikhsan, M. N., Prayuda, H., & Saleh, F. (2017). Effect of Addition of Broken Glass As A Replacement Material for Fine Aggregate and Addition of Fiber Optics Against Strong Press Concrete Fiber. Teknika Universe, 19(2), 148-156

[11] Herbudiman, B., & Januar, C. (2011). The Benefits of Glass Powder as Powder in Self-Compacting Concrete. In The 1st Indonesian Structural Engineering and Materials Symposium (pp. 1-8).