



Effect of Various Curing on High Strength Concrete Using Slag Cement

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Abstract: A The current environmental problem is regarding to CO₂ gas emissions from cement production and the presence of hazardous material waste (B3) from steel production. One solution for that problem is by applying slag cement as a substitute for type I portland cement in concrete mix to create a high quality concrete that is environmentally friendly with a high durability and initial strength. This research aimed to compare a high quality concrete made from slag cement and a high quality concrete with conventional mixture. The slag cement used was obtained from PT. Indocement Indonesia. It is coupled with the use of Master Ease 3029 superplasticizer. The results showed that from the samples of concrete of 3, 7, 14, 28, 56 and 90 days of age, the maximum absorption value of normal concrete occurs at the age of 90 days with acid water curing of 1.57%. While the maximum absorption value of slag cement concrete occurs at the same age with acid water curing of 1.50%. The curing of normal concrete with water at 56 days of age has the largest compressive strength from all. It is also found that slag cement concrete has higher maximum compressive strength than that of normal concrete with acid water curing at 56 days of curing.

Keywords: High strength concrete, slag cement, superplasticizer

1. Introduction

Concrete technology continues to experience growth until now. Various types of concrete have now been developed according to their needs, one of which is high quality concrete. Based on the SNI 03-6468-2000, high quality concrete is a concrete that has characteristics as a very dense material unit with a compressive strength greater than 41.4 Mpa. It is widely believed that to produce a high quality concrete requires a lot of cement.

However, the use of cement in large quantities will increase the hydration heat. The high heat of hydration causes shrinkage and cracks at the beginning of concrete hardening process which can reduce the strength and durability of concrete. In addition, CO₂ gas emissions and the presence of waste products from cement production results in the environmental problem. Cement production produces CO₂ gas emissions around 7% of total CO₂ emissions. The source of CO₂ gas emissions in the cement production comes from 50-55% of limestone calcination (CaCO₃), 40-50% of fuel combustion and 0-10% of electricity.

Regarding the use of cement in concrete production, it might be difficult to replace it, but it can be minimized by using a supplementary cementitious materials, such as Granulated Blast Furnace Slag (GBFS) (ASTM C 642-97). In Indonesia, there are many industries engaged in steel smelting and refining, including PT Krakatau Steel in West Java which produces at least 150 tons of slag every day. Every ton of steel production produces 20 percent of slag waste. The slag side products produced from the steel smelting and refining company can be utilized as a more valuable material through waste co-processing. Besides, the use of slag also can reduce hazardous material waste (B3) (Departemen Pekerjaan Umum, 1990). In fact, in September 2017, two largest cement companies in Indonesia developed a technology and the use of industrial waste from other companies as raw materials to become products that have more value and provide efficiency benefits for the company. One of the company's industrial wastes that can be used as raw materials for making cement is slag (Effendi and Karolina, 2013) (Keputusan Menteri Negara Lingkungan Hidup Nomor 231 Tahun 2010).

Slag is a waste that is produced from the by-products of the smelting process of metal ores. The dominant chemical compositions in slag were iron oxide and silicate. The addition of GBFS, which has similar properties to slag, is expected to enhance the compressive strength. Also, slag cement is the main physical requirement for OPC cement based on SNI 15-2049-2004 (Hanif, 2012).

On a good fineness, slag cement shows the same or higher quality compared to portland cement (type I) and has "Low Heat Hydration" feature that is to produce low hydration heat and CO₂ emissions produced when its production is very low. Therefore, it can substitute the function of portland cement with a certain mass ratio. Various substitution levels started from 30% - 70% (Hunggurami, Elia, Sudiyo, Utomo, & Amy, Wadu, 2014). Besides, there are several advantages of using slag in concrete mix, namely, increasing the compressive strength of concrete due to the tendency of a slow increase in compressive strength; increasing the ratio between flexibility and compressive strength of concrete; reducing variations of concrete compressive strength; heightening sulfate resistance in sea water; reducing alkali-silica attacks; reducing heat hydration and to lower temperature; improving the final completion and to give a bright color to the concrete; heightening durability due to the influence of volume changes; reducing porosity and chloride attacks.

The use of slag cement in Indonesia has just begun by focusing on the construction of docks and dams. Through this research it is expected that the optimization of slag cement can be developed in the field of concrete construction, especially a high quality concrete that is environmentally friendly with high durability and initial concrete strength.

2. Materials and Method

2.1 Materials

Slag cement was obtained from PT. Indocement Indonesia, Fig.1 Showed the photograph of it and the composition is given in Table 1 with the physical characteristic of it given in Table 2.



Fig. 1 - Slag cement from PT. Indocement Indonesia

Table 1 - The content of chemical elements in steel slag obtained from PT Indocement Indonesia

Oxide	% of Weight
CaO	51.68
SiO ₂	29.59
Al ₂ O ₃	10.05
Fe ₂ O ₃	2.59
MgO	2.11
S ²⁻	0.22
Na ₂ O	0.44
SO ₃	2.31
LOI	0.21
IR	0.95
If Cao	0.18
Cr ⁶⁺	0.52

Table 2 - Physical characteristics of slag cement

Description	Test Results
Air content, %	5.4
Blaine, Fineness, m ² /kg	388
Residue 45 mm, %	5.9
Autoclave Expansion, %	0.00
Shrinkage, 28 days	0.08
Compressive Strength:	
3 Days, kg/cm ²	107
7 Days, kg/cm ²	161
28 Days, kg/cm ²	358
Normal Consistency, %	26.13
Time of Setting, Vicat Test:	
Initial Set, min	260
Final Set, min	238
False Set, %	87
Heat Hydration:	
7 Days, cal/g	50
28 Days, cal/g	57

Other compositions used were fine aggregates (sand) that has a 5 mm grain size and meets the specifications set by ASTM; coarse aggregates (gravels / splits) that has grain sizes between 5-40 mm; water that is needed in the making of concrete to trigger the chemical process of cement, wet the aggregate and provide ease in concrete work; and superplasticizer of Master Ease 3029 type. Master Ease is designed to provide a high rheological feature in fresh concrete so as to increase the ease of placement and completion of concrete, as well as concrete pumping for all construction activities.

The aggregates used was examined first before employed to the production method, Table 3 gives the examination results.

Table 3 - Examination results of aggregates

Type of Analysis	Results	
	Sand	Gravel
Sieve Analysis (FM)	2.77	5.88
Mud Content, %	0.3	0.3
Organic Content	Yellow	(Color No.2)
Clay Lump, %	0.2	-
Weight of Content		
Mashed, kg/m ³	1570.72	1524.51
Loose, kg/m ³	1343.87	1407.95
Weariness, %	-	16.30
Specific Gravity		
SSD, kg/m ³	2500	2680
Dry, kg/m ³	2420	2650
Apparent, kg/m ³	2640	2730
Absorption, %	3.52	1,05

2.2 Mix design

There are two different concrete made, the composition of which are given in Table 4 dan Table 5.

Table 4 - Normal concrete compositions

Portland Cement	Split	Sand	Water	HRWR
12.515 kg	20.351 kg	18.278 kg	3504 ml	150.182 ml

Table 5 - Slag cement concrete compositions

Slag Cement	Split	Sand	Water	HRWR
12.515 kg	20.351 kg	18.278 kg	3504 ml	150.182 ml

2.3 Curing of concrete

After experiencing the mixing process, the curing process was then applied. Curing is carried out for 7 days minimum and high initial strength concrete for 3 days minimum and must be maintained in humid conditions, unless it is done with an accelerated curing (Labib, Naufal Makarim. dkk, 2016). Concrete that were treated for 7 days is 50% stronger than the concrete that is not treated (Li, Zongjin, Dr., 2011).

In the curing of concrete, the methods and materials and tools used will determine the feature of the hard concrete made, especially in terms of strength. In this test, two different treatment methods were used: soaked (drink water, sea water, acid water) and compound curing. The curing time was varied, namely, 3, 7, 14, 28, 56 and 90 days (3 samples for each). The samples grouping was given in Table 6.

Table 6 - Samples grouping

Age and Variation		Type of Curing			
		PDAM Water	Sea Water	Acid Water	Compound
3 Days	BN	3	3	3	3
	BS	3	3	3	3
7 Days	BN	3	3	3	3
	BS	3	3	3	3
14 Days	BN	3	3	3	3
	BS	3	3	3	3
28 Days	BN	3	3	3	3
	BS	3	3	3	3
56 Days	BN	3	3	3	3
	BS	3	3	3	3
90 Days	BN	3	3	3	3
	BS	3	3	3	3
Total					144

2.4 Concrete absorption test

Concrete absorption test was conducted according to ASTM C-642. The absorption of concrete water is calculated as follows in equation (1)

$$w\% = \frac{A - B}{B} \times 100\% \tag{1}$$

where :

A = weight of wet concrete

B = weight of dry concrete

2.5 Concrete compressive strength test

Concrete compressive strength test was conducted according to SNI- 1974-2011 (ASTM C 39-99). The compressive strength of concrete is the most important feature in hard concrete, and is generally considered in the planning of concrete mixture. The compressive strength of concrete is calculated by the formula:

$$f'c = \frac{P}{A} \times \text{correction factor of cylinder dimension} \tag{2}$$

where :

- $f'c$: compressive strength (kg/cm²)
- P : compressive load (kg)
- A : surface area of the sample (cm²)
- Correction factor : 1.04 (cylindrical shape of 100 x 200 mm)

3. Results and Discussion

3.1 Slump flow test results

The test results of slump value for concrete with slag cement and normal concrete can be seen in Fig.2.

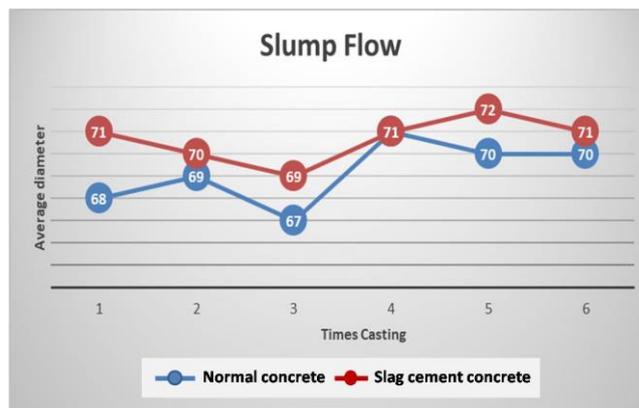


Fig. 2 - Graph of slump flow test results

From Fig.1, it can be seen that the slump value of both concrete is within the normal limits of the diameter size of the slump flow test. Slump flow test between normal concrete and slag cement concrete does not show a significant effect difference on workability. Slump flow value of slag cement concrete has a larger diameter than the normal slump flow value. High slump flow value is caused by the use of superplasticizer which serves to improve the workability of fresh concrete.

3.2 Concrete absorption test results

The test results of absorption test for concrete with slag cement and normal concrete can be seen in Fig.3.

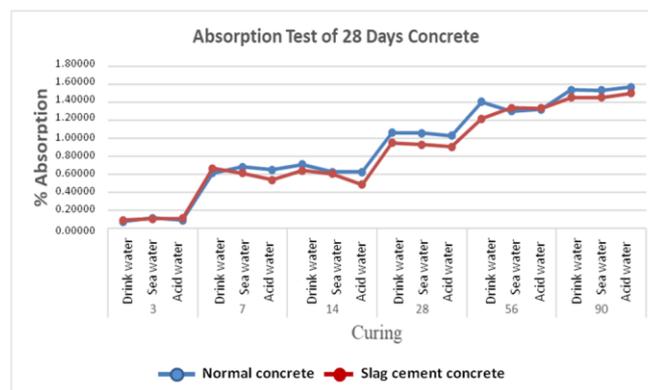


Fig. 3- Graph of concrete absorption test results

The maximum absorption value of normal concrete occurs at 90 days of age with 1.57% of acid water curing. While the maximum absorption value of slag cement concrete occurs at 90 days of age with 1.50% of acid water curing.

3.3 Concrete compressive strength test

The test results of compressive strength test for concrete with slag cement and normal concrete can be seen in Fig.4.

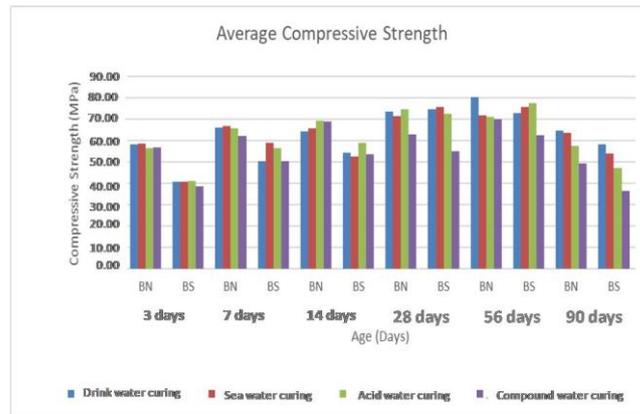


Fig. 4 - Graph of concrete compressive strength test results

From the compressive strength test results in Figure 3, it is obtained that the highest value of compressive strength of normal concrete is at 56 days of age with PDAM water curing of 80.38 MPa. The highest value of compressive strength of slag cement concrete is at 56 days of age with acid water curing of 77.72 MPa.

4. Conclusions

Based on the research that has been done, it can be concluded that the slump flow test between normal concrete and slag cement concrete does not show a significant effect difference on workability. Based on the absorption test results with different water curing, it is shown that the higher the pH of the water used in the curing of concrete, the higher the absorption value is. The curing of normal concrete with drink water at 56 days of age has a maximum compressive strength that is greater than other concrete curing for normal concrete. In addition, the maximum compressive strength of a high quality concrete with slag cement concrete is higher compared to a high quality concrete with normal concrete with acid water curing at 56 days of age.

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