Compressive Strength of Concrete Containing Recycled Glass Powder

Bimantara Putra Nugraha, Eddy Triyanto Sudjatmiko[1], Ika Bali

Department of Civil Engineering, President University, Cikarang, Indonesia

Received 15 February 20xx; received in revised form 04 March 20xx; accepted 11 March 20xx

Abstract

Glass bottle waste takes a million years to decompose. Recycling is the best option to solve this problem. One alternative is to use recycled glass in the form of powder as a material for making concrete. This study proposes the use of recycled glass powder as a concrete material to partially substitute fine aggregate. This study aims to determine the effect of glass powder as a partial substitute for fine aggregate on the compressive strength of concrete. Partial substitution of fine aggregate was selected with a percentage of 5%, 10%, and 15%. Standard cylindrical specimens aged 28 days used in compressive strength testing in this study. Then, the test results of concrete containing recycled glass powder compared to ordinary concrete. The test results show that the compressive strength of concrete containing 15% recycled glass powder gives an average compressive strength of 35.57 MPa which is slightly higher than the compressive strength of normal concrete of 35.10 MPa. This study found that the use of glass powder as a substitute for fine aggregate can be used as a substitute for normal concrete in terms of compressive strength and reduce glass waste.

Keywords: concrete, recycled glass powder, compressive strength, glass bottle

1. Introduction

There is a lot of glass in various forms such as glass bottles, glass jars, and mirrors that become waste that is simply thrown away without further use. Based on the National Waste Management Information System of Indonesia Ministry of Environment, the amount of glass waste in 2021 was 71 million tons or 2.34% of total amount of waste [1]. This is a sizeable amount and is a particular concern for sustainable management of glass waste.

Glass is also a combination of various inorganic oxides that cannot be decomposed, resulting from the composition, and smelting of alkaline and alkaline earth compounds. Glass powder has chemical compounds such as SiO_2, Al_2O_3, Fe_2O_3 and CaO which have the potential to be used as a partly substitute for cement and are expected to increase to the compressive strength of concrete because the grains are small and can fill the pores in the concrete where SiO_2 is a binder and CaO is a reinforcement that can strengthen the concrete mixture.

As a partially substitute for cement, several studies have reported the use of glass powder as a partial substitute for cement in reactive powder concrete to obtain high-strength concrete mechanical properties such as compressive strength and split tensile strength [2], [3], [4]. The studies show the use of glass powder to smaller than 0.15 mm size with the content as much as 20% of cement mass produces a compressive strength of 102~180 MPa. In several other studies, the use of glass powder as a partial replacement of cement was carried out on normal concrete [5], [6], [7].

In this study, glass powder of recycled glass bottles was used as a filler for pores in the normal concrete [8], [9]. For this purpose, glass powder is used as a partial substitute for fine aggregate with a percentage of 5%, 10%, and 15%. As a

1 Corresponding author. E-mail address: eddy.triyanto@president.ac.id
Tel.: +62(0)21 89109763

substitute for fine aggregate, the glass powder used passed the No. 30 sieve with a grain size smaller than 0.600 mm opening size. The objective of this study is to investigate the effect of recycled glass powder as partly substitute of fine aggregate on the compressive strength of normal concrete. In addition, this study is motivated by the environment concern of using local waste in the form of glass powder of recycled glass bottle as a substitute for fine aggregates material in normal concrete.

2. Material and Method

This study aims to determine the effect of glass powder as a partial substitute for fine aggregate on the compressive strength of concrete. Partial substitution of fine aggregate was selected with a percentage of 5%, 10%, and 15%. Standard cylindrical specimens aged 28 days used in compressive strength testing in this study [10]. Then, the test results of concrete containing recycled glass powder compared to ordinary concrete. The study methodology is shown in Fig. 1.

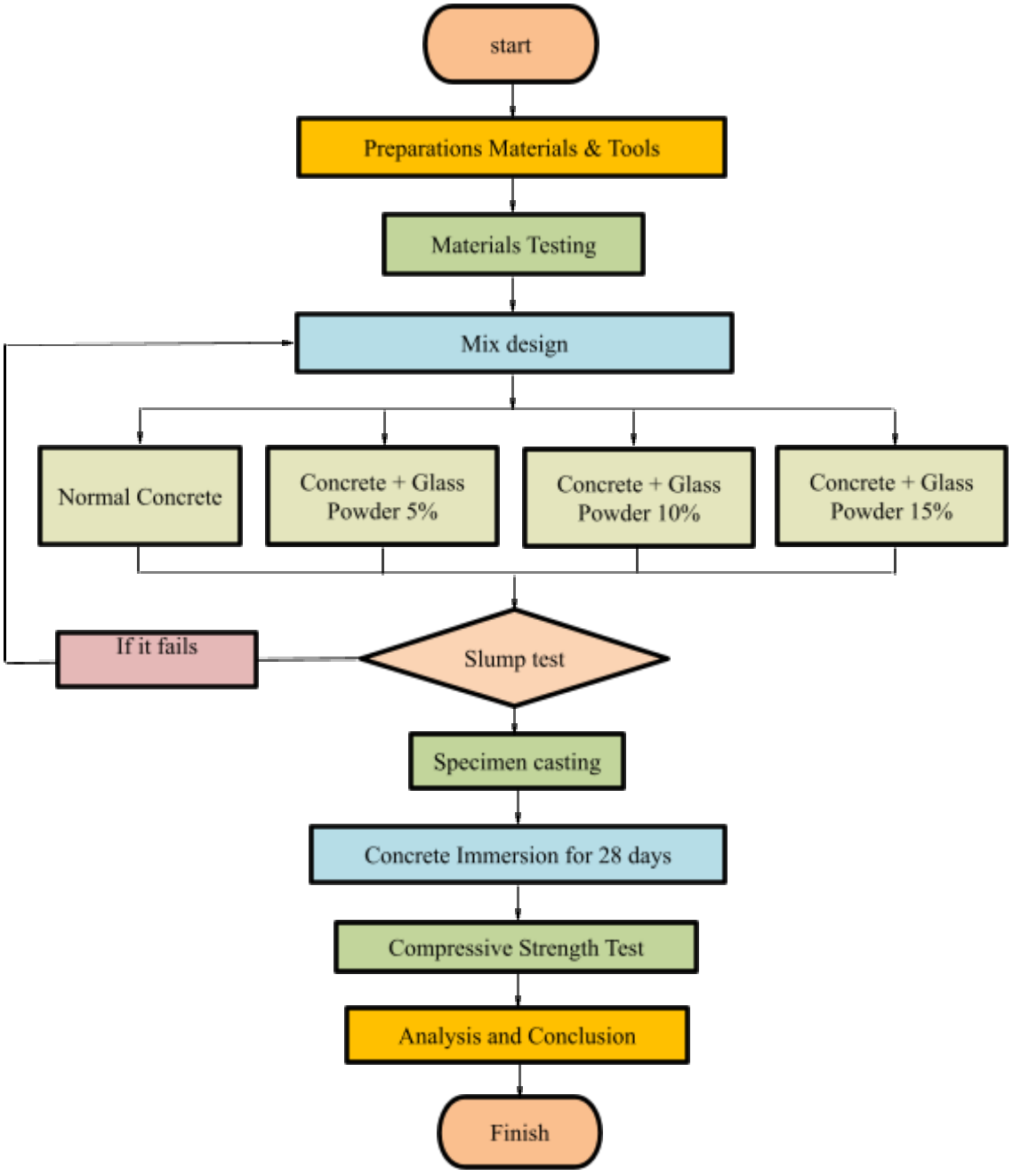

Fig. 1 Study methodology

The main study materials for concrete glass powder formation are cement, water, coarse aggregates, fine aggregates, and glass powder which are described in this section. A brief description of the materials used is as follows [11], [12], cement uses Portland Pozzolan Cement type I (PPC) as a binder of the concrete mixture, the coarse aggregate is crushed stone with a maximum diameter of 40 mm (Fig. 2), the fine aggregate used is aggregate with Fineness FM modulus = 2.95% (Fig. 3). Before use, fine aggregate will be tested in the form of inspection of specific gravity and absorption, mud levels, aggregate gradation, and aggregate moisture. The glass powder used is from waste glass bottles which are grinding until the particle size passes the No. 30 sieve with an opening of 0.600 mm (Fig. 4).

Concrete with a percentage of glass powder 5% (GPC 5%), 10% (GPC 10%), and 15% (GPC 15%) as a substitute for fine aggregate will be compared with normal concrete (NC) in terms of compressive strength. The number of concrete samples is 12 samples in 28 days of age (each variation of concrete has 3 samples). The mix design of the glass powder concrete and normal concrete can be seen in Table 1. The concrete specimens used in this study are cylinders with a diameter Ø = 150 mm and height h = 300 mm (Fig. 5), for determining the compressive strength [10]. For the curing of the specimens, the water curing method is used by immersing it in water (Fig. 6). Then, the compressive strength test setup is showed in Fig. 7.

Table 1 Mix design of the glass powder concrete and normal concrete

Concrete types	Volume (m^3)	Composition Materials				
		Cement (kg)	Fine Aggregate		Coarse Aggregate (kg)	Water (kg)
			Sand (kg)	Glass Powder (kg)		
NC	0.0175	7.019	100%	-	17.313	2.942
			9.317			
GPC 5%	0.0175	7.019	95%	5%	17.313	2.942
			8.851	0.466		
GPC 10%	0.0175	7.019	90%	10%	17.313	2.942
			8.385	0.932		
GPC 15%	0.0175	7.019	85%	15%	17.313	2.942
			7.919	1.398		
Total		28.076	34.47	2.80	69.25	11.77

PRESUNIVE Civil Engineering Journal, vol. x, no. x, April 20xx, pp. xx-xx

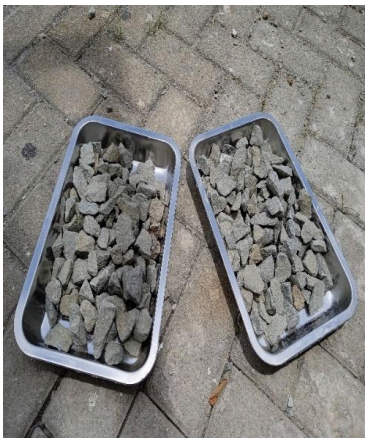

Fig. 2 Coarse aggregate

Fig. 3 Fine aggregate

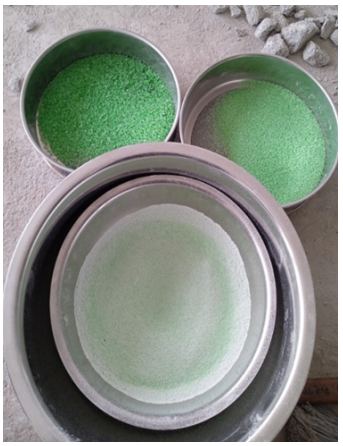

Fig. 4 Glass powder

Fig. 5 Cylindrical mould, size of 150 mm × 300 mm

Fig. 6 Water curing

Fig. 7 Compressive strength test

3. Results and Discussion

All slump heights in normal concrete mix and glass powder concrete in this study have an average value of 7~8.5 cm and this is in accordance with the design target of 6~18 cm (Fig. 8). The test results of compressive strength (f'_c) on the glass powder concrete and normal concrete specimens are shown in Table 2. From the data in Table 2, the compressive strength (f'_c) of these two types of concrete specimens is almost the same. The average compressive strength of glass powder concrete reaches the highest value of 35.57 MPa for the concrete with glass powder of 15% (GPC 15%), which is 1.34% higher than normal concrete. This value indicates that it can be rationally accepted as an alternative material to normal concrete.

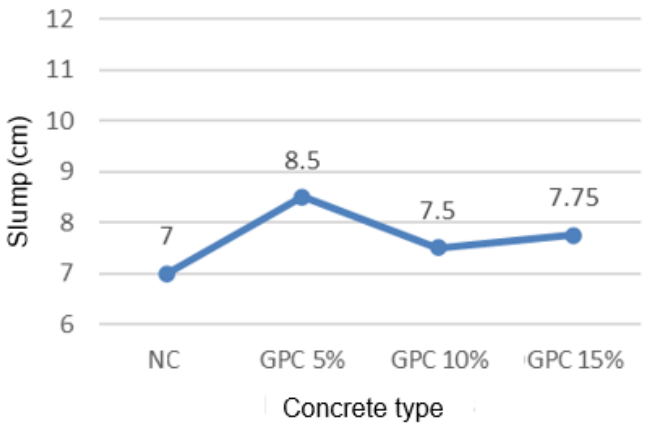

Fig. 8 Slump height of the glass powder concrete and normal concrete

Table 2 Testing results of the compressive test

Concrete type	Cylinder specimen Ø × *h* (mm)	$f_c^{'}$ average (MPa)
NC	150 × 300	35.10
GPC 5%	150 × 300	35.01
GPC 10%	150 × 300	35.10
GPC 15%	150 × 300	35.57

Partial substitution of fine aggregate in the percentage of 15% with glass powder with the slightly higher of compressive strength than normal concrete indicated that the use of glass powder as a substitute for fine aggregate can be used as a substitute for normal concrete in terms of compressive strength.

4. Conclusions

This study has presented the compressive strength testing of the glass powder concrete with partial substitution of fine aggregate of 5%, 10%, and 15%, compared to normal concrete. According to the results, the following conclusions can be obtained. The average compressive strength of glass powder concrete with glass powder of 15% (GPC 15%) indicates the highest compressive strength of 35.57 MPa. It is 1.34% higher compared to normal concrete (NC). This compressive strength value indicates that the glass powder concrete with glass powder content of 15% can be rationally accepted as an alternative material to normal concrete and is environmentally friendly to reduce glass bottle waste.

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