MATEC Web of Conferences **27**, 02005 (2015)
DOI: 10.1051/matecconf/20152702005

Investigation on Compressive Strength of Special Concrete made with Crushed Waste Glass

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Abstract. Special concrete is the type of concrete that produced by using waste material or using unusual techniques/method of preparation. Special concrete made with waste material is becoming popular in a construction site. This is because the special concrete is selected due to quality, integrity, economic factor and environmental factor. The waste glass is selected as an additional material to provide a good in compressive strength value. The compressive strength is the importance of mechanical properties of concrete and typically the concrete is sustained and stiffed in compression load. The significant issue to utilize the waste glass from the automotive windscreen is to improve the strength of concrete. The waste glass is crushed to become 5 mm size and recognised as crushed waste glass that be used in concrete as additional material. The main objective of the study is to determine the appropriate percentage of crushed waste glass in concrete grade, 30 in order to enhance the compressive strength. There are four mixes of concrete that contained of crushed waste glass with percentage of 2 %, 4 %, 6 % and 8 % and one control mix with 0 % of crushed waste glass. As the result, crushed waste glass with an additional 4 % in concrete is reported having a higher value of compressive strength in early and mature stage. In addition, if the percentage of crushed glass wastes in concrete increases and it leads to a reduction in the workability of concrete.

1 Introduction

In general, the world population is created and produced a lot of solid waste over 15,000 tons per day. Most of the solid wastes such as paper, steel, plastic and glass are disposed at the dumpsites or landfill. Normally, the dumpsites produce a lot of environmental problems, for example landslide, air pollution and water pollution. This problem can be settled by using the 3R principle is Reduce, Reuse and Recycle. But, the problem of the dumpsites is solved for only reuse and recycles method. Method of reduction can't be utilized due to the increase in world population and germination of developed countries. With the attraction of economical and environmental factor, the special concrete made with waste material especially waste glass is established.

Glass is produced in many forms such as container glass (bottle and jars), flat glass (windows and windscreens), cathode ray tube glass (TV screen and monitors) and bulb glass [1]. Reference [1] have reported all the glass in various forms has a limited life and it should be reused or recycle at the end of their life to prevent environmental problems. Reference [2] has estimated at 3 million tons of glass mainly used in the construction and automotive industries were produced.

Many researchers are studied the waste glass as cement replacement [2, 3, 4], fine aggregate [3], coarse aggregate, additives and fibre reinforcement in concrete. Reference [5] has investigated the performance of concrete that used waste glass powder as cement replacement and showed the ability to increase workability and compressive strength. Concrete with waste glass powder become lighter when compared with normal concrete [5].

Most of the waste glass especially windscreen glass is disposed daily worldwide at the dumpsites or landfill [2]. Besides, waste glass as residue is sent to dumpsites when the glass colours get mixed and can't be reused again because the high cost of cleaning and colour sorting [6]. The high number of vehicles in Malaysia has generated a lot of waste glass from windscreen or windshield. The waste glass is not biodegradable material in order that dumpsites are not the best way to dispose. In this study, the need for the use of waste glass from a mirror as additives in concrete is very high to achieve advantages in concrete properties, especially compressive strength.

The main objective of the study is to determine the appropriate percentage of waste glass after being crushed in order to enhance the fresh and hardened concrete properties particularly workability and compressive strength. In addition, the study is to avoid the environmental problem that produced from the dumpsites.

2 Material and method

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2.1 Sample preparation and test methods

As a normal concrete, the materials that used is basically being fine aggregates, coarse aggregates, cement and water and classified as special concrete when combined with the other unordinary material. Cement that used in the study is Portland cement. The coarse aggregate size is between 5 mm to 20 mm and fine aggregate with size below 5 mm was sieved and prepared. Waste glass from windscreen that obtained from the car mudguard workshop was sorted and selected as shown in Fig. 1. Waste glass was clean and clear from any substances that can affect the strength of concrete such as glue and plastic tinted. Waste glass was crushed by using grinder machine. Then the crushed waste glass was sieved to pass sieve size of 6 mm and retained sieve size of 5 mm. The crushed waste glass must be sieved to obtain only 5 mm size as additional material. From observation crushed waste glass was became angular, elongated, sharp and flat surface that suitable in enhancing the compressive strength.

Figure 1. Crushed waste glass that used as an additional material in concrete

2.2 Design mix

In the study, the concrete mix design was proposed by using density that converted from density to mass. The proportion of sand and gravel was maintained for every design mix. The water cement ratio, 0.5 and concrete grade, 30 was selected. Then, the concrete mix was placed the crushed waste glass as additional material. The design of concrete mix was stated as 403.85 kg/m^3 of cement, 686.34 kg/m^3 of sand, 1119.81 kg/m^3 of gravel and 210 kg/m^3 of water. The amount of an additional material of crushed waste glass in the mix is around 2 % - 8 % of the total mass concrete mix.

2.3 Testing

Five concrete mixes have been produced and each mix consisted of six cubes in order to obtain the average compressive strength at an early age (7 days) and mature age (28 days). One normal concrete mix without any crushed waste glass was arranged as a control parameter of compressive strength. Another four concrete mixes with crushed waste glass as additional material in percentage 2 %, 4 %, 6 % and 8 % was prepared as shown in Table 1. The special concrete was tested to check their fresh and hardened concrete properties. The workability test (slump test) was organized for fresh concrete properties and compressive strength test for hardened concrete properties. The compressive strength test was conducted by using 3000 kN Concrete Strength Testing Machine.

Table 1. Concrete mix label without and with additional material

No.	Sample labels	Percentage of crushed waste glass (%)
1	M1 (Control Mix)	0
2	M2	2
3	M3	4
4	M4	6
5	M5	8

3 Results and discussion

3.1 Slump test

Table 2 is represented the height of slump for every concrete mix. The height of the slump is decreased when the percentage of crushed glass waste usage increased. Therefore, the workability of the concrete mix was reduced with increasing of crushed waste glass. Normally, utilization of waste material in concrete was affected the workability of the mix because the higher water absorption of the material. Since the quantity of crushed waste glass was produced higher, it was increased the aggregate/cement ratio and changed the fluidity of the concrete mix that finally disturbing the workability of concrete.

Table 2. The slump test result of fresh concrete containing different percentages of crushed waste glass.

Concrete Mix	Height of slump (mm)
M1	80.30
M2	72.50
M3	69.40
M4	49.20
M5	20.00

3.2 Compressive strength test

Table 3 and Fig. 2 show the result of compressive strength of concrete without and with crushed waste glass. From the analysis of the results, it was found that the compressive strength of concrete for all mix with additional crushed waste glass has been increased in early and mature age. The compressive strength of concrete with a percentage of crushed waste glass in the range 2 - 6 % was dramatically increased. However, the concrete mix with more than 6 % of crushed waste glass was decreased in their compressive strength but still higher than the control mix. M3 was illustrated the highest value of compressive strength at 7 and 28 days when compared with other concrete mix. M2 concrete mix showed the

highest percentage difference between early and mature age, 23.93 %. M2 and M3 was represented a higher value, but M4 and M5 were shown less percentage different when compared with control mix.

In the early stage of compressive strength, concrete mix M2, M3, M4 and M5 was noted about 8.30 %, 15.11 %, 14.39 % and 9.80 %, respectively when compared with control mix. All concrete mix was achieved 75 % of design strength for early compressive strength that noted approximate, 22.5 MPa. Whilst, percentage difference in 28 days between M2, M3, M4 and M5 with control mix is 18.28 %, 19.13 %, 5.68 % and 2.05 %, respectively. The smaller sizes of ground glass lead to a higher compressive strength in concrete, especially in a late age [7]. Fig. 3 is shown the relationship of compressive strength of concrete with the percentage of crushed waste glass. The relationship compressive strength can be determined using Eq. 1 for early age. This equation is established for design mix guide for early stage until maximum added in concrete.

$0 \leq p \leq 4$

$$CS = 2.32\ p + 23.753 \quad (1)$$

Where, CS is the compressive strength of concrete

p is the percentage of crushed waste glass.

Evidently, the concrete mix with 4 % crushed waste glass was given a high compressive strength in early and mature age. More than 4 % crushed waste glass added in concrete were affected the compressive strength due to alkali silica reaction and also some deleterious chemical effect. It can be concluded that a high percentage of use of crushed waste glass in the concrete will produce the high alkali silica reaction. These are serious issues concerning the use of coarse waste glass in concrete will cause a chemical reaction that takes place between the silica-rich glass particles and the alkali in the pore solution of concrete. So that, concrete with more than 4 % crushed waste glass is still can be used with reasonable compressive strength, but the waste glass must be crushed or ground until achieving suitable size. Reference [2] has reported chemical composition of waste glass and cement could be beginning the formation of the delayed ettringite due to expansive component.

Table 3. The compressive strength of special concrete

Concrete mix	Average Compressive strength (MPa)		Percentage difference between 7 and 28 days (%)
	7 days	28 days	
M1	26.06	30.53	14.64
M2	28.42	37.36	23.93
M3	30.70	37.75	18.68
M4	30.44	32.37	5.96
M5	28.89	31.17	7.31

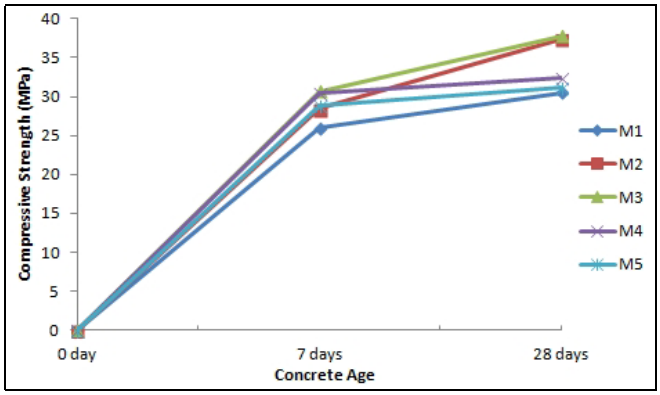

Figure 2. The compressive strength of special concrete

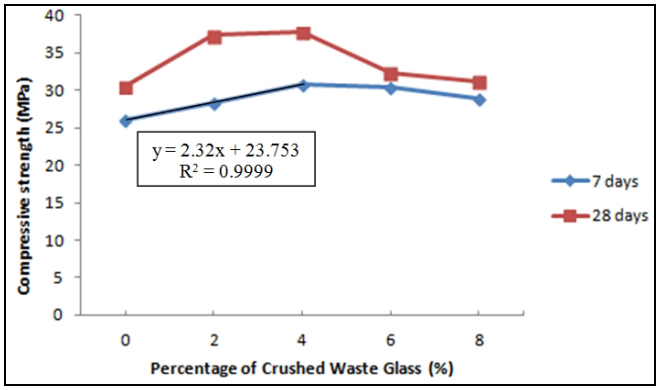

Figure 3. The relationship between the compressive strength with percentage of crushed waste glass.

4 Conclusion and recommendation

The workability test of the concrete mixes is reported the height of slump decreased with increasing of the percentage of crushed waste glass. Through this study, a special concrete with a percentage 2 % and 4 % of crushed waste glass as an additional material has caused a great increment in the compressive strength of concrete. Crushed waste glass could be used with more than 4 % in concrete mix, but the waste glass must be crushed and ground until it becomes finer.

As a suggestion for the further study, some issues must be taken:

1. Determine the other percentage and size of crushed waste glass that can improve in workability and strength of concrete.
2. Determine the mechanical properties by using crushed waste glass as a partial or fully replacement of cement, fine aggregate or coarse aggregate.
3. Study on the effect of alkali silica reaction and also the chemical composition of crushed waste glass in the concrete.

Acknowledgements

The authors gratefully acknowledge the financial support from the Universiti Teknologi Mara (UiTM) Pahang and Universiti Teknologi Malaysia (UTM) Johor. Thanks also extend to Faculty of Civil Engineering of UiTM for providing machinery and equipment. Special thanks are extended to the lecturer and technician of UiTM Pahang and UTM Johor Bharu for their help during the experimental program.

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