Effect of partial replacement of cement by waste glass powder on the properties of self-compacting concrete

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Abstract

The need to find new sources of building materials led to examine the using of waste materials resulted from the production plants. This paper investigates using of waste crushed glass as part of cement at 5, 15 and 25% of cement weight. Well graded sand from Zliten quarry was used in the production of concrete. Concrete mixes were produced using w/c ratios 0.4, 0.425 and 0.45. Workability of fresh self-compacting concrete (SCC) and compressive strength at 28 days were tested. Test results showed that fresh concrete was within the range of self-compaction needs, and concrete strength was also satisfied at 28 days. From analysis of test results, it was obviously noticed that replacing part of cement by powder of crushed glass gave good self-compacting concrete at percentages as large as 25% with enough workability and good strength. And this proves that waste glass from plants can be used in the production of self-compacting concrete. As a result this will protect the environment from gas emission from cement plants and provides a new sources building material.

Keywords: waste glass, self-compacting concrete, workability, compressive strength.

1 Introduction

In recent years, environment pollution has become an important issue because of the large quantities of waste materials produced from the manufacture, house waste from food also added waste materials to the environment, these materials like glass, plastic, paper, building materials, car tyres, etc. On the other hand, recycling these wastes has also become a new trend to make an advantage in both minimizing the effect of pollution on the environment, and saves the depletion of raw materials needed for the development. Structural engineers have been engaged in protecting the environment by employing some of these waste materials partially in concrete production. And that is another advantage to the environment in which, some cement in concrete has been replaced partially by waste materials like, marble powder, clay brick powder, glass powder, slag powder, etc. To clarify the problem, in Libya, the design production capacity of Libyan cement factories was 7.5 million tons annually according to Alborg cement factory in 2005 [1], and to produce this quantity a large volume of emission gases will be produced and can effect adversely on the environment and needs a high quantity of heat for the production. Recently, self-compacting concrete (SCC) has become an important material because of its high workability which allows it to penetrate the structural element under its own weight even those elements with high reinforcement. SCC is produced by employment super plasticizers in concrete, where sometimes called flowing concrete [2]. The wide use of SCC in construction leading to produce high quantity of cement which effects on the environment. A replacement part of cement by other materials is beneficial, as it helps in reducing the hazard waste material and reducing gas emission from cement production as reported by Du H. and Tan K [3]. Ganaw and Salama were employed waste glass in concrete as sand and powder, partially alternative to sand and powder as a filler respectively, they reported that both cases of replacement were resulted in good concrete mechanical properties [4].

Fareed was swapped parts of cement up to 15 % by fine material from waste powder of crushed aggregate and reported that good setting times were obtained and required concrete strength was achieved [5]. Khatib and others were replaced some of cement by glass powder and described that concrete slump increases by glass powder increase with high strength at 10% replacement [6]. Waste glass was also employed as fine aggregate in mortar production and resulted in worthy concrete strength with percentage up to 30% of fine aggregate [7]. Karim and Salama replaced cement by micro glass powder up to 20%, and concluded that mortar workability increased with slight decrease in strength. Although, their research was on mortar they suggested that their achievement on mortar can be applied to produce self-compacting concrete [8]. Mssoed and Ganaw were used glass powder of waste glass collected from local workshops, replaced some of cement by this powder up to 15 % and produced self-compacting concrete, the result was beneficial in both fresh and hardened at 28 days [9]. Bouty and Homsi were tested fresh and hard SCC at 28 days, in their mixes they replaced cement with glass powder at 10,15, 20 and 25% and measured concrete strength at 28 days. The design mixes were 25 MPa and 32MPa, they concluded that, the 10% replacement mix was higher strength for the 25MPa than others and the 15% replacement mix was the best one for the 32MPa mixes [10].

Consequently, from the presented work done it is obviously that the use of waste glass can be added to concrete to improve its properties and minimizing the quantities of waste materials on the environment. The aim and objective of this paper was to study the effect of glass powder on the properties of self-compacting concrete. In terms of collecting waste glass and grinding it to the micro scale, after that producing concrete of different mixes with variable cement replacement percentages, and testing the possibility to get concrete with self-compaction and satisfied fresh and hardened properties. The target result of this work will help to protect the environment from gas emission, find new source of building materials and protect our land from increasing of harmful waste landfill.

2 Materials

Ordinary Portland cement from Elmergib factory- Alkhums was used in concrete production with Blain fineness of 2977 cm2/gm. and its initial and final setting times are satisfying to BS EN 196 – 3: 1995 [11]. Used water in the mix was taken from Alkhums school of engineering network. It is suitable for the production of concrete. Fine aggregate used was imported from Zliten quarries. It is clean with satisfied gradation to the requirements of British standard BS 812:1992 [12]. All used glass in the research was collected from local glass windows workshop. Waste glass was collected and crushed by los angles drum machine, then sieved to pass 75 micron. After that all sample were collected and mixed again with the mixer until became consistent. The material then reserved sealed in a dry container until the time of mixing. Coarse aggregate was imported from a quarry in Alkhums area with max aggregate size of 14 mm, this size is suitable for SCC production. Specific gravity and absorption of aggregates were 2.65 and 0.019 respectively. Superplastisize (EG-3500) manufactured by SIKA especially for SCC was used at 1.5% for all mixes.

3 Methodology

Concrete mix was first produced at w/c ratios of 0.40, 0.425 and 0.45 without any addition of cement replacement by glass powder, then cement was replaced by glass powder of 5%, 15% and 25% by weight at the same w/c ratios and constant quantity of sand and coarse aggregate and 2% superplasticizer (SP) . Fresh concrete was mixed by the mixer and its workability was measured by the slump flow test and J-ring test according to the EFNARC 2002 [13]. Fresh concrete then casted in cubic moulds of 15mm. Therefore, after 24 hours concrete samples then removed from their forms and put in water for 28 days for compressive strength measurement.

4. Results and discussion

4.1 SCC workability

4.1.1 Flow test results

Figure 1 shows the relation between fresh SCC seepage and w/c ratio at different glass powder contents. It is clear that concrete seepage decreases with the decrease of powder content for the same water content. Mixes without glass powder and w/c ratio of 0.40 resulted in the lowest value of diameter of 660 mm and this satisfies the requirements of self-compacting concrete limits of EFNARC 2002 with (650 mm to 800mm) diameter.

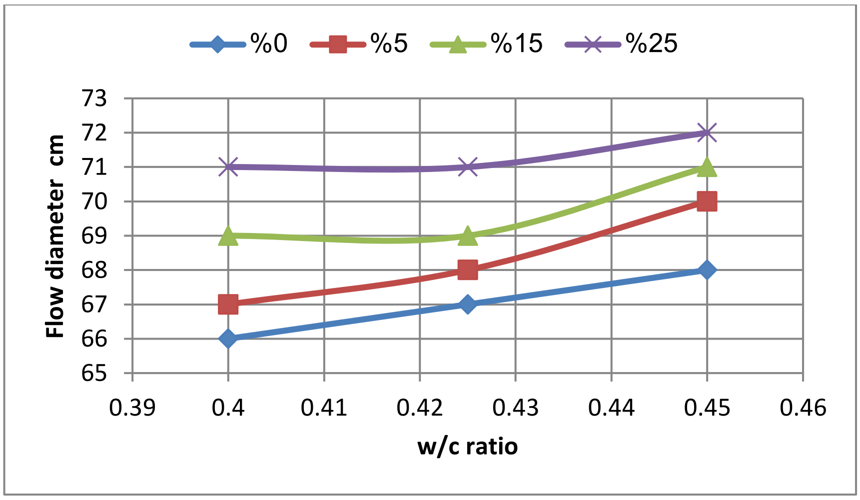

Figure 1 *Concrete flow at different w/c ratios*

4.1.2 J-ring test results

Figure 2 shows the relation between fresh J-ring readings and w/c ratio at different glass powder contents. It is clear that J- ring reading decreases with the increase of w/c ratio. The highest one was resulted in the mixes of no glass replacement where mixes of 5% percentage gave the lowest measurements at all w/c ratios in the mix. From the workability tests, it is clear that glass powder replacement helps in improvement of concrete flow and this gives an advantage to the self-compacting concrete.

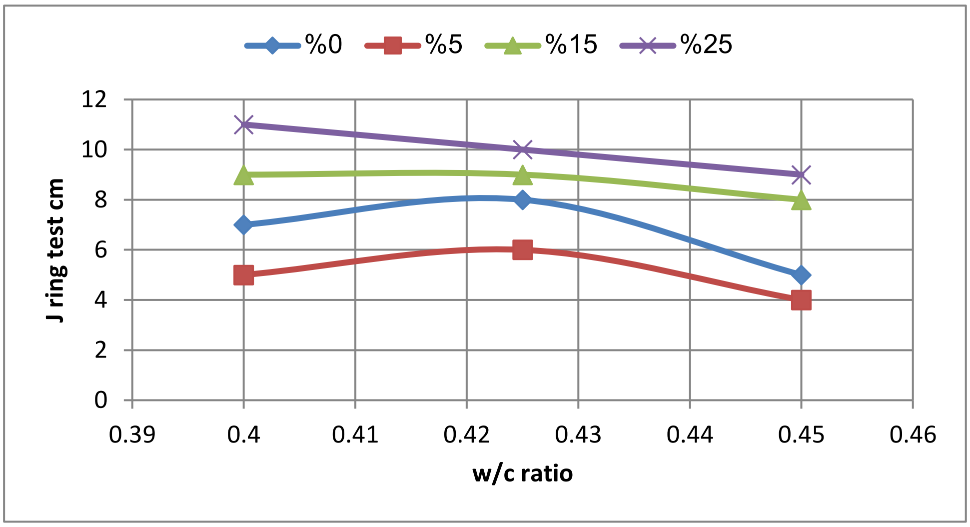

Figure 2 *Concrete seepage at different w/c ratios*

4.2 Compressive strength of hardened concrete

Figure 3 shows the relation between hardened concrete compressive strength and w/c ratio at 28 days for different glass powder contents. SCC compressive strength decreases with the increase in w/c ratio for all mixes. Although the graphs show that as the powder content increases the strength decreases for all w/c ratios. It is well observed that compressive strength decreases with the increase in powder content. Although of the decrease in strength obtained by increasing powder content, good strength higher than 30MPa still available even at powder replacement of 25%. This result agrees with that of Bouty and Homs for the mixes with replacement of 15% which designed for 32MPa.

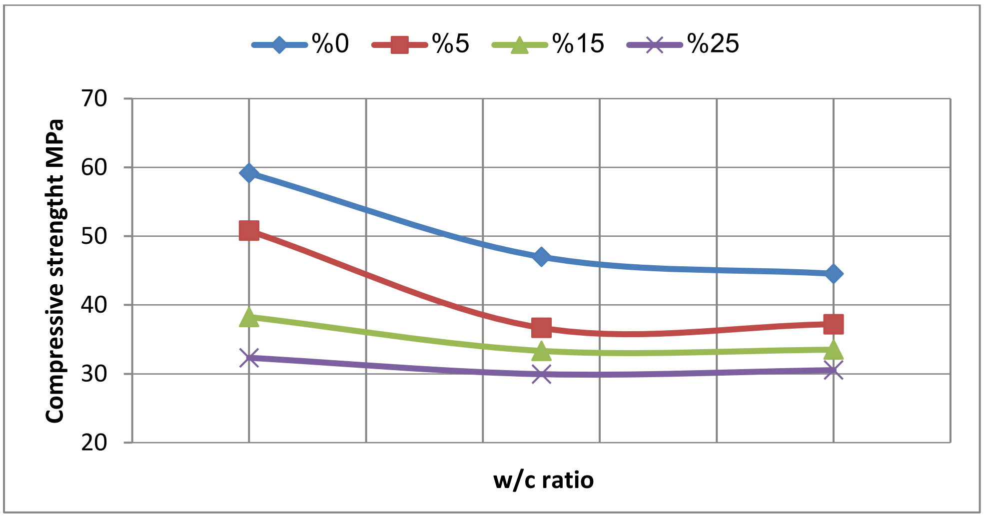

Figure 3 *Compressive strength vs w/c ratio at 28 day*

5 Conclusions

The concluding remarks from the investigation can be summarized as follows;

1. SCC with good workability can be achieved by the use of super plasticizer and waste glass powder in concrete production as part of cement.
2. It is very valuable to get high replacement of cement by glass powder up to 25% of and get concrete strength at 28 days higher than 30MPa. This can demonstrate that employment of waste glass powder in concrete is advantageous, and this will minimize the cost of concrete production as well as resulting in low gas emission during the cement production.

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