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The Influence of Replacing Sand with Waste Glass Particle on the Physical and Mechanical Parameters of Concrete

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Abstract

Glass is a special type of materials which is widely used in various forms and colors for different usages. Colored bottles comprise a large part of waste glass. To reduce the destructive effects of waste glass on the environment, it might be recycled. However, some indecomposable waste materials are buried. This will have harmful effects on the environment. A practical solution for reducing non-recyclable waste colored glass is using them as replacements for materials in other industries such as concrete industry. The effect of replacing aggregate with waste glass particle on the compressive strength and weight of concrete is investigated in this study. To achieve the goal, totally 27 cubic specimens were created; 6 specimens were made of concrete, while waste glass particle was added to the mix of other specimens. To prevent Alkali Silica Reaction (ASR), Microsilica was added to the mix of specimens containing glass. Generally, Results indicated that replacing aggregate with glass particle more than 30% lead to increment in compressive strength of concrete. The weight of concrete remains almost the same in all of the specimens. Briefly, based on the results it could be concluded that the optimum percentage for replacing aggregate with glass particle is 50%.

Keywords: Glass Particles; Concrete; Non-Recycled Material; Compressive Strength Weight.

1. Introduction

A huge amount of waste materials have been produced because of the considerable increase in population. Many of these rubbish will be decayed after hundreds of thousands of years, thus special plans to lessen their harmful effect should be made [1]. Glass, which is considered as a type of waste materials, has been rapidly increased in recent decades because of the growth of using glass products. A remarkable amount of colorless waste glass has been recycled and returned to the industry, however, it should be taken into account that increasing colored waste glass has become a big concern due to its low recycling rate and lack of landfilling sites. On top of that, since they cannot be decayed in a short time, they can threaten the environment seriously. Considering all of the above, replacing various materials like concrete aggregate with colored glass particle has become the center of researchers' attention recently. Although using colored glass in specific industries would be costly, when it is used for producing concrete, the production of waste glass will fall though the development of reproducing technology and the extension of reproducing facilities, which will make concrete with waste glass economically viable [2].

Because of various advantageous of using waste glass in concrete industry, a vast array of studies have been done by researchers. In 2009 Z.Z.Ismail and E.A.Al-Hashmi investigated the properties of concrete containing waste glass as fine aggregate. In this study, the strength property and ASR expansion of concrete mixes in which sand was replaced

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with crushed waste glass at percentages of 10%, 15% and 20% were evaluated. The results proved 80% pozzolanic strength activity given by waste glass after 28 days. The compressive and flexural strength of the mix contacting 20% crushed glass were 10.99% and 4.23% higher than those of the control specimen, respectively. The test on the mortar bar showed that in comparison with the control specimen the finely crushed waste glass decreased expansion in size of 66% [3]. The influence of replacing fine aggregate with recycled glass waste on the fresh and hardened properties of self-compacting concrete (SCC) was reported by E.E.Ali and Sh.H.Al-Tersawy in 2012; in this experimental study eighteen specimens containing various cement contents (350, 400 and 450 Kg/cm^3) and with the ratio of W/C in size of 0.4 were created. Fine aggregate was replaced with crushed recycled glass in percentage of 0%, 10%, 20%, 30%, 40% and 50%. Based on the results when the recycled glass content increased, the slump flow rose. Moreover, the compressive strength, splitting tensile strength, flexural strength and static elasticity modulus of the concrete fell with increasing the percentage of recycled glass particle; therefore, according to this study recycled glass particle can be utilized for producing SCC [4].

Y.Sharifi et al evaluated the effect of replacing fine aggregate with glass on the properties of SCC in 2013. In this study, fine aggregate were replaced with crushed glass in various weight percentages including 0%, 10%, 20%, 30%, 40% and 50%. The results demonstrated that by using waste glass, the flow-ability characteristics increased, while compressive strength, flexural and splitting strength of specimens decreased. As the amount of concrete strength reduction was negligible, glass particle can be successfully chosen as a replacement for fine aggregates to produce SCC [5]. Another experimental study carried out by T.S.Serniabat et al to assess the performance of concrete specimens containing various percentages of crushed glass to 5-20 mm maximum size and glass marble in size of 20 mm to be used as coarse aggregate. The results of the test demonstrated that the specimen containing the balanced of percentage of glass particle and round marbles possess the highest compressive strength because of good performance of glass beads in bond formation and strong marbles with high strength [6]. T.Ganiron Jr conducted an experimental study to investigate the effect of replacing coarse aggregate with crushed glass bottles in physical and mechanical characteristics of concrete mix. Based on the results, up to 10% coarse aggregate weight can be replaced with recycled crushed glass in concrete mix and a mix design of 5% weight insertion to the concrete mix will lead to an acceptable compressive strength [7]. A.B.Keyron and G. J. Ibrahim carried out similar study on the fresh and hardened mechanical properties of the concrete containing window waste glass. According to the results, replacing coarse aggregate with window glass particle decreased the slump and fresh density owing to angular shape of grain, while other properties including compressive, splitting and flexural strength increased. On top of that, results indicated that when the ratio of waste glass increased, the strength rapidly rose to a given limit beyond which they decrease [8].

Some of mechanical properties, Fresh properties, abrasion resistance, water absorption, chloride ion penetration, permeability, chemical resistance, carbonation resistance, drying shrinkage and alkali-silica reaction expansion of mortar/concrete mixtures containing waste glass as fine aggregate replacement have been reviewed by A. M. Rashad in 2014 [9]. In another study done by V.Srivastara et al, it was concluded that coarse aggregate can effectively be replaced with waste glass (limited to 50%) without remarkable change in strength [10]. In 2015 the influence of ground waste glass (GWG) micro particle as cementary material on mechanical and durability response properties of SCC was evaluated by Y.Sharifi et al. the obtained results revealed that by increasing the percentage of GWG micro particle, the workability of fresh concrete rose. In addition, utilizing GWG micro particle limited to replacement of 15% will result in concrete with enhanced hardened strength. Furthermore, by increasing the ratio of GWG particle, ASR expansion dropped down; hence SCC can be produced by using GWG as cementary material [11]. The results of another experimental study on the effect of using recycled glass on mechanical properties of green concrete revealed that while compressive and flexural strength of concrete showed highest amount when 13% of cement is replaced with neon glass, splitting tensile strength reached the maximum size at the same ratio but by using green glass [12]. H.G Patel and S.P Dalal investigated the mechanical and physical properties of concrete containing waste glass particle. Results of their research demonstrated that the physical, mechanical properties and durability aspects of concrete remained in a desirable range according to Codes. The microstructure evaluation showed that glass and PVC particle have formed a good and even distribution across the concrete [13]. Using fluorescent light tube waste as fine aggregate in concrete was investigated by P.Seenu and K.Kaviya in 2017. Results indicated that replacing fine aggregate with fluorescent tube light waste less than 10% replacement reaches the highest level [14].

The main novel of this study is to examine the influence of replacing sand with glass on compression strength and weight of concrete. The most important concern regarding replacing aggregate with glass in concrete is the chemical reaction between Microsilica in glass and Alkali material in concrete mix, which is known as Alkali Silica Reaction. This reaction can lead to concrete corrosion. One of the effective ways which can prevent ASR is using Pozolani material like Microsilica in concrete mix [2, 15-17], therefore, Microsilica was added to the specimens containing waste glass particles. Moreover, the effect of using Microsilica on above-mentioned parameters of concrete is presented.

2. Research Significance

Replacing aggregate with waste glass particle in concrete mix have various upwards; firstly, the amount of waste glass would be decreased. Consequently, its negative effects on environment would be remarkably reduced. Moreover, the less the glass waste are, the more lands would be available for other industries and farming. Further and even more importantly, when waste glass particle is used instead of aggregate in concrete mix, the cost of concrete and construction would be decreased.

3. Experimental Study

In this study, sand and gravel are obtained from SEMNAN MASE SARA factory and the glass replaced as sand is supplied from waste bottles which are introduced by NOOSHIN factory and HOLSTEN factory. It should be mentioned that glass bottles were in two colors; green and brown, and as shown in Figure 1 they were crashed using manual instruments.

To investigate the effect of replacing sand with waste glass particle on compressive strength and weight of concrete, totally 27 Series of mixes were prepared; three of them were made of concrete, six of them contained glass particle without Microsilica, three of them contained Microsilica without glass particle and other mixes contained both of glass particle and Microsilica. The percentage of materials used for each specimen is provided in Table 1. ASTM C33 was considered for distribution of aggregate particle size [19]; the grading curve for the aggregate is demonstrated in Figure 2. letters were used to nominate specimens; C: Concrete, G: Glass, M: Microsilica and the first number following them shows the glass percentage replaced as sand, and the second number express the specimen number. For instant, CGM20-1 means the first specimen which contains 20% glass replaced as sand and contains Microsilica in its mix. The name of other specimens and their properties are given in Table 2.

Figure 1. Glass particle used as sand

Table 1. The percentage of material used for specimens

Sample	W/C	Water (gr)	Cement (gr)	Sand (gr)	Gravel (gr)	Glass (gr)		Microsilica (gr)
						#100<R<#16	#16<R<#4	
C	0.54	625	1150	3000	3000	0	0	0
CG10	0.54	625	1150	2700	3000	150	150	0
CG20	0.54	625	1150	2400	3000	300	300	0
CM	0.54	625	1150	3000	3000	0	0	57.5
CGM10	0.54	625	1150	2700	3000	150	150	57.5
CGM20	0.54	625	1150	2400	3000	300	300	57.5
CGM30	0.54	625	1150	2100	3000	450	450	57.5
CGM40	0.54	625	1150	1800	3000	600	600	57.5
CGM50	0.54	625	1150	1500	3000	750	750	57.5

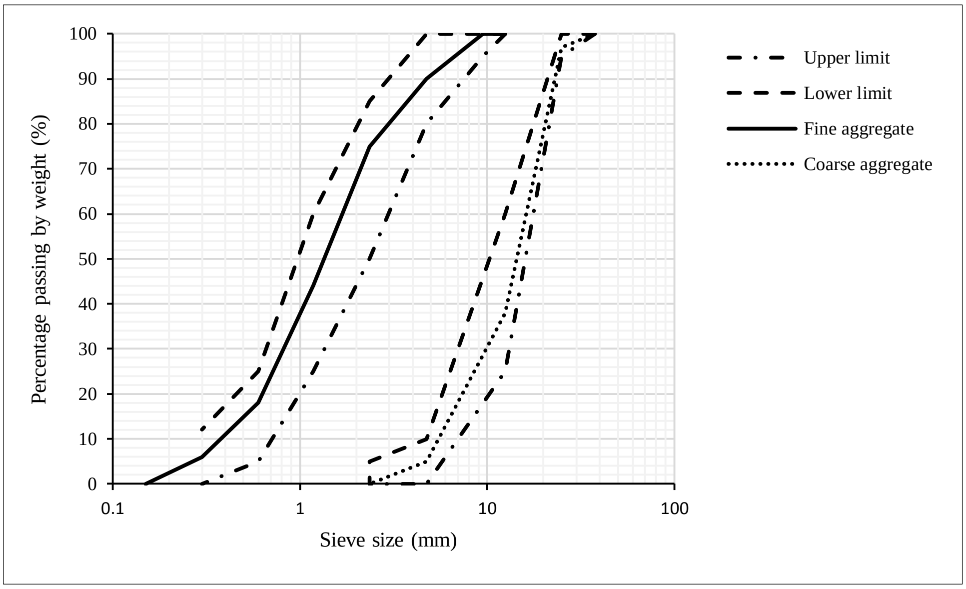

Figure 2. Grading curve for concrete aggregate

Table 2. Percentage of glass and Microsilica added to mixes

Sample	No.	Glass Percent (% Sand)	Microsilica (% Cement)
C	1	0%	0
	2		
	3		
CG10	1	10%	0
	2		
	3		
CG20	1	20%	0
	2		
	3		
CM	1	0%	5
	2		
	3		
CGM10	1	10%	5
	2		
	3		
CGM20	1	20%	5
	2		
	3		
CGM30	1	30%	5
	2		
	3		
CGM40	1	40%	5
	2		
	3		
CGM50	1	50%	5
	2		
	3		

4. Test Procedure

Having been prepared, the 100×100×100 mm cubic molds were coated by industrial oil to prevent adhesion of concrete. Then, concrete was casted in three 30 mm layers and each of which was compacted using steel bar and shaking table. After one day the molds were removed from concrete and the specimens were placed in water. Having been cured for 7 days, the weight of specimens was measured using digital balance and then axial force was applied to specimens using concrete compression machine as shown in Figure 3.

Figure 2. Concrete compression test

5. Results and Discussion

The measured weight and the results of concrete compression test are provided in Table 3.

Table 3. Results of the test

Sample	No.	Weight (kg)	Average of Weight (kg)	Compression strength (kg/cm^2)	Average of CS (kg/cm^2)
	1	2.394		330	
C	2	2.364	2.373	299	325
	3	2.360		346	
	1	2.280		178.5	
CG10	2	2.378	2.307	167.9	162.86
	3	2.264		142.2	
	1	2.448		240	
CG20	2	2.416	2.453	245	278.33
	3	2.442		350	
	1	2.364		280	
CM	2	2.370	2.370	360	320.33
	3	2.376		321	
	1	2.406		204	
CGM10	2	2.434	2.388	280	241.33
	3	2.324		240	
	1	2.434		355	
CGM20	2	2.466	2.440	410	385.000
	3	2.420		390	
	1	2.402		390	
CGM30	2	2.442	2.443	420	396.666
	3	2.486		380	
	1	2.408		569	
CGM40	2	2.474	2.443	423	473.666
	3	2.446		429	
	1	2.410		525	
CGM50	2	2.390	2.408	510	513.600
	3	2.424		505.8	

As it could be seen in Table 3 the maximum and minimum amount of compressive strength belongs to CGM50 and CG10 in size of 513.60 and 162.87, respectively. The other note which could be found based on the results is that there is no significant change in weight of the specimens and it almost remained the same.

To have better comparison between different specimens, variable parameters are shown in Figure 3 and 4.

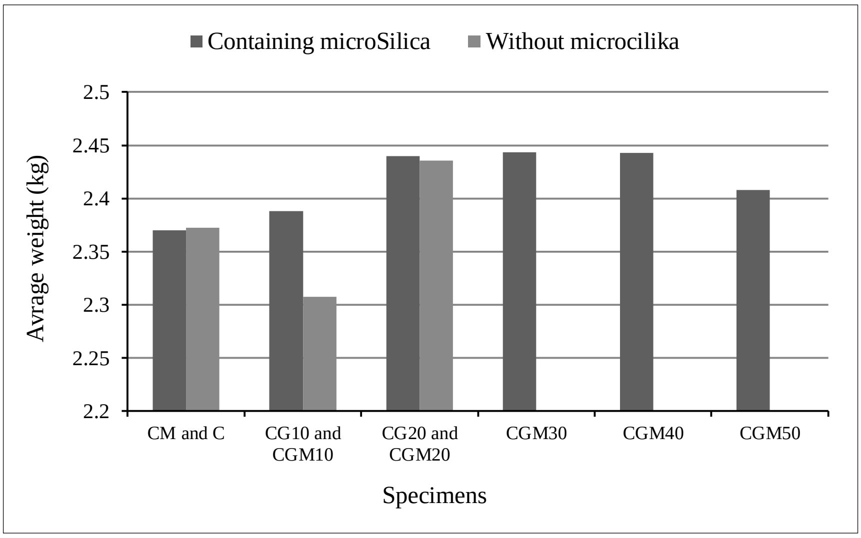

Figure 3. Comparison of average weight of specimens

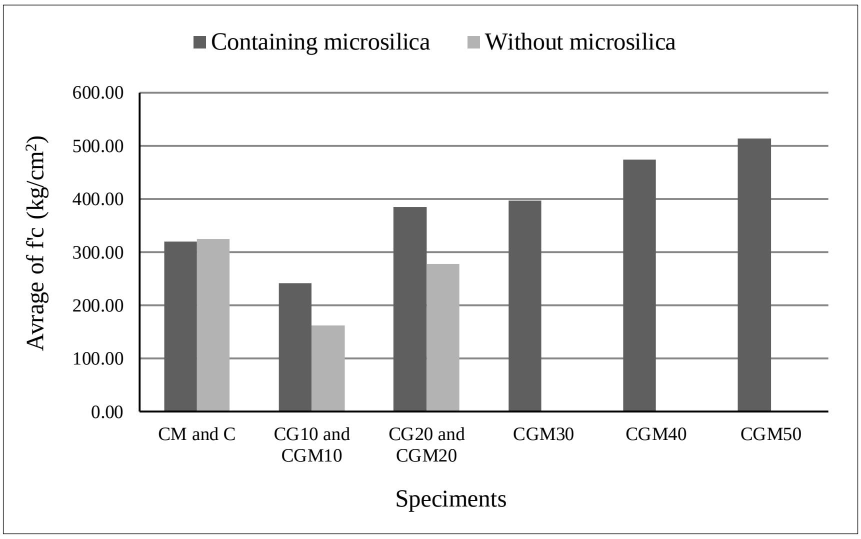

Figure 4. Comparison of average compressive strength of specimens

Figure 3 illustrates the average weight of specimens. The first point which could be found from the Figure 3 is that the weight of the specimens fluctuates and no specific relation between the percentage of added glass particle and the weight of concrete could be presented. Based on the data provided by Figure 3 the weight of CM and C could be considered almost the same. In other words, as it was expected, adding Microsilica to the mixture does not change the weight of concrete significantly. On top of that, although the weight of CGM10 and CGM20 are more than the weight of CM10 and CM20 in size of 3.51% and 0.21%, respectively, their difference is not remarkable. Briefly, the maximum difference in all of the weight of specimens is less than 136 gr which could be neglected.

The compressive strength of the specimens is demonstrated in Figure 4. Taking a glance at the Figure 4, it could be realized that generally when the percentage of waste glass particle increase, the compressive strength rise. Going through the details, the compressive strength of CGM20, CGM30, CGM40 and CGM50 is higher than that one of C in size of 18.46%, 22.05%, 45.74% and 58.03%, respectively. The other considerable point which should be mentioned is that in addition of preventing ASR, adding Microsilica increase the compressive strength of specimens. To put it simply, the compressive strength of CGM10 and CGM 20 is greatly more than the one of CM10 and CM20 in size of 48.17% and 38.33%, respectively. It should be noted that by comparing CM and C it could be found that adding Microsilica to the concrete mix made of natural aggregates does not alter compressive strength significantly.

6. Conclusion

To evaluate the effect of replacing sand with waste glass particle in concrete, 27 specimens were prepared and tested; compressive strength and weight of specimens were analysed. Taking the results into account, following conclusions could be drawn:

- The most notable conclusion in this study is that using waste glass particle instead of sand in concrete mix containing Microsilica, increase the compressive strength of concrete. To put it simply, by increasing the percentage of glass particle, the compressive strength rise. In this study the optimum percentage of glass particle is 50%.
- As mentioned before, the only concern with using waste glass in concrete is ASR which could be prevented by Adding Microsilica to concrete mix [2, 15-17]. Moreover, based on the results adding Microsilica to concrete mix increase the compressive strength of concrete.
- Replacing sand with waste glass particle does not affect the weight of concrete. To put it another way, the dead load due to concrete structure does not change by using waste glass particle.

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