Recycling Glass Powder and its use as Cement Mortar applications

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Abstract: This study was carried out to investigate the mechanical properties and thermal conductivity of mortar cement produced from glass waste at different values of glass to cement . It was found that Increasing ratio of glass waste weight affects the compressive strength and hardness of the mortar . As for the thermal conductivity and water absorption, these value were found to with increase of glass decreased and were affected positively. It was concluded that glass waste can be used environmentally and cost- effective cement substitute as in mortar cement mortar production.

Key words: Waste glass, recycling, mortar cement ,green environment

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1. Introduction

Domestic and industrial wastes are serious source of pollution which requires great attention. Disposal of wastes has become a major problem in metropolitan areas. Quantities of glass waste have been on the rise in recent years due to an increase in industrialization and the rapid improvement in the standard of living. Unfortunately, the majority of glass waste is not being recycled but rather abandoned and is therefore, the cause of certain serious problems such as waste of natural resources and environmental problem. For these reasons, this study has been conducted in order to investigate the possibility of using glass waste as fine aggregates in mortar. If the large amount of waste materials generated is used instead of natural materials in the construction and industry, there would be three benefits: conserving natural resources, disposing of waste materials (which are often unsightly) and freeing up valuable land for other uses [1].

The utilization of waste glass in construction has attracted a lot of interest worldwide due to the large quantity consumptions and widespread construction sites. Recently,many studies have focused on the uses of the glass waste as partial replacement of natural aggregates in mortar. [2]

Finely ground glass powders exhibited very high pozzolanic activity [3,4] .A major concern for using waste glass in mortar is the alkali-silica reaction (ASR) that takes place between the alkali in cement and the reactive silica in glass. this reaction can be very detrimental to the stability of mortar. The combined usage of glass waste with industrial by products can be more suitable instead of using it alone in mortar [5,6] .As a Pozzolan, glass powder provides a more uniform distribution and a greater volume of hydration products. Addition of glass powder to a concrete mix alters the cement paste structure. The resulting paste contains more of the strong calcium-silicate hydrates (C-S-H) and less of the weak and easily soluble calcium hydroxides ($Ca(OH)_2$) than ordinary cement pastes. The calcium silicate hydrate formed is the glue, or binder, which holds the system together, and is the main source of concrete strength. The weaker calcium hydroxide does not contribute as a binder, and can occupy space. Further, the calcium hydroxide can combine with carbon dioxide to form a soluble salt which will leach through the concrete, and can cause efflorescence. The small particles size of glass powder particles is advantageous to infiltrate and plug capillary pores in concrete making pores smaller and fewer and concrete more dense. The micro filler effect greatly reduces permeability and improves the paste-to-aggregate bond of concrete with glass powder compared to conventional concrete.[7].

2. Experimental Work

Table 1 summarizes the compositions of the mortar investigated in this work, some of their properties and sources.

3. Perpetration of glass waste

Glass waste used in this study was green and brown glass bottles collected from recycle center and from the manufacturer. Glass bottles were cleaned with water to remove paper on the surface and to eliminate contaminations, and The broken windows glass was used as waste which was supplied from windows glass market.

Recycling of waste glass is attractive to glass manufacturers, because it decreases the costs associated with raw materials and Technological processes. Recycling also lowers energy consumption and eliminates the need to dump waste glass in landfills .However, to recycle waste glass effectively within the glass Industry, it must contain glass of similar composition, which has been separated from contaminants that can decrease the quality of new glass products.

The waste glass was milled for 15 minutes. The glass waste were measured using particle size analysis and surface area to show the effect of milling time on the average particle size and specific surface area. The glass powder was also subjected to

X-ray Diffraction (XRD) measurement using diffractometer -6000 using CuKα radiation at 60 kV/80 mA, CPS = 1k, width 2.5, speed 2°/min and scanning with angle of 2θ from 3 – 70°, shimadzu was performed to determine the phases of the produced samples, the glass waste particle size used to measure the particle size distribution for powder used in this study. glass waste samples were also measured The chemical composition of the waste glass is determined using the Inductively coupled plasma optical emission spectroscopy (ICP-OES) chemical analysis machine.

A mortar specimen of approximately(4.5cm×4.5cm× 4.5cm)as shown in figure 1 for compression test was cast for each mix considering a control mix, four mixes corresponding to 10%, 20% ,30% and 40% waste glass cement replacement .The specimens were left for setting for 28 days. Mixing proportions are given in table 2.

5. Results and discussion

The particle size distribution of the glass waste is shown in figure 2 exhibiting sizes in the range 0.1 –1000 μm. Figure 1 shows. The average size of the particles is found equal to (45.905 μm) for window glass powder. The average size of the particles is found equal to(93.323 μm) for green glass powder and the average size of the particles is found equal to(0.691μm) for brown glass powder .This powder is expected to mix homogeneously with the mortar cement providing reinforcement centers in the mortar cement at macro scale dimension.

X-ray diffraction (XRD) is a rapid analytical technique primarily used for phase identification of a amorphous material and can provide information on unit cell dimensions. The analyzed material is finely ground, homogenized, and average bulk composition is determined .The x-ray diffraction of waste glass powder for all types of glass shows in figure 3 no diffraction peak was observed in the (2ɵ) range $(0\text{-}60)^0$. It shows the at the glass powder is amorphous in nature.

The results of the chemical analysis of glass powder are given in table 3. For the water absorption test, the dried specimens are weighed. The material is then emerged in water at room temperature for 24 hours, specimens are removed, patted dry with a lint free cloth, and tested by using equation 1 [9, 10].

$$\textbf{Water Absorption\%} = \left(\frac{(\textbf{Wet Weight} - \textbf{Dry Weight})}{\textbf{Dry Weight}}\right) * \textbf{100} \quad \ldots\ldots\ldots\ldots \quad (1)$$

The water absorption values are calculated then the results are shown in figure 4 which shows that increasing the glass waste to cement ratio in the cement mortar resulted into a decrease of water absorption by 26% compared with pure mortar. This behavior was found reproducible in all reinforced mortars regardless the time interval after which measurements were taken .Fig 4 shows that increasing the waste glass powder to the cement ratio in the cement mortar result into a decrease of water absorption by the specimen except the brown glass is increases because increase the porosity. This behavior is attributed to the fact that the waste glass powder might have filled the micro-cracks and the pores in the mortar leading to decrease of voids being otherwise occupied with water.

Hardness may be defined as a material's resistance to permanent indentation. Durometer, like many other hardness tests, measures the depth of an indentation in the material created by a given force on a standardized presser foot, measures the depth of an indentation in the material created by a given force on a standardized presser foot. Three Measurements of hardness were made at different positions (H1, H2, H3), the mean hardness value of three measurements (H) is defined as shown in eq.(2).

The results of hardness measurement on the mortar and reinforced materials are shown in Figure 5. The results reveal that an increase in the percentage of glass waste powder particulates in mortar increases the material hardness. The increase in hardness is due to the presence of glass waste powder formed as a result of reaction between waste glass powder and mortar cement .

Compression strength test results are shown in figure 6. Results show that time has a great effect on compression which is obvious for all cement mortars (i.e. cement mortars get harder with time so more resistant to compression). Increasing the glass waste to cement ratio in the mortar was found to enhance this property. Cement mortar with 40 % waste glass to cement ratio showed compression value of(25. 36MPa) which is higher than compression of the glass - free mortar (10.6 MPa). This void is believed to act as a microstructure responsible of eliminating tensile stresses and resolving forces into compressive stresses at micro scale in a manner similar to arches spanning spaces and supporting weights in buildings [9].In general, the waste glass powder mortar had higher compressive strengths at various ages and up to 28 days when compared with the pure mortar. The results show that it was possible to obtain a compressive strength of as high as (5) MPa after 28 days. In addition, strengths up to (5 to 12.6) MPa according to the type of glass powder were obtained at 28 days.[10]

The thermal conductivity of the prepared samples is presented in figure 7 exhibiting a continuous decrease in value with increase of weight percentage of glass waste powder in the mortar. The increase of glass waste powder in the specimen and the associate reduction of cement content led to increase of specimen volume which led to a decrease of specimen density.

The waste glass powder free specimen exhibited a thermal conductivity of 1.705W/m.K. This value was observed to decrease with the increase of waste glass powder addition in the specimen until a thermal conductivity of 0.907 W/m.K for brown waste glass, 1.201 W/m.K for green waste glass and 1.234 W/m.K for window waste glass and was measured at 50% powder to cement ratio. This means that the waste glass powder has a lower thermal conductivity than the mortar and that the enhancement of thermal insulation of the specimen is due to the inherent low conductivity of the waste glass .[11]

6. Conclusions

Glass waste powders were added as a partial substitute of ordinary Portland cement mortar. Compressive strength and hardness of the cured mortar increased with increasing the powder ratio. The thermal conductivity of the mortar decreased with the increase of the powder. Results suggest the possibility to use the glass waste powders in cement mortar for construction and plastering applications.

7.Resumo

Este estudo foi realizado para investigar as propriedades mecânicas e condutividade térmica de argamassa de cimento produzido a partir de resíduos de vidro em diferentes valores de vidro para cimento. Verificou-se que o aumento da razão entre o peso dos resíduos de vidro afecta a resistência à compressão e da dureza da argamassa. Como para a condutividade térmica e absorção de água, esses valores foram encontrados para com aumento de vidro diminuiu e foram positivamente afetadas. Concluiu-se que os resíduos de vidro pode ser utilizado o meio ambiente e de custo eficaz como substituto do cimento na produção de argamassa de cimento de argamassa.

Table 1. Compositions, properties and source of mortar.

	Raw materials	Properties	Source
a.	Ordinary Portland Cement (OPC)	53µm fine powder as measured by particle analyzer (SALD-301V) produced by (United Cement Company-Tasluja- Bazian) Sulaymaniyah (Iq.s 5/1984 Type I BS EN 197-1:2011 CEM I 42,5R)	Iraq
b.	Sand	Particle size less that 600 µm as specified by sieving method. ASTM c778-13	Iraq
c.	Water	Ordinary water used as mixing by water /cement ratio =0.5	Iraq
d.	Waste Glass	**See section 3**	Iraq

Table 2. Mortar cement mixture proportioning

Specimens	glass waste powder (g)	Cement (g)	Sand (g)	Water (ml)	Replacement of cement weight %
1	0	100	300	50	0%
2	10	90	300	50	10%
3	20	80	300	50	20%
4	30	70	300	50	30%
5	40	60	300	50	40%

Table 3: The chemical analysis of waste glass powder

Chemical composition (%)	Window glass	Green glass	Brown glass
SiO_2	69.72	64.03	57.41
Al_2O_3	1.02	1.6	1.68
Fe_2O_3	0.55	0.52	0.86
CaO	8.76	12.41	4.88
MgO	3.43	3.31	2.75
Na_2O_3	8.42	7.76	6.42
K_2O	0.13	0.32	0.60
SO_3	0.20	0.11	0.18
Total	92.55	94.14	94.08

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Figure 1:specimens of test

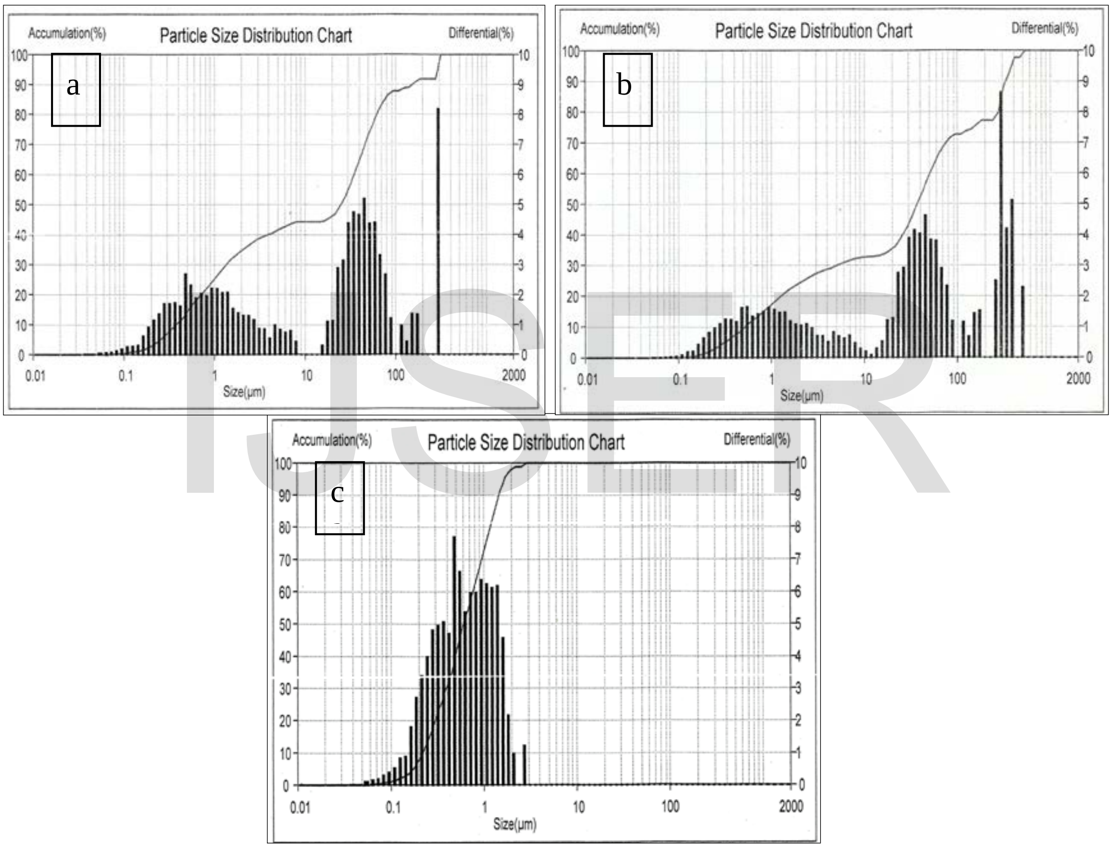

Figure.2: particle size distribution of glass waste

(a) Particle Size Analysis of window glass powder (b) Particle size analyzer of green glass powder (c) Particle size analysis of brown glass powder

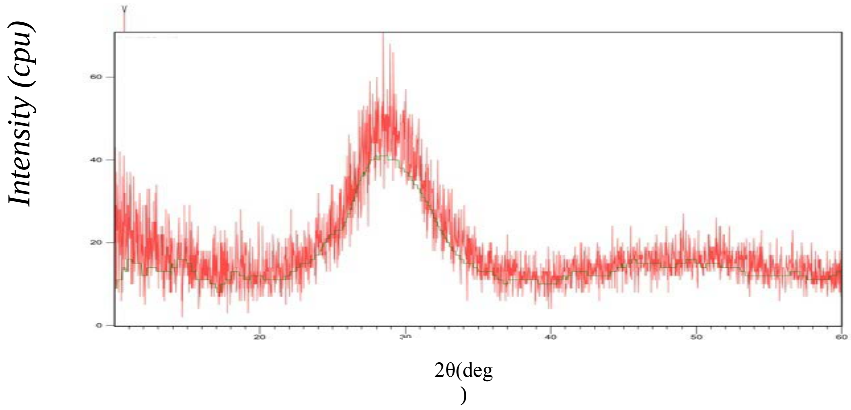

Figure 3: X-ray diffraction of all type of waste glass powder

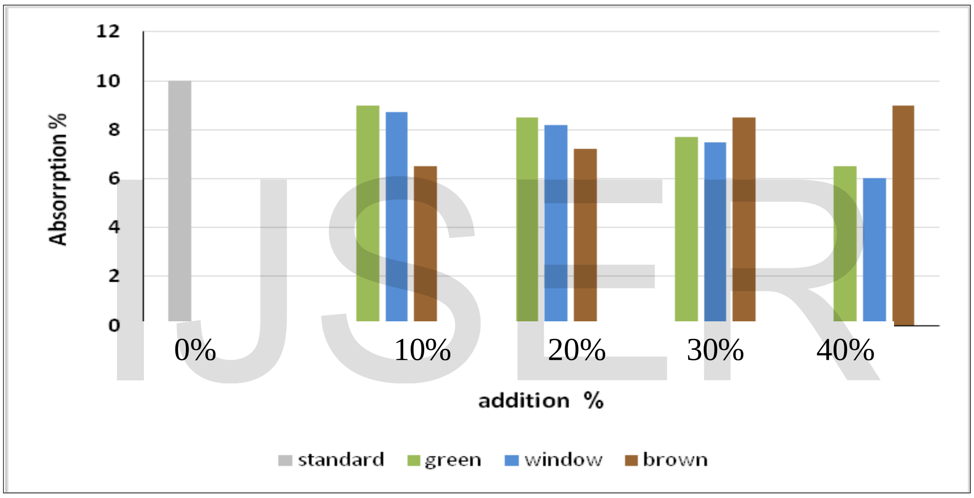

Figure 4: water absorption of waste glass powders

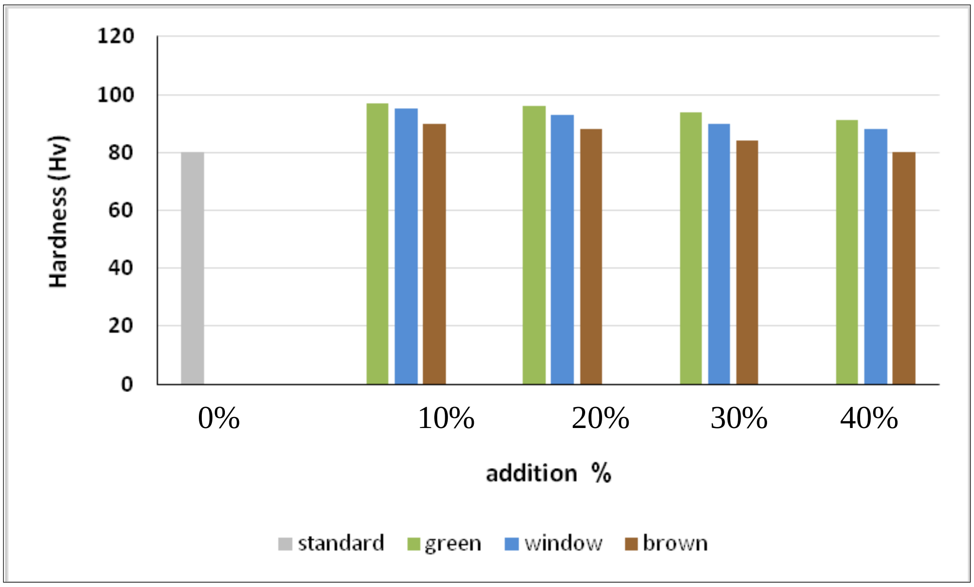

Figure 5: Hardness of specimens mortar before and after addition of glass waste.

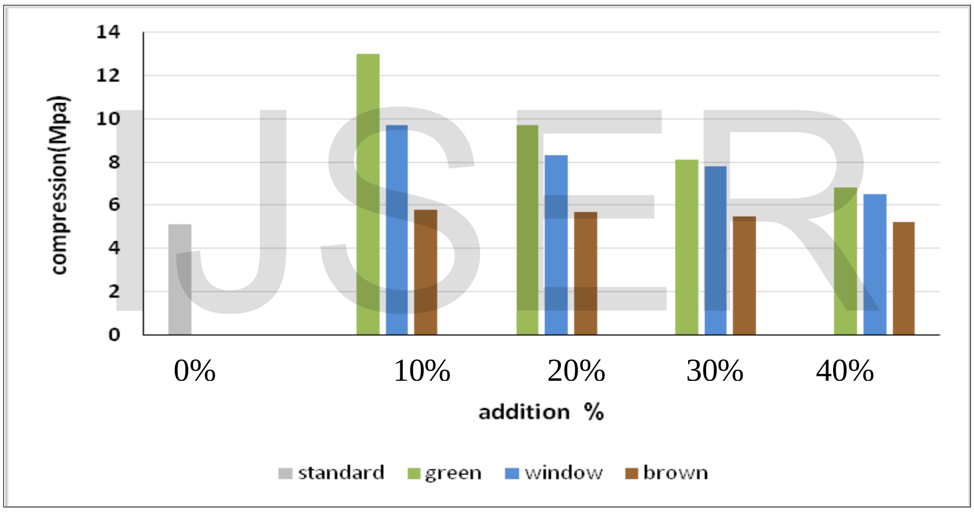

Figure 6: Compression Strength Of mortar with waste glass powder

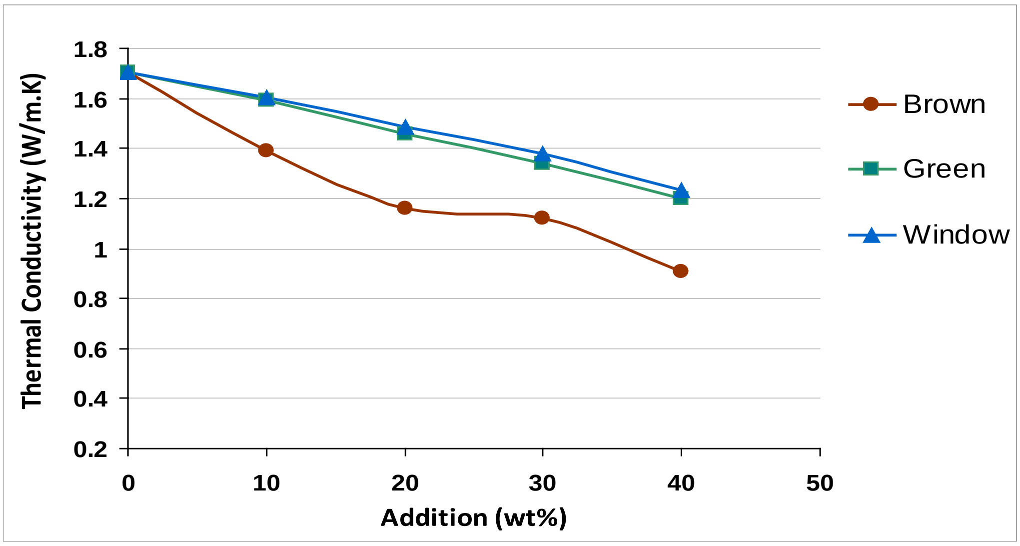

Figure 7: Thermal conductivity of waste glass powder

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