A Study of the Effect of Recycled Mix Glass on the Mechanical Properties of Green Concrete

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Abstract

In this paper we utilized mixing of different types of recycled glass such as (neon glass, brown glass, and green glass) that has high percentage of silicon dioxide (SiO_2) with different concentrations. Utilization these landfall materials can be considered as keeping on resources. Different waste glasses used as a partial replacement of cement with different concentrations 11%, 13%, and 15% of cement weight for each type, and study the effect of it on the mechanical properties of concrete. After mixing, casting, and curing in water at (20±2)°C for (7, 14, and 28) days, the mechanical properties showed that the compressive strength and flexural showed highest results at 13% from cement weight of neon glass, whereas splitting tensile strength showed the highest value at the same percentage, but from green glass.

Key words: Recycled glass, Environment impact, Compressive, Splitting, Tensile strength.

الخلاصة

في هذه الورقة البحثية تم استخدام خليط من الزجاج ك(زجاج شمعات النيون (الفلورسنت، الزجاج الجوزي و الزجاج الاخضر) والذي يحتوي على نسب سيليكا عالية(SiO_2). استخدام هكذا مواد تالفة معاد تدويرها يعد من المحافظة على المصادر الطبيعية. تم استخدام مسحوق خليط الزجاج كبديل جزئي للاسمنت بثلاث تراكيز (11%، 13%، و 15%). من وزن الاسمنت. بعد عملية الخلط والصب والمعالجة بالماء العادي بثلاث اعمار (7، 14، و 28) يوم. أظهرت الخواص الميكانيكية ان مقاومة الانضغاط و متانة الانحناء اعلى قيمة لها عند النسبة (13%) لزجاج النيون من وزن الاسمنت. في حين متانة الانشطار (فحص شد بصورة غير مباشرة)، اظهرت النتائج اعلى قيمة لهما عند نفس النسبة السابقة لكن من الزجاج الاخضر.

كلمات المفتاحية : – زجاج معاد تدويرها، التأثير البيئي ، مقاومة الانضغاط، متانة الانشطار، ومتانة الانحناء

1. Introduction

The increase in the cost of construction materials, and rapid development in it. At the same time, the world is heading to use materials have less harmful effect on the environment, so there are many ways to get green concrete from recycling the materials. One of them is the utilization of colored, crashed, and waste ground glass (WGP) in concrete. The general advantage of using it might prevent creeping of metals because the ground glass improved the workability of concrete that's led to reduce the permeability of it due to the high alkali-silica reaction (ASR) that presents in cement and waste glass **(Ramana *et.al.*, 2015).**

The utilization of this type of waste material as a replacement of cement with specific percentage led to reduce the cost of using cement also to produce concrete with less environmental impact with low-cost of production. Glass is non-crystalline silica which has almost the content of ordinary Portland cement, but with different concentrations, as shown in Table2 below. Therefore it is used as a replacement of cement because its pozzolans materials and has limestone that is released through hydration reaction **(William, 2013)**. Crushed waste glass (CWG) as a replacement of cement at ratios (0%, 5%, 10%, 15%, 20% and 25%) and admixture (sugar) (0.05%). In addition to, water to cement ratio (w/c = 0.65) at (28 days) of curing time. The results observed that the compressive strength of the concrete increased more than

normal concrete (without glass powder addition and admixture of sugar) by (12%) at (5%) of replacement. Also, it is appeared that is the compressive strength exhibited decrement with increasing content of glass powder **(Oyekan *et.al.*, 2011)**. While, waste glass milled into micro-scale particle size, that is used as a partial cement replacement that sued in recycled concrete. The presence of waste glass in this form improved of the properties of concrete such as moisture absorption resistance, and harmful transportation.

As a result, milled waste glass (about 20- wt. % are not exceeded) as a partial replacement of cement improved many properties of concrete such as abrasion resistance, long-term strength and durability characteristics. Also, it has many advantages in saving environment energy, cost benefits, and played an important role in reducing carbon footprint in structure industry. Recycled concrete glass with 20% of milled glass replacement of the cement is used in the field of pavement and curb that applied over two years of vulnerability (exposure) to mid- Michigan weathering effects (and traffic loads) **(Roz-Ud-Din et*al.*, 2011)**.

2. Research Significance

To study the effect of mix glass (Neon, Brown, and Green glass) as a partial cementation on mechanical properties (compressive, splitting, and tensile strength).also to compare the results of different concentrations of the substitution material with the normal concrete. All of that, in order to produce concrete has less environmental effect that are related to cement production, therefore materials are used that works as a partial replacement of cement.

3. Experimental Investigation

Cubic, Cylindrical, and Splitting specimens without steel reinforcement was used with dimensions (3.94 inch. [100mm], 16 inch [40mm] length and 3.94 inch [100mm] the dimensions of both width and height, 4 inch [10mm] diameter and 8 inch [20mm] height) shown respectively. The utilization materials included ordinary Portland cement (OPC), water, sand, and aggregate, also the different type of glasses that used as a partial replacement of cement. The specimen numbers (27) specimens for each concentration and age and compared it with normal concrete.

I. Materials

The properties of materials that utilized in this research measured according to the Iraqi specifications IQS. **:**

A- Cement

Ordinary Portland cement was used fabricated by United Cement Company is known for the marketing (Al-Mass Basin), the physical properties of cement shown in Table 1.

Table 1:- Physical properties of cement.

Type of test	Result	Limit of IQS. No.5
Specific surface (m^2/kg)	376	>230
Setting time (Vicat`s method) -Initial setting (hrs:min) -Final setting (hrs:min)	 2:05 4:00	 ≥ 45min ≤ 10 hrs
Compressive Strength of Mortar -3 Days -7 Days	 20 Mpa 25 Mpa	 ≥ 15 ≥ 23
Autoclave (Soundness)	0.12	≤ 0.8

B - Crashed Waste Glass (CWG)

All types of glass that used in this research paper were brought from landfall ground in Baghdad. Glass is non-crystalline material (amorphous) see figure -1, that appeared in the amorphous state for all glass that used in this research, each type of broken glasses was crushed individually by ball milling machine figure -2 and 3, and then mixed together with same weighting for each concentration. In addition to, all the three types of glass have the same range of particle size (75-600) µm. Whereas, the chemical analysis by Energy Dispersive X- Ray Fluorescence Spectrometer (EDX-7000) of glasses powder show that have a high content of calcium (Ca), silicon (Si), aluminum (Al) and iron (Fe) in the powder. In the same of time Ordinary Portland Cement have almost the same content but with different percentages. These results encouraged us to utilize it as a partial replacement of cement and study its effect in the field of mechanical and physical properties.

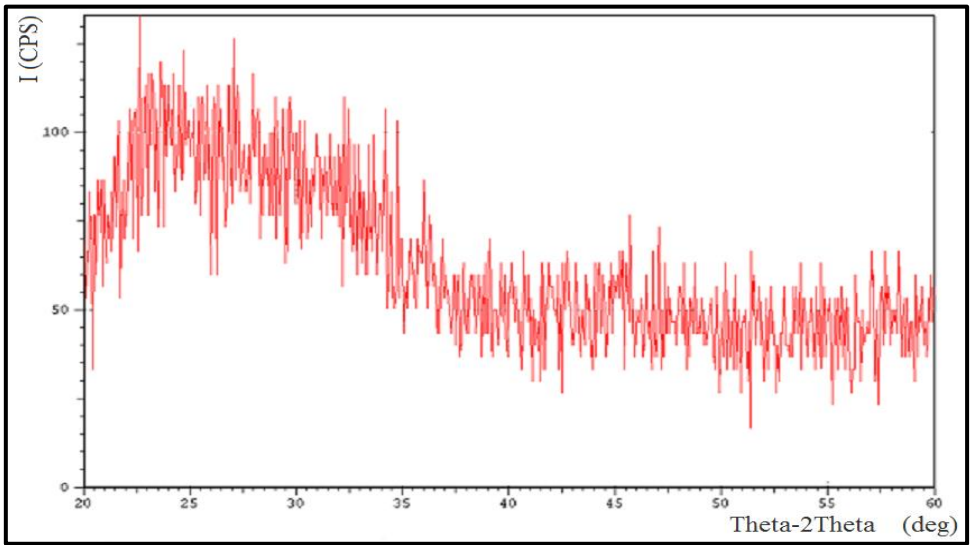

Figure-1: X-ray Diffraction of all waste glass

Figure -2: Ball machine mill.

Figure -3: Waste glass powder after milling.

C- Aggregate

The fine aggregate that used in this research is in line with zone II (5-19) mm of IQS No: 45 has fineness modulus 1.83, specific gravity 2.6, and water absorption 2%. While coarse aggregate that used (19/5) with specific gravity and absorption (2.68, 0.58) shown respectively

D- Water

Spigot water was used in this research for all mixing and curing process.

II-Mixing Procedure

A pan with capacity (0.1 m^3) was utilized to supply the mixture of the concrete. Dry heterogeneous aggregates (sand and crashed gravels) were first admixed together for (2) minutes. In addition, Cement and a partial replacement material of the cement were mixed and added to the first mixture of aggregate, the total drying mixing time of the materials for (10) minutes. Then water was added to the total mixture, the mixing process was by trowel and hand, this process continues for (10-15) minutes.

III- Specimens

The type and dimension of specimens that used in this research cubic, cylindrical, and splitting specimens (3.94 inch. [100mm], 16 inch [40mm] length and 3.94 inch [100mm] the dimensions of both width and height, 4 inch [10mm] diameter and 8 inch [20mm] height) have shown respectively figure -4.

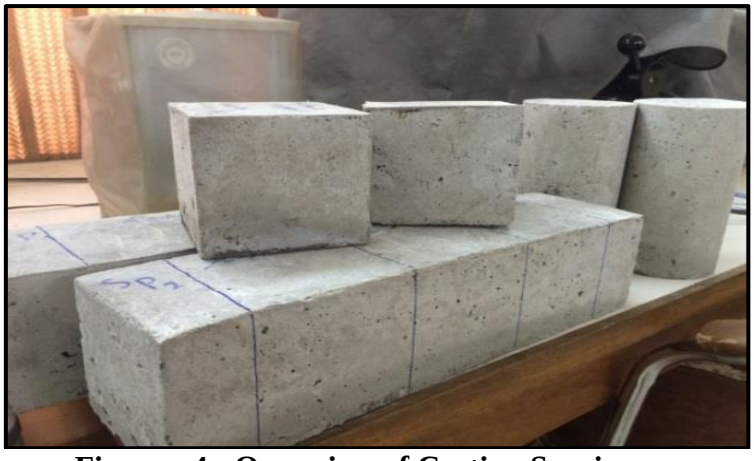

Figure - 4: Over view of Casting Specimens.

IV-Testing

The compressive strength was done in this research according to the **(B.S. 1881: part 116)**, while flexural tensile strength and splitting tensile strength according to **(ASTM C-78)**, and **(ASTM C-496)** respectively. Whereas, water absorption test was done according to **(ASTM C642)**.

4. Results and Discussion

I-Compressive Strength

The evolution of compressive strength of the normal concrete and different concentrations of the mix glass that worked as a partial replacement of cement with curing shown in figure -5.

The results pointed out that the compressive strength increased proportionally with curing process because the hydration process still continuous until getting the full strength of concrete, but in case of using mixing of waste glass as a partial replacement of cement, appeared reduction in compressive strength less than normal concrete at all concentrations. The reason may be due to the reduction in calcuim hydroxide after reaction that played a major rule in production calcium silicate hydration that responspile on the strengthen of concrete. Also, the presence of impurties in each in the crashed waste glass affected the strength properties of the concrete.

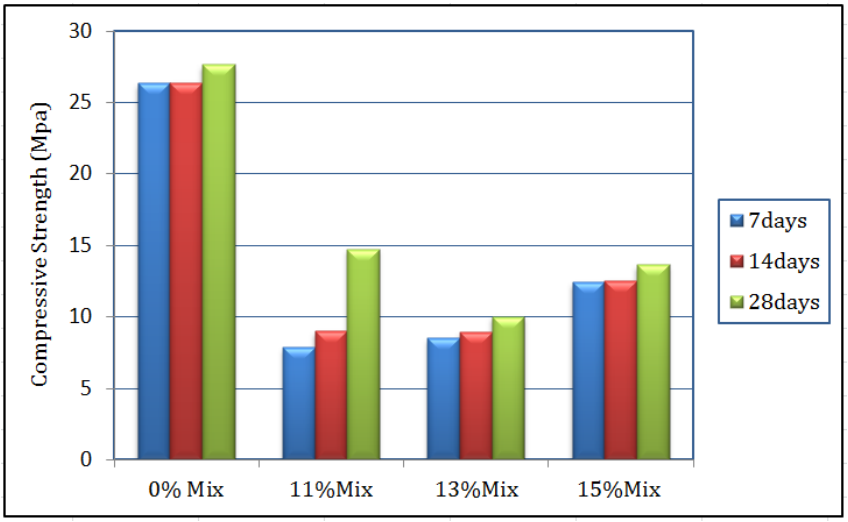

Figure -5: Compressive strength of mix glass as a partial replacement of cement.

II-Flexural Tensile Strength

The bending tensile strength for the normal concrete without any replacement, and mixing of waste glass shown in figure -6. It is showed that the flexural strength at all concentrations for mixing the crashed waste glass decrease to the half of the normal concrete because of reduction in calcium hydroxide, and presence of impurities in the waste glass.

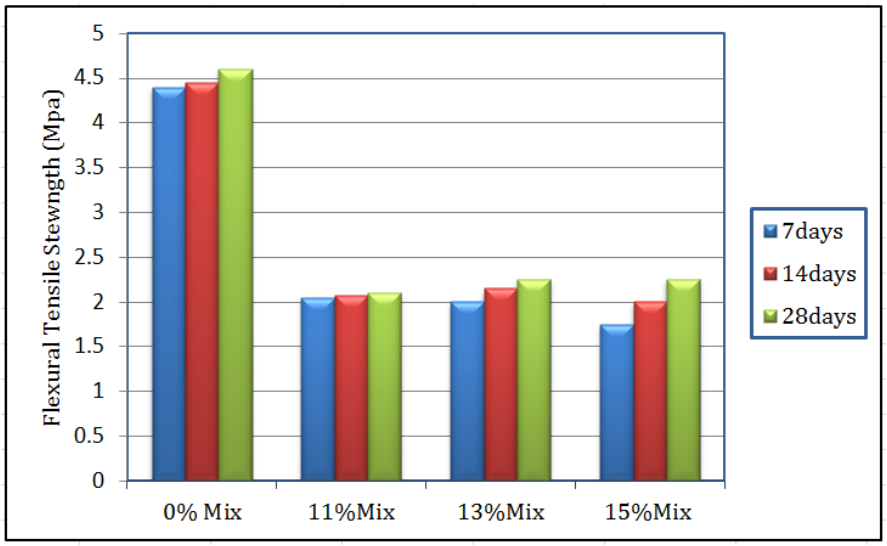

Figure -6: Flexural tensile strength of mix glass as a partial replacement of cement.

III- Splitting Tensile Strength

The results of this test for normal concrete and three concentrations of the crashed waste glass, as a partial replacement of cement in the concrete at ages (7, 14, 28) days as shown in figure -7, respectively.

The results appeared a very high reduction on splitting tensile strength at all concentration of partially replacement of cement. As we maintained in the previous testing, the important compound in the concrete that have the capability to improve the strength of concrete was calcium- silicate hydration (C-S-H). Thus, the slightly reduction in this compound affected the final properties of concrete.

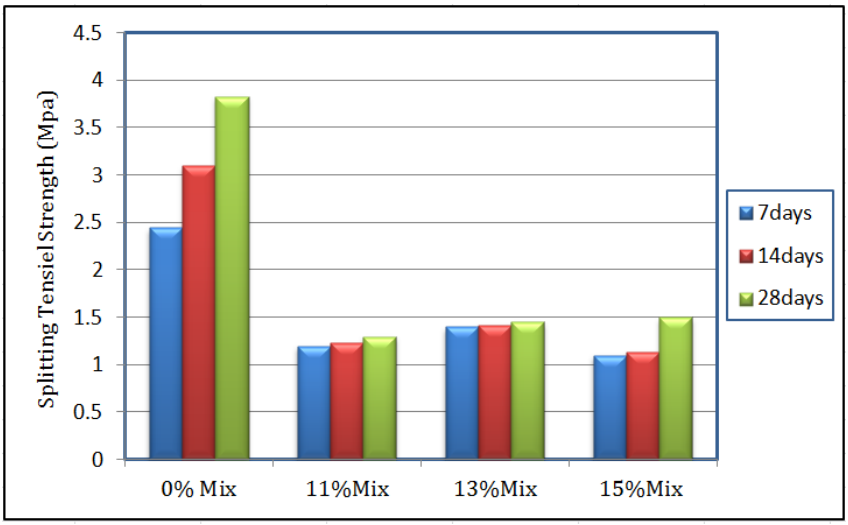

Figure -7: Splitting tensile strength of mix glass as a partial replacement of cement.

IV- Water Absorption

Cubic samples with dimension (100 mm) have de-molded after 24 hrs of casting. The de-molded samples were oven-dried at temperature (100-110 °C) for 24 hours, and then the samples were taken out in order to be weighted. In the second step, the samples soaked in water for 24 hours; the samples were taken out in order to dry the surface of the samples with dry cloth, and then weighted them. The test was applied at curing time (7, 14, and 28 days). The results showed that mixing glass

exhibited the reduction in water absorption proportionally with increasing the dosage of partial replacement material even with increasing of curing time, as compared with normal concrete that shown in figure -8.The reason behind this behaviour that the decrement in water absorption due to the continuous hydration process to produce more calcium silicate hydration (C-S-H) by consuming calcium hydroxide (CH), that played a major rule in filling the pore that existed in microstructure of concrete. Also, glass has a low capability to absorb water.

V-Slump Test

Slump test measures the workability of normal concrete and marble powder with different concentrations, which works as a partial replacement of cement. The results showed the capability to homogeneity during blending the mixture of water to cement (w/c) ratio 0.45 due to the pozzolanic reaction, but reducing the workability of the mixture up to (1.5) as shown in figure -9 **(ASTM C143-03)**.

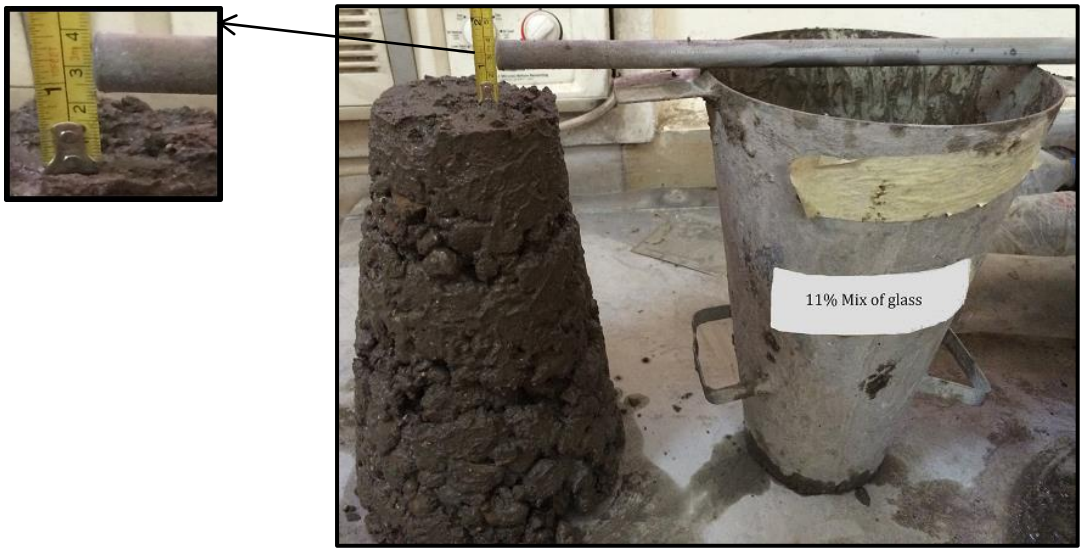

Figure -9: Slump measurement for 11% mix of glasses as a partial replacement of cement in the concrete mixture.

5. Conclusion

According to the results above that turnout, an effect of mixing crashed waste glass on the mechanical properties of concrete. Where the compressive strength show very high reduction more than the normal concrete at 13% of mixing glass at (28 days) of curing time. Also, flexural and splitting tensile strength shows decreasing in tensile strength at 11% of the partial replacement of cement at the same age of curing. Although, the utilization of mixing of the crashed waste glass consider effective way to dispose of waste glass on the ground; but appear reduction in general properties of concrete, and the presence of mixing of the crashed glass inside the concrete form a little amount of calcium carbonate ($CaCO_3$) in the concrete, have a harmful effect because it reduces the alkalinity. Also, the ability to releasing carbon dioxide (CO_2). Thus; reduce the durability of the concrete, and it cannot be used as a partial replacement of cement, because of a negative effect on the environment for pre-long of time.

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