The effect of replaced recycled glass on thermal conductivity and compression properties of cement

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Abstract. This study deal with recycling of waste colorless glass bottles which are prepared as a powder and use them as an alternative for cement to save the environment from west and reduce some of cement(ceramic) damage and interactions with conserving physical properties of block concrete. Different weight percentage (0%, 2%, 4%, 5%, 6%, 8%, 10%, 15%, 20%, and 25%) of recycled glass bottle were use in this research to be replaced by a certain percentages of cement. Thermal conductivity was studied for prepared samples. Results show that the thermal conductivity decrease with the increase of weight percentage of glass powder comparing with the stander sample.

1. Introduction
Cement (Portland cement) is on kind of a ceramic material [1] The importance of ceramic materials in the possession of a high melting point, good mechanical chemical properties and they provide first-hand in most parts of the world [2,3]. The most important hydraulic cement used extensively in various types of construction as mortars, grouting plasters, and concrete. The Portland cement mainly as calcium silicates and aluminates and even smaller quantities of potassium and sodium oxide may also be present [4]. Cement is one of the most cost and energy-intensive components of concrete. Across the world, significant environmental problems result from the manufacture of Portland cement. [5]. The heat produced by the hydration of cement may prevent freezing of the water in the capillaries of freshly placed concrete in cold weather, and a high evolution of heat is, therefore, advantageous [6]. Most of the world suffer from the problem of the accumulation of industrial waste and special waste resulting from the concentration of defective material or because of consumer use, such as broken glass and causing other environmental and health problems that require the development of practical solutions to get rid of them through the re-use or by taking advantage of them partial substitute for some construction materials (cement, sand,) involved in asphalt or concrete admixtures [7-10]. The reuse of waste glass is one of the most important issues around the world due to the increase of solid wastes in the landfill and non-degradable nature at its disposal. The use of recycled waste glass in concrete has attracted much interest worldwide and numerous researchers have been carried out, showing the possibility of use of waste glass as building materials by partially replacing concrete mixtures (Shi and Zheng 2007)[11]. The glass powder pozzolanic of materials that can be added to concrete or mortar (pozzolanic material) or cement paste. pozzolanic materials are natural materials or industrial contain the active silica (amorphous) and which are the Association of properties when they
interact with calcium presence of water and varying unusual heat hydroxide, (Ca (OH)2) and calcium hydroxide is one of the outputs of the process of cement interaction with water Shown in the ‘figure 1’. This research deal with replacing cement with recycling transparency bottle glass powder.

![Figure 1](image1.png)

**Figure 1.** Schematic representation of the formation and hydration of Portland cement [12].

2. **Experimental work**

2.1. **Cement**

In this study, Portland cement was used, commercially known as (TASLUJA), which stored in dry place. Particle size was examined by using Mastersizer 2000 laser diffraction particle size analyzer delivers rapid as shown in ‘figure 2’ and chemical analysis was used to study the cement Chemical composition and main compounds, the material analyzed according to ASTM C150- 02. The result agrees with the standard value as shown in (table 1) and (table 2) which show the calculation potential composition of Portland cement by Bogue’s equation [13] as shown in ‘figure 2’.

![Figure 2](image2.png)

**Figure 2.** Particle size of cement. The diameter from (5.344 µm- 57.822 µm)

| Table 1. Chemical composition and main compounds (Bogues) equation) of Portland cement |
|-----------------|-----------------|-----------------|-----------------|
| Element         | Content %        | Standard[14]    |
| SO3             | 2.33%            | 3.0 max         |
| Na2O            | 0.4366%          | --              |
| Fe2O3           | 2.611%           | 6.0 max         |
| SiO2            | 24.24%           | 20 min          |
| CaO             | 60.18%           | --              |
K2O 0.698% --
MgO 1.318% 6.0 max
AL2O3 2.53% 6.0 max
L.O.I 5.86% --

**Table 2.** Potential composition result for Portland cement (Bogue’s equations) [13]

| Element | Expe. Content % | Standard[15] |
|---------|----------------|--------------|
| C3S     | 39.99          |              |
| C2S     | 39.33          |              |
| C3A     | 2.286          |              |
| C4AF    | 7.945          |              |

2.2. *Fine aggregate (sand)*

According to the ASTM C33-03, the proportion of salt in the sand used in this research studied and the results show a good agreement with standard values as shown in the (table 3). By sieving (1kg) of the used sand the particle size of sand was measured by using different size of sieves (9.5, 4.75, 2.36, 1.18, 0.60, 0.30, 0.15) mm respectively, and then weighing the outcome of sand for each sieve, the result show a good agreement with standard values, as shown in (table 4)

**Table 3.** Chemical composition of sand

| Element | Expe. Content % | Standard[15] |
|---------|----------------|--------------|
| SO3     | 0.6%           | 0.5%         |

**Table 4.** Grading of fine aggregate*

| Sieve size(mm) | Weight % Passing by | Specification Limit[15] |
|----------------|---------------------|-------------------------|
| 9.5            | 100                 | 100                     |
| 4.75           | 93.2                | 90-100                  |
| 2.36           | 84.2                | 75-100                  |
| 1.18           | 68.0                | 55-90                   |
| 0.60           | 37.8                | 35-59                   |
| 0.30           | 19.6                | 8-30                    |
| 0.15           | 8.8                 | 0-10                    |

2.3. *Recycled Transparent Glass Bottles (RTGB)*

The glass used in this study is from the waste, it is colorless glass bottles used as partial substitute for cement, at first all bottles washed carefully and then crushed in a mill specification. The particle size of the glass powder was examined by the Mastersizer 2000 laser diffraction particle size analyzer delivers rapid. The diameter is in between (3.733 μm - 51.938 μm) as shown in ‘figure 3’
3. Chemical analysis
The used Glass was analyzed according to ASTM C618 and the result showed a good agreement with standard values of element as shown in the (table 5).

**Table 5.** Chemical composition of glass powder

| Element | Content % | Standard % [14] |
|---------|-----------|-----------------|
| SO₃     | 0.7%      | ---             |
| Na₂O    | 13.626%   | 12-15%          |
| Fe₂O₃   | 1.321%    | ---             |
| SiO₂    | 72.52%    | 73%             |
| CaO     | 7.21%     | 10%             |
| K₂O     | 0.227%    | ---             |
| MgO     | 2.208%    | ---             |
| AL₂O₃   | 1.75%     | ---             |
| L.O.I   | 0.347%    | ---             |

4. Water
According to (IQS 1992/1703). Ordinary drinking water was used for all concrete admixtures.

5. Sample preparation
According to ASTM C133-97 standard, the molds were prepared by using wood. According to ASTM C109/C109M, the weight percentages of the used components of concrete, cement, sand, and water was (1:2.75:0.485) respectively. ‘Figure 6’ shows the Scheme Stages of sample preparation.
6. Thermal Conductivity Measurement
Lee's disc method was used to measure thermal conductivity and Compressive test have been done according to ASTM C109/C109M-02 for prepared samples.

7. Results and discussion
The effect of waste glass addition on Thermal conductivity is shown in ‘figure 7’ and list in the (table 8). The result show that thermal conductivity coefficient gradually decreases with increasing of recycling glass content in specimen because of thermal conductivity of class is less than cement. Sand as a fine aggregate has a good thermal conductivity, replacing the cement with recycling glass powder...
will reduce the ability of sand to heat transfer [16]. The recycled glass then will be function as sand in term aggregates are uniformly distributed in the mix but in same time reduce the ability of concrete to transfer heat. These results are a good agreement with by Krishnamoorthy [17].

**Figure 5.** Thermal conductivity (K) vs Mixing rates for samples.

| Sample | K (W/m°C) |
|--------|-----------|
| 1      | 0.30      |
| 2      | 0.29      |
| 3      | 0.28      |
| 4      | 0.28      |
| 5      | 0.27      |
| 6      | 0.27      |
| 7      | 0.27      |
| 8      | 0.25      |
| 9      | 0.22      |
| 10     | 0.21      |

Compressive strength results show that maximum value for compression strength was at 4% of additives and these results showed a decrease of maximum stress for concrete samples with increasing the weight percentage (wt. %) substituted cement which means decrease in adhesive material and the maximum stress increase in the low ratios as shown in the ‘figure 7’. increases of glass wt. % will lead to failure the samples 8, 9 and 10 which shows the vertical view spread of the cracks.
8. Conclusion

Replacing cement with recycled glass bottles powder show that:
1. Possible to use west in a useful way to protect the environment and return to use with good production properties.
2. The obtained results show that thermal conductivity decrease with increasing wt% of replaced glass powder.
3. Compressive strength results show that maximum value for compression strength was at 4%wt% replaced glass powder.

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Figure 6. Compressive strength v.s to various percentages Replacement of Glass powder with cement.
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