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# The Effects of Petroleum Products on Reactive Powder Concrete Using Waste Glass as a Partial Replacement for Fine Aggregate

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**Abstract:** ***The aim of this research is to study the effect of partial replacement of river sand with glass wastes on some of the mechanical properties (compressive strength, flexural and absorption) of reactive powder concrete (RPC). Moreover, the effect of curing the samples has been studied by using two types of curing (water and kerosene). RPC was designed using local cement, silica fume, and super plasticizer with a water/cement ratio of (0.2) to reach a compressive strength of (70 MPa) at the age of (28 days). (58 cubes) and (48 prisms) have been casted and tested with four percentages of glass wastes replacement (0%, 25%, 50%, and 100%). The results showed that the (25%) of glass wastes replacement increased the compressive strength of RPC up to (4.35 and 2.6) % and the flexural strength up to (4 and 2.2) % for both methods of curing (water and kerosene) respectively. A reduction in the compressive strength, flexural strength, and absorption has been produced when the percentage of glass wastes was increased more than 25%. Furthermore, the results showed that the mechanical properties of samples cured in oil product (kerosene) were reduced when compared to those cured in water.***

**Keywords:** Reactive Powder Concrete (RPC), waste glass, compressive strength, oil product

## 1. Introduction

Reactive Powder Concrete (RPC) is considered as a new descent concrete with high performance. It was developed through microstructure enhancement techniques for cementitious materials [1]. It has substantial strength with high ductility which is about 250 times higher than that of conventional concrete [2]. RPC is a composition of very fine powders (cement, sand, quartz powder, and silica fume), steel fibers (optional) and super plasticizer. The super plasticizer, used at its optimal dosage, decreases the water to cement ratio (w/c) while improving the workability of the concrete. A very dense mixture can be achieved by optimizing the granular packing of the dry fine powders. This compactness gives RPC ultra-high strength and durability [3].

Oil products can be considered as one of the most vital energy resources and efficient characteristics. Their importance was increased with the discovery of hug oil reserves in different parts of the world [4]. The effect of oil products on concrete strength showed a reduction in the compressive strength up to (17%) and (11.8%) for both low and high strength concrete respectively. Also, the degree of oil absorption in concrete can be substantial measured of compressive strength [5]. The experiments showed that the RPC compressive strength in fuel oil is a bit higher than samples exposed to kerosene. This reduction was caused by the low viscosity of kerosene which made it penetrate the concrete easily when compared to fuel oil [6]. To make concrete manufactural sustainable, waste materials were used to replace natural resources. An enormous quantity of glass wastes is generated all around the world [7]. The use of these wastes as fine aggregate in concrete showed that when a (20%) replacement of glass wastes were used an increment of (15% and 25%) in the compressive strength at the ages of (7 and 28) days respectively. Also, the use of glass wastes in concrete may have an economic and environmental impact. Moreover, the use of glass wastes can maintain the natural resources of river sand and make the concrete industrially sustainable [8].

## 2. Experimental work

### 2.1 Material Properties

The adopted constitutive material properties are summarized as:

- **Ordinary Portland Cement**: It was produced by Al-Mass cement factory according to Iraqi Specification No.5/1993. The physical and chemical properties are shown in Tables (1 and 2) respectively.
- **Fine Aggregate**: A natural river sand from zone 4 according to the Iraqi Specification No. 45 /1993 with maximum size of (0.6mm) as shown in Table (3) was used in this study. The sand was free from contamination and its physical properties are shown in Table (4).
- **Glass Wastes:** The waste of window glass was adopted in this study. It was crushed and milled in the laboratory using Loss Angeles abrasion apparatus then sifted through sieves set to get the same gradation of the used river sand as shown in Table (5).

**Table 1**: Physical properties of cement

| *Property* | *Result* | *Iraqi Specifications Limits No. 5/1984* |
|---|---|---|
| Fineness, Blaine Method ($m^2/kg$) | 300 | Min 230 |
| Setting time (hr:min)<br>-Initial setting<br>- Final setting | <br>2:15<br>4:30 | <br>Min 45 min.<br>Max 10 hrs. |
| Compressive strength (MPa)<br>3 days<br>7 days | <br>19.6<br>27.9 | <br>Not less than 15 MPa<br>Not less than 23 MPa |


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**Table 2:** Chemical composition and major compounds of cement

| *Oxides* | *Content (%)* | *Iraqi Specification Limits (I.Q.S 5/1984) (%)* |
|---|---|---|
| CaO | 64.07 | - |
| $Fe_2O_3$ | 4.28 | - |
| $Al_2O_3$ | 3.92 | - |
| $SiO_2$ | 20.60 | - |
| MgO | 1.93 | Max 5 |
| $SO_3$ | 2.19 | Max 2.8 |
| L.O.I | 1.78 | Max 4 |
| L.S.F | 0.89 | 0.66 - 1.02 |
| In. Residue | 0.72 | Max 1.5 |
| *Major compounds (Bogue's equations)* | | |
| $C_3S$ | 52.16 | - |
| $C_2S$ | 21.1 | - |
| $C_3A$ | 6.43 | - |
| $C_4AF$ | 9.1 | - |

**Table 3:** Grading of fine aggregate

| *Sieve opening (mm)* | *Passing (%)* | *Iraqi Specification Limit (I.Q.S. 45/1993) (zone 4)* |
|---|---|---|
| 10 | 100 | 100 |
| 4.75 | 100 | 95-100 |
| 2.36 | 100 | 95-100 |
| 1.18 | 100 | 90-100 |
| 0.6 | 85.6 | 80-100 |
| 0.3 | 20.4 | 15-50 |
| 0.15 | 8 | 0-15 |
| Fineness Modulus (F.M) = 1.26 | | |

**Table 4:** Properties of fine aggregate

| *Item* | *Result* | *Iraqi Specification Limits (I.Q.S. 45/1993)* |
|---|---|---|
| SO3 content (%) | 0.12 | Max 0.5 |
| Bulk density (kg/m$^3$) | 1680 | - |
| Specific gravity | 2.58 | - |
| Water absorption (%) | 0.7 | - |

**Table 5:** Grading of glass wastes

| Sieve opening (mm) | Passing (%) | Iraqi Specification Limit (I.Q.S. 45/1993) (zone 4) |
|---|---|---|
| 10 | 100 | 100 |
| 4.75 | 100 | 95 - 100 |
| 2.36 | 100 | 95 - 100 |
| 1.18 | 100 | 90 - 100 |
| 0.6 | 88.3 | 80 - 100 |
| 0.3 | 33.4 | 15 - 50 |
| 0.15 | 11 | 0 - 15 |
| Fineness Modulus (F.M) = 1.67 | | |

- **Water**: Tap water was used for mixing and for the first method of curing.
- **Oil products**: The oil product used in this study was kerosene and its properties were listed in Table (6). In this study, kerosene was adopted as the second curing method.
- **Silica Fume:** Densified silica fume from Switzerland was used. Tables (7 and 8) show the chemical compositions and physical properties of silica fume respectively.

**Table 6:** kerosene properties

| *Kerosene Inspection Data* | *Results* |
|---|---|
| Moisture content (%) | 0 |
| Sulfur content (%) | 0.4 |
| Specific gravity @ 25°C | 0.8665 |
| Viscosity @ 25°C | 1.082 |

**Table 7:** Chemical compositions of silica fume

| *Oxides* | *Content (%)* | *ASTM C1240 Specification (%)* |
|---|---|---|
| $SiO_2$ | 87.59 | Min 85 |
| $Fe_2O_3$ | 1.65 | - |
| $Al_2O_3$ | 0.72 | - |
| CaO | 0.72 | - |
| MgO | 1.12 | - |
| $SO_3$ | 0.69 | - |
| L.O. I | 2.60 | Max 6 |
| Moisture content | 1.13 | Max 3 |

**Table 8:** Physical properties of silica fume

| *Property* | *Test result* | *ASTM C 1240 Specification* |
|---|---|---|
| Specific surface area, (m$^2$/kg) | 20000 | Min 15000 |
| Retaining on sieve 45μ, (%) | 4.0 | Max 10 |
| Pozzolanic Activity (%) | 105 | Min 105 |
| Bulk Density* (kg/m$^3$) | 550 - 700 | - |

* Bulk density from the manufacture data sheet was adopted (MEYCO®MS610).

### 2.2 Mix proportions

The Reactive Powder Concrete (RPC) was designed to have a compressive strength of ($f_{cu}$= 70 MPa) with water to cement ratio of (0.2) and Glineum 51 of (20 Lit/m$^3$). The mixing proportions are presented in Table (9) with the glass weight replacements of (0, 25, 50, 100) %.

### 2.3 Casting and curing

Standard cubes of (50x50x50) mm were used to study the compressive strength and prisms of (50x50x280) mm were selected to study the flexural strength of RPC. The designed mix was used to cast both cubes and prisms then the specimens were covered with plastic to ensure the humidity of the air around the specimens and to reduce water evaporation from the fresh surface for 24 hours. After 28 days of water curing, some of the specimens were placed in kerosene for (32 and 62) day.

**Table 9:** The mixing proportion of RPC

| *Mix* | *Cement (Kg/m$^3$)* | *Silica Fume 87 (kg/m$^3$)* | *Fine Aggregate (kg/m$^3$)* | *Glass waste (kg/m$^3$)* | *Water (kg/m$^3$)* |
|---|---|---|---|---|---|
| NG (0%) | 800 | 200 | 1000 | 0 | 200 |
| NG1 (25%) | 800 | 200 | 750 | 250 | 200 |
| NG2 (50%) | 800 | 200 | 500 | 500 | 200 |
| NG3 (100%) | 800 | 200 | 0 | 1000 | 200 |

### 2.4 Tests of hardened concrete


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- **Compressive strength test:** cubes were tested by applying a rated compressive axial load. The test was conducted according to B.S 1881: part 116(1985) [9]. The compressive strength was obtained by averaging the reading of three cubes.
- **Flexural test:** One-point flexural test was conducted in accordance with ASTM (293-07) [10]. A digital flexural testing machine with a capacity of (650 kN) was used and the flexural strength was obtained by taking the average of two prism.
- **Density test:** The density test was performed according to ASTM C-642, 2003 [10]. The average of three cubes at 28 days was adopted.
- **Absorption test:** Water and oil absorption were detected by calculating the average dry weight of cubes for both water and oil curing methods after being immersed for 60 days.

## 3. Results and Discussion

The effect of glass wastes replacement ratio on the compressive strength of the RPC at different ages is shown in Figure (1) and Table (10). It can be concluded that the replacement percentage of (25%) had a positive effect on the compressive strength that can reach up to (12% and 5%) at the ages of (28 and 90) days respectively. When the samples cured in water, approximately (90%) of cement chemical reactions would be completed at the age of (90 days). Therefore, the increment in the compressive strength of the sample having (25%) of glass wastes was caused by the additional compressive strength produced by strength of glass particles (E=70000 MPa). However, the results showed that increasing the percentage of glass wastes replacement to (50% and 100%) had a negative effect on the compressive strength reached to (11% and 17%) at the age of (28 days) and (29% and 34%) at the age of (90 days) respectively. Since the measured density of the glass wastes (1170 Kg/m$^3$) is closely to the sand density (1200 Kg/m$^3$), the reduction in the compressive strength for (50% and 100%) was caused by the increase of the void ratio as the percentage of glass wastes increased. Figure (3) shows the reduction of the density for the samples with the increase of glass wastes percentage.

In case of kerosene curing, the behavior of the samples was similar to those cured by water as shown in Table (11) and Figure (2).

**Table 10:** Tests result of samples cured in water

| *Sample* | *Glass wastes content (%)* | *Compressive strength (MPa)* | | |
|---|---|---|---|---|
| | | *28 (days)* | *60 (days)* | *90 (days)* |
| NG | 0 | 72.3 | 86.4 | 105.7 |
| G1 | 25 | 80.9 | 92.5 | 110.3 |
| G2 | 50 | 64.6 | 68.9 | 75.3 |
| G3 | 100 | 60.1 | 62.8 | 70.1 |

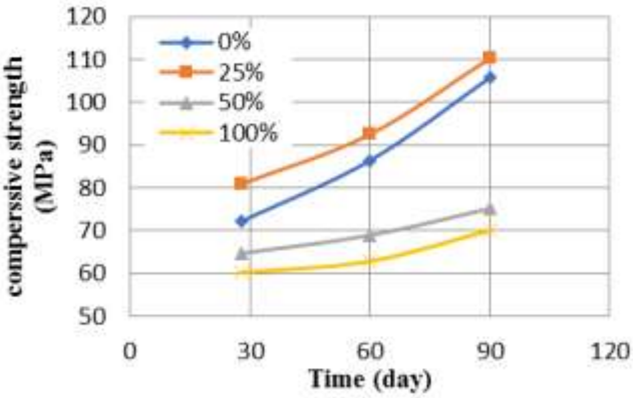


**Figure 1:** Compressive strength of samples cured in water

**Table 11:** Tests result of samples cured in kerosene

| *Sample* | *Glass wastes content (%)* | *Compressive strength (MPa)* | |
|---|---|---|---|
| | | *32 (days)* | *62 (days)* |
| NG1 | 0 | 82.2 | 100.1 |
| GR1 | 25 | 88.4 | 102.7 |
| GR2 | 50 | 65.7 | 72.4 |
| GR3 | 100 | 60.1 | 68.2 |

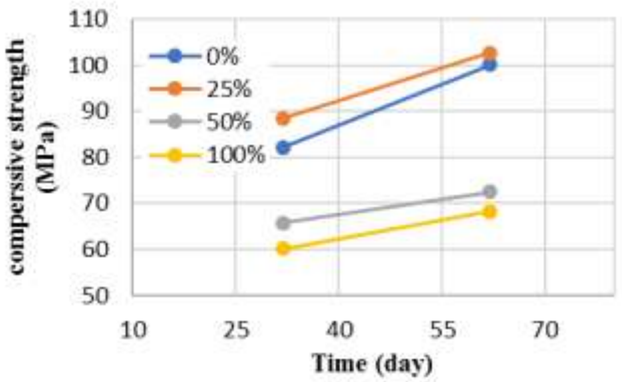


**Figure 2:** Compressive strength of samples cured in kerosene

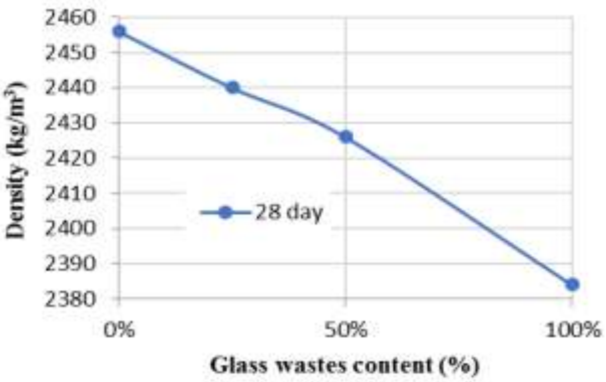


**Figure 3:** Density of samples curing in water

Table (12) and Figures (4 and 5) show the effect of the glass wastes percentage on the flexural property which was similar to that on the compressive strength with less tendency about (1-17) % and (1-18) % for both water and kerosene curing methods respectively.

A reduction in both compressive strength and flexural strength was observed in kerosene curing method. The reduction in the compressive strength was between (4.4 -


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4.8) % and (2.7 - 6.8) % for (60 and 90) days respectively while, the reduction in the flexural strength was between (6.4 - 10.1) % and (4.6 - 8.8) % for (60 and 90) days respectively. This reduction was caused by the effect of kerosene on the cementitious particles which led to a delay in the cementitious reactions.

The results of the absorption test showed that the glass wastes content is proportioned inversely with absorption percentage. Furthermore, the glass wastes had the same effect on both methods of curing as shown in Figures (6 and 7).

**Table 12:** Tests result of samples

| *Sample* | *Glass wastes content (%)* | *Flexural (MPa) – (water curing)* | | |
|---|---|---|---|---|
| | | *28 days* | *60 days* | *90 days* |
| NG | 0 | 7.5 | 8.3 | 9.8 |
| G1 | 25 | 8.3 | 8.7 | 10.2 |
| G2 | 50 | 7.1 | 7.8 | 8.6 |
| G3 | 100 | 6.4 | 6.9 | 7.8 |
| *Flexural (MPa) – (kerosene curing)* | | | | |
| *Sample* | *Glass wastes content (%)* | *32 days* | *62 days* | |
| NG | 0 | 7.7 | 9.1 | |
| GR1 | 25 | 8.9 | 9.3 | |
| GR2 | 50 | 7.3 | 8.2 | |
| GR3 | 100 | 6.2 | 7.3 | |

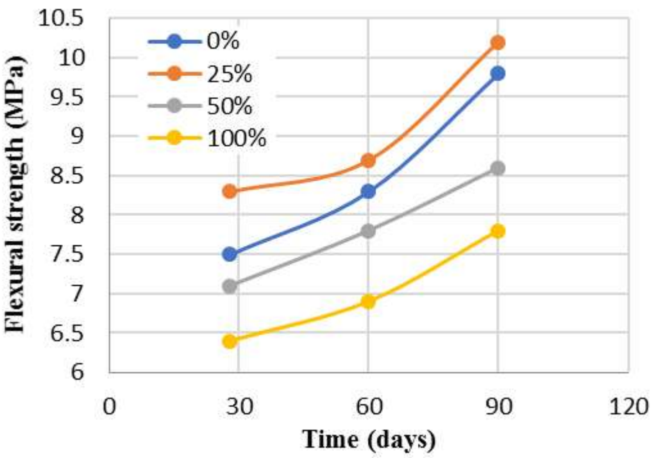


**Figure 4:** Flexural strength of samples cured in water

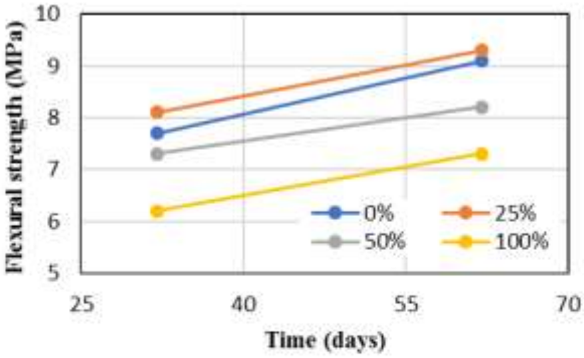


**Figure 5:** Flexural strength of samples cured in kerosene

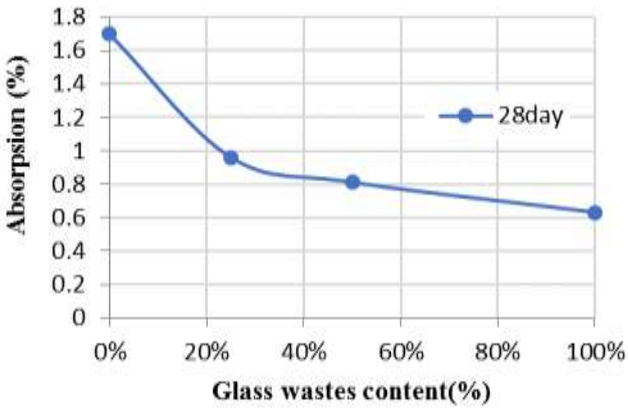


**Figure 6:** Absorption of samples cured in water

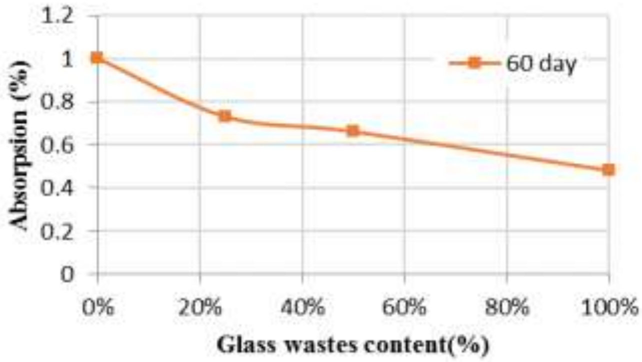


**Figure 7:** Absorption of samples cured in kerosene

## 4. Conclusions

1) Increasing the glass waste particles up to 25% as a replacement of sand had a positive effect on the compressive strength of RPC for both water and kerosene curing methods.
2) The flexural property of the RPC was modified by increasing the percentage of glass wastes particles up to 25% for both methods of curing (water and kerosene).
3) Increasing the percentage of glass waste produced a reduction in the measured density of the RPC.
4) There was a reduction in the absorption percentage as the percentage of glass wastes increased.
5) Kerosene curing method showed a negative effect on both compressive and flexural strengths.

## References

[1] Richard, P., and Cheyrezy, M., 1995, *Composition of Reactive Powder Concretes*, Cement and Concrete Research, 25(7), 1501-1511.
[2] Shaheen, E., and Shrive, N., 2006, Optimization of Mechanical Properties and Durability of Reactive Powder Concrete, ACI Materials Journal, 103(3), 444-451.
[3] Bonneau O, Vernet C, Moranville M, and Aitcin P. C, "Characterization of the granular packing and percolation threshold of reactive powder concrete", Cement and Concrete Research, Vol. 30 (2000) pp. 1861 – 1867.


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[4] Ra'ed K.H.A., 2002, "Behavior of high performance concrete in direct contact with an oil product", M.Sc. Thesis, University of technology Baghdad.
[5] Hesham Diab, 2002," Compressive Strength Performance of Low and High –Strength Concrete Soaked in Mineral Oil", Construction and Building Materials 33 pp.25-31.
[6] Sana Taha Abdul Hassain, 2013," Effect of Oil Products on Compressive Strength of Reactive Powder Concrete ", Al-Qadisiya Journal for Engineering Sciences, Vol.6, No.4.
[7] Asoka P., Mohini S., and Shyan R. "Soild Waste Generation in India and Their Recycling Potential in Building Materials", Regional Research Institute (CSIR) and (IIT), Bombay, India.
[8] M.Iqbal Malik, Muzafar B., Sajad A., Tabish T., Umar Ch.," Study of Concrete Involving use of Waste Glass as Partial Replacement of Fine Aggregate ",2003, IQSR Journal of Engineering (IQSRJEN), Vol.3, Issue 7 pp.08-13.
[9] B.S.1881: part116," Methods for determination of compressive strength of concrete cubes", British Standard Institution, 1983.
[10] ASTM C293, 2006," Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading)", American Society for Testing and Materials, 2006.

## Author Profile

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