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Influence of Waste Concrete and Glass Recycled on the Strength Properties of Green Reactive Powder Concrete

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ABSTRACT

These days, the world is facing a global environmental and sustainability problem due to the increasing generation of large amounts of waste through construction and demolition work, which causes a serious problem for the environment. Therefore, this research was conducted to get rid of the waste disposal problems, including old glass and concrete, which were used as recycled fine aggregates. Seven different mixtures were prepared. The first mixture was with the used sand, which is glass sand, and it was adopted as a reference mixture (ORPC), and three mixtures were prepared for each of the recycled materials (waste concrete and glass) and partially replaced by glass sand in different proportions (25, 50, and 75) %. Some mechanical properties, including compressive strength and flexural strength, were determined and tested at the age of (14, 28, and 90) days. Samples were processed at 20°C and heat treated at 90°C for 90 days. The results showed that the resistance reductions increased with the increase in the percentage of recycled fine aggregate, and the best replacement ratio is 25% for both materials used from waste concrete and glass.

Keywords: recycled reactive crushed concrete (RRPC), waste concrete and glass, compressive strength, bending strength, local waste.

تأثير نفايات الخرسانة والزجاج المعاد تدويره على خصائص قوة خرسانة المساحيق الفعالة الخضراء

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الخلاصة

يواجه العالم في هذه الأيام مشكلة بيئية واستدامة عالمية بسبب زيادة توليد كميات كبيرة من النفايات من خلال أعمال البناء والهدم ، مما يسبب مشكلة خطيرة على البيئة. لذلك تم إجراء هذا البحث للتخلص من مشاكل التخلص من النفايات ، بما في ذلك الزجاج القديم والخرسانة التي كانت تستخدم كركام ناعم معاد تدويره. تم تحضير سبعة خلطات مختلفة. كان الخليط الأول مع الرمل المستخدم وهو الرمل الزجاجي ، وتم اعتماده كمزيج مرجعي (ORPC) ، وتم تحضير ثلاث خلطات لكل من المواد المعاد تدويرها (نفايات الخرسانة والزجاج) ، واستبدالها جزئيًا بالرمل الزجاجي. بنسب مختلفة (25 و 50 و 75٪). تم تحديد واختبار بعض الخواص الميكانيكية ، بما في ذلك مقاومة الانضغاط وقوة الانحناء ، في أعمار (14 ، 28 ، 90) يومًا. تمت معالجة العينات عند 20 درجة مئوية والمعالجة الحرارية عند 90 درجة مئوية لمدة 90 يومًا. أظهرت النتائج أن انخفاض المقاومة يزداد مع زيادة نسبة الركام الناعم المعاد تدويره ، وأن أفضل نسبة إحلال هي 25٪ لكلا المادتين المستخدمتين من نفايات الخرسانة والزجاج.

الكلمات المفتاحية: الخرسانة المكسرة التفاعلية المعاد تدويرها (RRPC) ، نفايات الخرسانة والزجاج ، قوة الضغط ، قوة الانحناء ، النفايات المحلية.

1. INTRODUCTION

The need for high strength requirements combined with the high performance of concrete was the main reason for the introduction of Reactive Powder Concrete (RPC), and that the first person who began researching this type of concrete was Richard Cherese from 1990 until 1995, when it became possible to produce concrete RPC by establishing and presenting the basic principles relating to structure, preparation, and mixing **(Richard and Cheyrezy 1995) and (Nada and Zahraa, 2021).**

The reactive concrete powder is a high-strength ductile material made from a special blend of component materials, including Portland cement, silica fume, quartz flour, fine silica sand, high-range water reducer mixture, water, and steel or organic fibers. This new group of materials has a compressive strength of 170 to 230 MPa and bending strength of 30 to 50 MPa, depending on the type of fiber used **(Yunsheng et al., 2008).**

The construction and demolition work is currently required due to urban expansion, which necessitates more construction and infrastructure, such as housing, roads, construction works, and bridges. There is another reason for construction and demolition work, which is natural disasters such as earthquakes or problems from wars such as the destruction of many buildings, bridges, and roads. All this leads to the generation of large quantities of building material aggregates. Huge amounts of building debris have been created in Middle Eastern countries, such as Iraq. All these vectors caused a large amount of rubble. As large areas of land need to be disposed of, the average tons of construction and demolition waste (CDW) is more than 500 million, which causes a serious problem for the environment. In order to reduce the risk of waste collection, we have used building concrete and waste glass as recycled groups in the production of new concrete called Recycled Reactive Concrete Powder (RRPC) **(Sura and Ghadeer, 2021).**

2. Objective and Significance of this Research

The main purpose of this work is to determine the properties of the strength (compressive strength and flexural strength) and the effect of using recycled fine aggregates (concrete and crushed glass) on the reactive powder mortar and its properties.

3. Materials.

3.1 Cement

In this study, ordinary Portland cement (Type I) was used. It is commercially made in Iraq, known as "Al-Mass". After examining the cement, the results were in accordance with **Iraqi Standard No. 5/2019 (IQS No. 5/2019).**

3.2 Fine Aggregate (Glass Sand)

The fine aggregate used in this study is glass sand, whose maximum particle size is 600 μm and whose specific gravity is 2.24. Its gradation is within zone 4, and when examining the sand, the percentage of sulfate and absorption was 0.11% and 0.5%, respectively, which conforms to the **Iraqi specification No.45/1984. (IQS No. 45/1984).** The fineness modulus of glass sand is 1.66.

3.3 Recycled Fine Aggregate

3.3.1 Recycled concrete

The fine recycled aggregate used in this work was obtained from demolishing an old home and is in a dry surface saturation state. This house is about 60 years old, and the old concrete has been broken into small pieces by drilling, then chipping into smaller pieces with a mallet. The product was then transferred to the grinder to make it fine enough to produce (fine recycled concrete aggregate), and finally, the product was sieved using a 600 µm standard sieve and a specific gravity of 2.28. The gradient is located in Zone 4, where the absorption results and sulfate content of the recycled aggregate were 0.7% and 0.37%, respectively, which is in accordance with **Iraqi Standard No. 45/1984 (IQS No. 45/1984).** The fineness modulus of recycled fine aggregate is 1.51.

3.3.2 Waste glass

The glass was collected from the waste, thoroughly washed, and dried. It was then cut by hand with a hammer into very small pieces. Quantities of these small pieces were then put into the mill and ground, and here transient glass granules were obtained from a 600-μm sieve and a specific gravity of 2.21. The gradient is located in Zone 4, where the results of absorption and sulfate content of the recycled aggregate were 0.52% and 0.04%, respectively, which is consistent with **Iraqi Standard No. 45/1984 (IQS No. 45/1984),** the fineness coefficient of the recycled fine aggregate is 1.45.

3.4 High-Range Water Reducing Admixture

The additive BETONAC-1055 was used, which is a plasticizing additive based on polycarboxylates. It is used to produce ready-mix concrete to significantly reduce the amount of mixed water while maintaining the sedimentation rate and workability. It is chloride free and conforms to **ASTM C494 type F (ASTM C494-89).**

3.5 Silica Fume

This powder and mineral mixture was obtained from SIKA® Company in Iraq. It was used in this work. The chemical composition and physical properties are shown in **Table (1)** and **Table (2)**. That silica fume conforms to **ASTM C1240-15 (ASTM C 1240-15).**

Table (1) Chemical properties of silica fume. *

Oxide composition	Oxide content	ASTM C1240-2015
SiO_2	90.9	min 85%
Al_2O_3	0.1	-
Fe_2O_3	0.05	-
MgO	0.21	-
SO_3	0.2	-
K_2O	0.39	-
Moisture Content	1.1	Max 3%
L.O.I	3	Max 6%
CaO	0.15	-

Table (2) physical properties of silica fume

Physical properties	Test Results	Limit of specification Requirement ASTM C1240
Specific gravity	2.25	-
Fineness m^2/gm	21	Min 15 m^2/gm
Percent retained on 45µm (No. 325)	8	
Accelerated Pozzolanic Strength Activity Index with Portland cement at 7 days, min. percent of control	134.22	min 105
Physical form	Powder	-

* manufacture properties.

3.6 Steel Fibers (Sf)

The straight steel (Sf) fibers are (13) mm long and (0.2) mm in diameter. The aspect ratio is 65.

3.7 Water

The water (W) used in this research is within **Iraqi to No.1703/1992 (IQS No. 1703, (1992).**

4. Mix Proportion

Various proportions of mixing have been tried according to previous researchers **(Richard and Cheyrezy 1995)** and the author's research **(Shatha and Doaa 2020)** in order to design a control mixture containing natural substances (ORPC). Seven mixtures were prepared in the laboratory of the University of Baghdad. The first mixture is ordinary concrete with reactive powder. In order to study the effect of using waste concrete and glass as a partial substitute for glass sand used in concrete with reactive powder, we prepared six mixtures, as shown in **Tables (3) and (4)**. **Table (3)** shows the mixing ratio of mixtures with recycled concrete and in proportions (25, 50, 75)% in a mixture of (RS/C25, RS/C50, RS/C75) as a partial substitute for fine aggregate. **Table (4)** shows the percentage of mixing with glass waste material and in proportions (25, 50, 75)% in a mixture of (RS/G25, RS/G50, RS/G75) as a partial substitute for fine aggregate as well.

Table (3) Mix proportions of (ORPC), mixtures made with different percentages of (recycled fine aggregate crushed concrete)

RPC with different (recycled concrete) % replacement	ORPC	RS/C25	RS/C50	RS/C75
Portland cement C (kg/m^3)	955	955	955	955
Silica fume SF(kg/m^3)	229	229	229	229
Glass sand (kg/m^3)	1051	788.25	525.5	262.75
Recycled concrete as fine aggregate (kg/m3)	-	262.75	525.5	788.25
(SP), liters/100 kg, of cementations material	2.5%	2.5%	2.5%	2.5%
(Sf), by volume	2%	2%	2%	2%
(W) (kg/m^3)	200	205	210	215
(W/C), %	0.209	0.214	0.219	0.225
(W/(c + cm)) %	0.168	0.173	0.177	0.181
Comp. strength at (28) days (MPa) and (20)°C	121.24	115.50	108.88	101.31

Table (4) Mix proportions of (ORPC), mixtures made with different percentages of (recycled fine aggregate from waste glass)

RPC with different recycled concrete % replacement	ORPC	RS/G25	RS/G50	RS/G75
Portland cement C (kg/m3)	955	955	955	955
Silica fume SF(kg/m3)	229	229	229	229
Glass sand (kg/m3)	1051	788.25	525.5	262.75
Recycled glass as fine aggregate (kg/m3)	-	262.75	525.5	788.25
(SP), liters/100 kg of cementations material	2.5%	2.5%	2.5%	2.5%
(Sf), by volume	2%	2%	2%	2%
(W) (kg/m^3)	200	210	214	218
(W/C), %	0.209	0.219	0.224	0.228
(W/(c + cm)) %	0.168	0.177	0.180	0.184
Comp. strength at (28) days (MPa) and (20)°C	121.24	118.70	111.61	103.78

5. Test Results and Discussion

I. Compressive Strength

The compressive strength of the original mixture and replacement ratio mixtures was checked according to **ASTM C109/C109M-05 (ASTM C 109/C 109M–05).** Compressive strength samples were used to determine the compression strength using the (2000) kN test tool. The average was taken for three samples for each test age (14, 28, and 90 days). It was noted in both variants (recycled concrete and glass) that 50% and 75% had a significant decrease in the compressive strength of the reference mix, then a slight decrease when the substitution ratio was set at 25%, compared to the RPC reference mix made with natural sand (glass sand), as shown in **Tables (5) and (6**) and in **Fig. (1) and (2).** The reason may be the good bonding between the recycled aggregate used due to its high quality. The recycled aggregate from glass is due to the increase in compressive strength due to a high percentage of silica, which is silicon dioxide (SiO_2). This means that the purity of the glass is very high and does not contain many impurities, so it is a good filler. The significant decrease in compressive strength when replaced by 50% and 75% compared to the reference mixture is due to the (fine recycled aggregate) being more porous, so the adsorption was greater, as well as more microcracks in the ancient adhesive mortar. These reasons will eventually be sufficient to make the interfacial transition zone (ITZ) weak compared to the sand used **(Ahmed et al., 2017).**

The results showed that steam curing at 90 °C for only 90 days for 48 hours gave better results for the original mix and RPC with recycled aggregate in terms of higher strength than the normal treatment at room temperature (20 °C). This performance improvement is due to the fact that the microstructure of the cement matrix is extra dense compared to the standard treatment **(Zena et al., 2021).**

Table (5) Compressive strength of (RPC) with fine recycled aggregate from concrete at two different curing

(Mix No.)		ORPC	RS/C25	RS/C50	RS/C75
14 days	20ºC	85.30	79.24	74.88	68.76
28 days	20ºC	121.24	115.50	108.88	101.31
90 days	20ºC	127.76	120.90	113.20	106.00
	90ºC	139.60	132.73	125.65	118.73

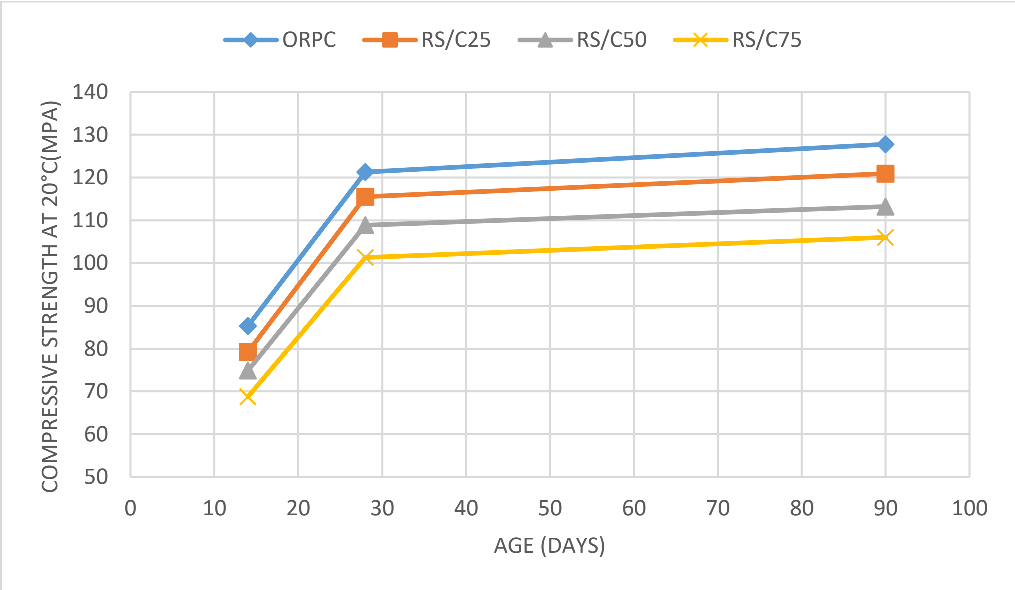

Figure 1. The compressive strength of (RPC) and (RRPC) from concrete at (20)ºC

Table (6) Compressive strength of (RPC) with fine recycled aggregate from glass at two different curing

(Mix No.)		ORPC	RS/G25	RS/G50	RS/G75
14 days	20ºC	85.30	81.36	76.07	70.14
28 days	20ºC	121.24	118.70	111.61	103.78
90 days	20ºC	127.76	123.89	116.13	109.86
	90ºC	139.60	134.79	128.61	121.60

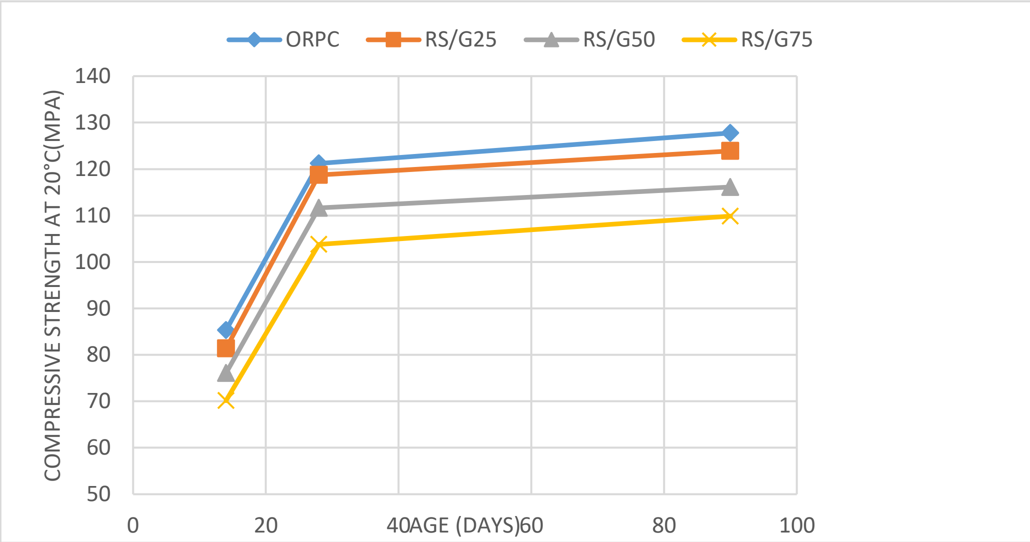

Figure 2. The compressive strength, of (RPC), and (RRPC) from glass at (20)ºC

II. Flexural Strength

This test was in accordance with **ASTM C-293-79 (ASTM 293-79).** A 40x40x160mm prism was used, and the machine capacity for this test was 10 kN. It was observed in the results that there was a greater decrease in the flexural strength when replacing 50% and 75% compared to the reference mixture, but the flexural resistance was high when the replacement ratio was low by 25%. These results were for both replacements (recycled concrete and glass), as shown in **Tables (7) and (8)** and in **Fig. (3) and (4).** This behavior is due to the recycled fine aggregate's physical and mechanical properties. Many factors affect the strength or weakness of the inter-transport zone (ITZ) between cement paste and aggregate. The most important factor is the water-to-c ratio. When water is added to the mixtures, a water film will be formed that surrounds the used aggregate particles. An increase in this amount of water will cause the follicles to grow and thus weaken (ITZ) and increase the cracks **(Ahmed et al., 2017).** Steam treatment has better results than the standard treatment. In this test, the improvement in results is due to the fact that the cement matrix's microstructure is higher density than the standard regular treatment **(Collepardi et al., 1997).**

Table (7) Flexural strength of (RPC) with fine recycled aggregate from concrete at two different curing

(Mix No.)		ORPC	RS/C25	RS/C50	RS/C75
14 days	20ºC	22.87	22.19	21.90	19.10
28 days	20ºC	25.63	24.10	22.78	19.86
90 days	20ºC	26.60	24.95	23.10	20.33
	90ºC	29.89	27.21	25.33	22.74

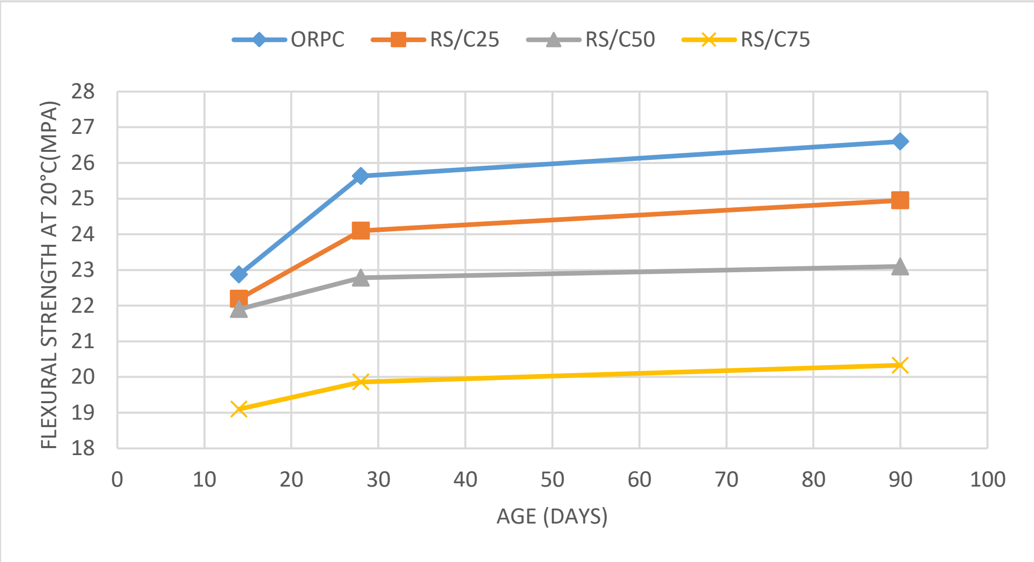

Figure 3. The Flexural strength of (RPC) and (RRPC) from concrete at (20)ºC

Table (8) Flexural strength of (RPC) with fine recycled aggregate from glass at two different curing

(Mix No.)		ORPC	RS/G25	RS/G50	RS/G75
14 days	20ºC	22.87	22.51	22.07	20.60
28 days	20ºC	25.63	24.95	24.00	22.10
90 days	20ºC	26.60	25.38	24.97	23.50
	90ºC	29.89	28.57	27.11	26.40

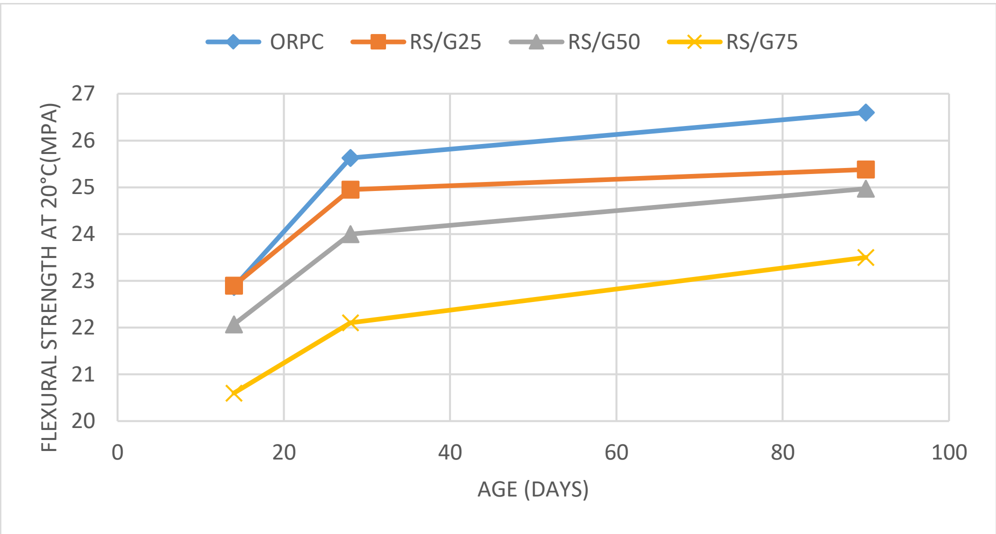

Figure 4. The Flexural Strength, of (RPC) and (RRPC) from glass, at (20)ºC

6. CONCLUSIONS

Upon completion of the work and comparing the RPC with the reactive concrete that contains recycled materials (concrete and crushed glass) as a partial substitute with different percentages of the fine aggregate used in this work, which is glass sand, it can be concluded that:

1. It is possible to produce RPC containing fine recycled aggregate as a partial substitute for vitreous sand.
2. The best replacement ratio was 25% for both materials substituted in this work.
3. The percentage decreases at 25% of replacing glass sand with recycled aggregate for concrete and glass at a normal standard temperature for 28 days were (4.73, 2.10) and (5.97, 2.65) for compressive strength and flexural strength, respectively. However, the decrease was very large at 50% and 75% replacement rates.
4. Steam treatment at 90°C on the 90th day had better results than standard treatment at 20°C for the two substituted materials.
5. The use of glass and concrete waste reduces construction's price and contributes to the proper and safe removal of waste.

References

Ahmed, L. A., Hassan, S. S., and Al-Ameer, O. A., 2017. Ultra-High Performance Reinforced by Polypropylene Fiber Concrete made with Recycled Coarse Aggregate, *Kufa Journal of Engineering*, 8(3), 128-141.

ASTM 293-79, 1979. Flexural Strength of Concrete (Using Simple Beam with Center – Point Loading Annual Book of ASTM Standards V0l. 04 02, pp 209-211.

ASTM C 109/C 109M 2005. Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens), Vol. 04.01.

ASTM C 1240 2015. Standard Specification for Silica Fume Used in Cementitious MixturAnnual Book of ASTM Standards.

ASTM C494-89 1992. Standard Specification for Chemical Admixture for Concrete, Annual Book of ASTM Standards American Society for Testing and Materials.

Collepardi, S., Coppola, L., Troli, R. and Collepardi, M., 1997. Mechanical properties of modified reactive powder Concrete, In: V-M. Malhotra Ed. Proceedings Fifth CANMET /ACI International Conference on Superplasticizers and the Chemical Admixtures in Concrete, Rome, Italy, and Farmington Hills, MI: ACI Publication SP-173, 1997.

Iraqi Specification, No.5/1984. Portland Cement, Ministry of Planning, Central Organization for Standardization and Quality Control.

Iraqi Specification, No.45/1984. Aggregate from Natural Sources for Concrete and Construction, Ministry of Planning, Central Organization for Standardization and Quality Control.

Iraqi Standard Specification, No. 1703, 1992. Water used in concrete.

Nada M. Fawzi and Zahraa F. Muhsin. Effect of Fly Ash on Some Properties of Reactive Powder Concrete, 2021 *Journal of Engineering*, No. 11 Vol. 27, November, PP. 33.

Richard, P. Cheyrezy. M., 1995 Composition of reactive powder concretes, J. Cem. Concr. Res. 25, PP. 1501‑1511.

Shatha S. Hasan and Doaa H. Nayyef, 2020. Investigation Some Properties of Recycled Reactive Powder Concrete Containing Waste Materials, PP. 46.

Sura K. Ali and Ghadeer J. Kassed, 202. 1Reuse of Glass waste as a partial replacement to fine aggregates in concrete, *Journal of Engineering*, No.8, Vol. 27 August, PP. 43.

Yunsheng, Z., Wei S., Sifeng, L., Chujie, J., and Jianzhong, L., 2008. Preparation of C200 Green Reactive powder Concrete and Its Static-Dynamic Behaviors, Cement and Concrete Composites.

Zena K Abbas, Suhair K. Abed and Duaa J. Abdullah, 2021. Study of Using of Recycled Brick Waste (RBW) to produce Environmental Friendly Concrete: A Review, *Journal of Engineering*, No. 11 Vol. 27, November, PP. 2.