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INVESTIGATION OF USING WASTE GLASS POWDER AS A SUPPLEMENTARY CEMENTITIOUS MATERIAL IN REACTIVE POWDER CONCRETE

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Some mechanical behaviors were tested by investigations of compressive strength and direct tensile strength of reactive Powder concrete (RPC) containing recycled glass powder (RGP) as a supplementary cementitious material. This study goals to survey the pozzolanic activity of recycled glass powder (RGP) up to (30%) silica fume replacement and its effect on the properties of recycled reactive powder concrete (RRPC) that made by waste glass (WG) and recycled fine concrete aggregate, which has not been investigated before. These properties contain compressive strength and direct tensile strength. Glass is principally composed of silica so that when waste glass is grind to micro particle size in RPC as a partial replacement of silica fume could be a substantial step to development of sustainable material. In this study, high strength reactive powder concrete (HSRPC) with mean compressive strength of 118.4 MPa at 28 days slightly decreased when 40% recycled fine concrete aggregate were used then the strength evolved afterward when 20% of waste glass powder WGP was utilized. The strength test outcomes indicated that waste glass powder gave greater strength compared to ordinary reactive powder concrete.

Keywords: Compressive strength, Recycled concrete, Silica fume, Steel fiber, Steam curing.

1 INTRODUCTION

In current years, the benefit of using waste glass powder (WGP) in concrete is rising because the waste glass (WG), which exists from building demolition have been increased. Recycled glass (RG) that ground to very fine powder (FP) shows pozzolanic properties so that, can replace cement or silica fume in concrete and contribute in strength development (Khatib *et al.* 2012, Jangid Jitendra and Saoji 2014, Sayeeduddin and Chavan 2016). Using recycled concrete from building rubbish of construction as recycled Aggregate (RA), instead of using ordinary aggregate, has significant advantages in preserving natural ingredients and lowering the amount of rubble materials that must be organized (Ahmed *et al.* 2017, Hassan 2018). This study reports the outcomes of the experimental study on the utilization of recycled glass (RG) powder from windows of building demolition as partially replacement silica fume in Reactive Powders concrete (RPC) containing recycled fine concrete Aggregate (RFCA) and brief behavior of RCP, including partial replacement of silica fume by WGP (10%, 20%, and 30%).

2 EXPERIMENTAL PROGRAM

2.1 Used Materials

2.1.1 *Cement*

In this study ordinary portland cement type (I) produced in Iraq was utilized throughout this research. The used cement stratifies to Iraqi specification No.5 in 1984 .

2.1.2 *Silica fume*

Micro silica from SIKA® Company in Iraq utilized as mineral admixture added to mixtures. The physical and chemical composition properties exhibit that the used silica fume (SF) stratifies to the physical and chemical requirements of ASTM-C-1240 Specifications.

2.1.3 *Waste glass powder*

Waste glass (WG) from building demolition (windows glass) was used as a mineral admixture. The glass was collected from the waste, washed well and dried. It was then hand-cut by a hammer into very small pieces. After that, quantities of these small pieces were placed in the mill and ground, after which the crushed glass in the mill was taken to the geological survey department for the purpose of grinding as powders. Oxide composition and oxide content of waste glass powder (WGP) are given in Table 1.

Table 1. Chemical properties of waste glass powder.

Oxide Composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	SO_3	K_2O	MgO	L.O.I
Oxide Content (%)	78.4	1.30	0.21	9.61	8.31	0.09	0.34	0.85	0.36

2.1.4 *Fine aggregate*

Two types of sand are utilized in this research. The first type is normal sand (NS) and the second kind is recycled sand (RS). Al-Ekhaider normal fine aggregate (NFA) with a specific gravity of 2.6 was used in this work. The recycled concrete from building demolition with a specific gravity of 2.2 was used in this study as fine recycled concrete aggregate (FRCA). The two types of sand were prepared by sieving and washing to satisfy the requirements of the research, i.e., particle size between (150 - 600) microns so that all particles greater than (600 micron) and less than (150 micron) were removed. The gradation lies in (zone 4) for the two kinds of fine aggregate (FA) used in this study.

2.1.5 S*uperplasticizer*

Superplasticizer utilized in this research is high range water reducing admixture (HRWRA) type Structuro 520 from SIKA® Company in Iraq and this material complies with (ASTM-C-494).

2.1.6 *Steel fibers*

The Steel fibers (S_f) utilized in this test program were straight steel fibers (S_f) with a nominal length and diameter of (13 and. 0.2) mm respectively. The aspect ratio is equal to 65.

2.2 Mix Proportions and Curing

Five mixes were used in this research. The first mix represents the original RPC, while the second mix ($RRPC_0$) represents the reactive powder concrete produced by replacing 40% of NFA by fine recycled concrete aggregate (FRCA) as a partial replacement by weight. The additional mixes ($RRPC_1$, $RRPC_2$, $RRPC_3$) were prepared to examine the impacts of replacing the NFA with fine recycled concrete aggregate and replacing the silica fume (SF) by WGP as a partial replacement of weight. The WGP is used as mineral admixture and their replacement levels were 10, 20 and 30%. Many mix proportions according to author research (Hassan 2006, Hasan 2019), and other previous research (Richard and Cheyrezy 1995) were tried in the present research to have ultra-high strength of original RPC and recycled RPC made with recycled concrete, in order to examine the impact of utilizing WGP as a supplementary cementitious material in RPC containing recycled aggregate.

Table 2. All mixes used in the present.

Materials (kg/m^3)	RPC	$RRPC_0$	$RRPC_1$	$RRPC_2$	$RRPC_3$
C	940	940	940	940	940
SF	210	210	189	168	147
NFA	990	614	614	614	614
FRCA		367	367	367	367
WG			21	42	63
W/C (%)	0.210	0.220	0.220	0.220	0.222

After twenty-four hours from Casting, the specimens were molded. Then RPC and RRPC specimens were moist cured in two different conditions. The first condition at a temperature of 20^{o}C while the second condition was steam curing at 90^{o}C after the samples curing at 20^{o}C, which is the room temperature for 24 hours.

3 RESULTS AND DISCUSSION

3.1 Compressive Strength

Compressive strength was determined by utilizing cubical samples (50*50*50) mm utilizing a digital compressive machine ELE international company with a rate of load 15000 kN/min and with a capacity of (2000 kN). The average of three samples was determined for compressive strength in (14, 28, and 90) days after removed from the curing solution. The results of the compression test on ordinary reactive powder concrete (RPC) and reactive powder concrete with waste materials (RRPC) cubes are shown in Table 3. Figure 1 and Figure 2 show the effect of curing at room temperature and 90^{o}C, respectively on compressive strength of RPC and RRPC mixes at various ages.

Table 3. Compressive strength (MPa) of RRPC and RPC with two different curing.

Curing	Days	RPC	$RRPC_0$	$RRPC_1$	$RRPC_2$	$RRPC_3$
	14	82.2	79.88	81.9	88.67	78.19
20 ^{o}C	**28**	118.4	117.08	119.34	125.82	114.99
	90	124.5	122.2	124.45	131.11	120.12
	14	109.2	106.88	108.33	114.61	104.3
90 ^{o}C	**28**	134.5	131.18	133.34	140.31	129.11
	90	137.6	134.1	134.81	142.22	131.12

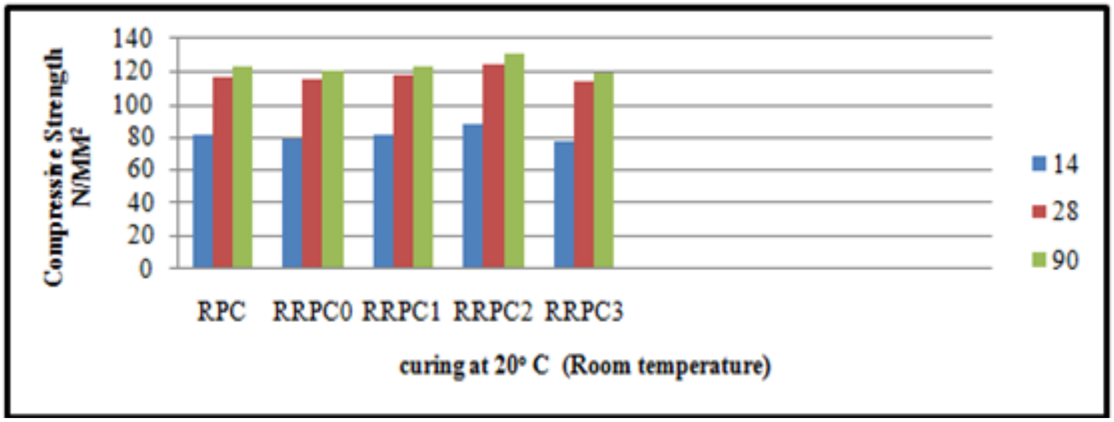

Figure 1. Compressive strength (MPa) at room temperature for all mixes.

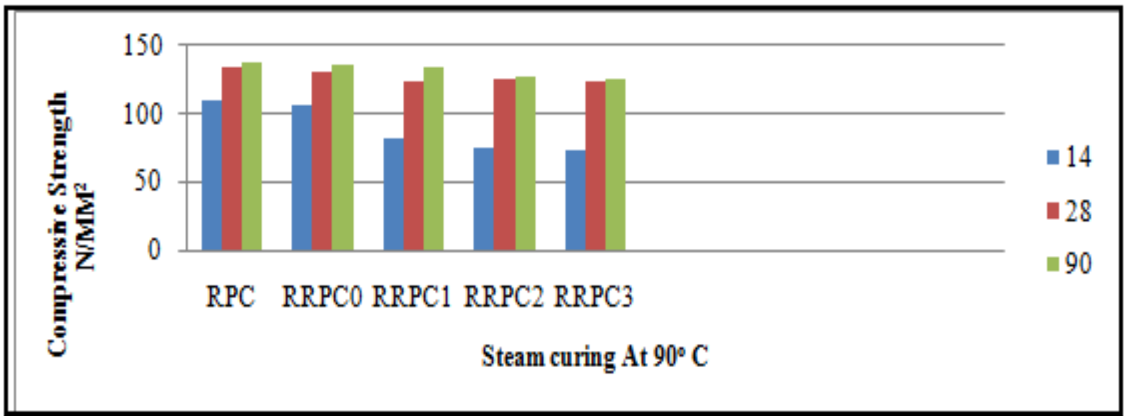

Figure 2. Compressive strength (MPa) at steam curing for all mixes.

The values of compressive strengths for RPC with waste glass powder vary between 120.12 MPa (for $RRPC_3$) and 131.11 MPa (for $RRPC_2$) at room temperature while the values of compressive strengths for RPC with waste glass powder at 90ºC vary between 131.12 MPa (for $RRPC_3$) and 142.22 MPa (for $RRPC_2$) for 90 days. Figure 2 shows the impact of utilizing recycled concrete on the compressive strengths of concrete incorporated with WGP. The outcomes show that increasing in the replacement level of SF by glass powder resulted in a slight decrease in compressive strengths of mixes ($RRPC_1$, $RRPC_3$) compared to original RPC. comparable, outcomes have been reported by other researchers (Sayeeduddin and Chavan 2016). The increases in strength up to (20%) replacement of cement by WGP may be due to the pozzolanic activity of WGP. Also, it effectively fills the voids and gives a dense concrete microstructure. Thus, it can be concluded that (20%) was the optimum level for replacing silica fumet with WGP. Although concrete with a 40% replacement level of fine aggregate $RRPC_0$ provides lower compressive strength than the ordinary RPC, these results agree with the results of other research (Hassan 2018, Hasan 2019, Ahmed *et al.* 2017).

3.2 Direct Tensile Strength

Dogbone-shaped of 76 mm length, 25 mm thickness and 645 mm^2 cross-section at mid-length were prepared for direct tensile strength tests at all ages, according to B.S 6319-7:1985. Figure 3 and Figure 4 illustrate the results of direct tensile strength for standard and steam curing, respectively. The maximum direct tensile strength achieved at 20% glass powder, which exceeds RPC and $RRPC_0$ by 9.6% and 15.95%, respectively, is due to glass powder in concrete having a function similar to SF in the pozzolanic reaction and binding process. After that, when 30% of glass powder was used, we also got a reduction in direct tensile strength by 11.03% and 5.88%, respectively, compared to RPC and $RRPC_0$.

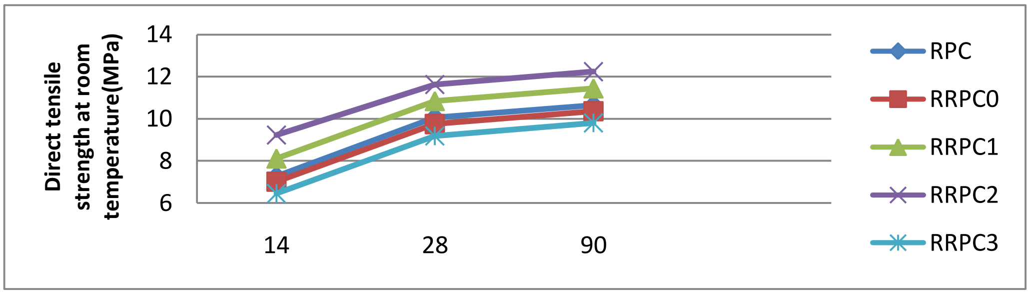

Figure 3. Direct tensile strength (MPa) at room temperature for all mixes.

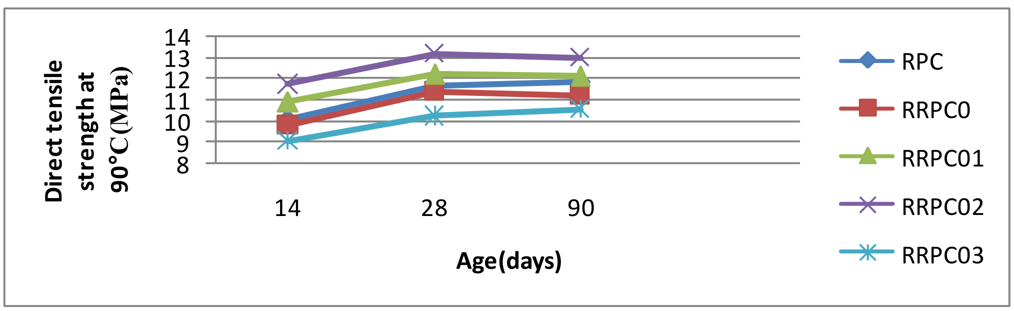

Figure 4. Direct tensile strength (MPa) at 90°C for all mixes.

4 CONCLUSIONS

Waste glass powder (WGP) partially replaced the silica fume in reactive powder concrete at 10%, 20% and 30% levels. Based on the comparison with reference mixer (ordinary RPC) without waste materials and $RRPC_0$ produced by replacing 40% of fine aggregate with FRCA, the following conclusions are made:

1) The overall results of this research show that it is possible to use waste glass (WG) as partial replacement to silica fume in Reactive Powder Concrete (RPC) containing recycled aggregate. However, further research is necessary to determine the effects of utilizing waste glass on the durability and other properties such as impact strength.
2) Compressive strength and direct tensile strengths increased with time for all replacement mixtures like the conventional mixture.

3) Mixes $RRPC_0$, $RRPC_1$, $RRPC_3$ have a reduction in compressive strength and direct tensile strength compared with their reference mixture RPC. The optimum mix ($RRPC_2$), designed with a combination of using recycled aggregate (RA) as a partial replacement for ordinary fine aggregate and 20% WGP as a partial replacement for silica fume, offered higher compressive and direct tensile strength than RPC.
4) From the outcomes above, it appears that utilizing waste glass as a powder in RPC has economic and environmental support.

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