Some Properties of Mortar and Concrete Using Brick, Glass and Tile Waste as Partial Replacement of Cement

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Abstract: ***The using of waste products as a recycled material was one of the most important studies for saving money and reduces the pollution. Mortar and concrete mixes with (10, 20 and 30)% of brick, glass and tile powder as replacement by weight of cement was investigated. The concrete mixes using brick or glass as 10%replacement of cement exhibited enhancement in compressive strength about (6, 4.7 and 2.0)% and (7.2, 5.6 and 2)% at age 7, 28 and 90 days respectively compared to reference mix. The 20% replacement of glass powder also showed an increase in the compressive strength up to (8, 6.3 and 4) %at age 7,28 and 90 days respectively compared to reference mix. Finally concrete mix using (10, 20 and 30) % tile powder as replacement of cement showed a reduction in the compressive and flexural strength with less density with age.***

Keywords: recycle materials, glass powder, brick powder, tile powder

1. Introduction

The using of waste or recycled materials in concrete industry is a new technology to overcome the pollution. During production and hydration process of cement, carbon dioxide CO_2 is produced which causes serious environmental damages and that can be prevented by partially replace of cement with materials which have desirable properties that saves natural material and reduces emission of CO_2 in to the atmosphere [1].

Many studies are continuing into the use of waste materials as a partial replacement of cement like furnace slag, pulverized fly ash, and waste glass powder.At the time of hydrationof the cement thismaterialstakes some part of reaction, also it acts as a filler material [2].

Islam et al, studied flow and compressive strength tests on mortar and concrete cubes by adding (0–25)% ground glass in which water to binder (cement + glass) ratio is kept the same for all replacement levels. The compressive strength was found to be increased slightly with glass powder content. The optimum glass content is 20% considering mortar and concrete compressive strength at 90 days. In this age the compressive strength was found slightly higher (2%) than the control concrete specimen. In general, considering the similar performance with replaced material, glass additioncan reduce cost of cement production up to (14%)[3].

Naceriand Hamina, produced a cement mortar by using partial replacement of cement with waste brick in different proportions (0, 5, 10, 15 and 20) %. The compressiveandflexural strength was studied at different ages. It was found that the addition of10% waste brickenhance the setting and grinding time of cement and improves themechanical strengths.[4].

Mohammad et al,used waste Glass as a partial replacement of cement with (5, 10,15,20,25 and 30)% in concrete mixes. Some mechanical properties studied at 28 days and compare the results with conventional concrete; they also studied the size effect of glass powder on strength of concrete. The results showed that the replacement of cement by 20% of glass powder gives higher compressive and flexural strength by about 18% and 27% respectively as compare to conventional concrete. From the results it is conclude that particle size of waste glass powder less than 75 micron gives higher strength thanparticle size 90 to 150 micron[5].

Shruthi et al, investigate the effect of using waste glass on compressive and split tensile strength with (5, 10, 15, 20 and 25)% as a replacement of cement. It was found thatthe strength increases when using waste glass powderup to 15%. And also the particle size less than 90 micron enhance the strength [2].

2. Experimental Study

2.1 Materials

Iraqi ordinary Portland cement (OPC) (Type I) known as (Tassloja) was used in the investigations the chemical and physical properties of the cement were presented in Table 1. The grading, physical properties and sulfate content of the fine aggregate (sand) with Fineness modulus of 2.9 and crushed gravel of 20 mm nominal size were presented in Table 2 and 3. The Specific gravity for both fine and coarse aggregate are 2.62 and 2.65 respectively**.**The tests were carried out in material Lab. /Civ. Eng. Dep. /University of Baghdad.

Table 1: Properties of cement

Abbreviation		Results	Limit of Iraqi Specification No. 5 [6]	Limit of ASTM C150 [7]
Chemical properties (%)	CaO	62	-	
	SiO_2	20.2	-	
	Al_2O_3	4.3	-	
	Fe_2O_3	4.1	-	
	SO_3	2.27	≤ 2.8 if $C_3A \geq 5\%$	≤ 3.0 if $C_3A \leq 8\%$
	MgO	2.55	≤ 5.0 %	≤ 6.0 %
	L.O.I.	2.9	≤ 4.0 %	≤ 3.0 %
	I.R.	0.5	≤ 1.5 %	≤ 0.75 %
	L.S.F	0.8	0.66-1.02	
Bogue's equations	C_3S	64.08	-	-
	C_2S	9.57	-	-
	C_3A	4.45	-	-
	C_4AF	12.47	-	-
Blaine surface area(m^2/kg)		340	≥ 230	≥ 280
Soundness (AutoclaveMethod) (%)		0.3	≤ 0.8	-
Setting time (Vicat's method) Initial setting / Final setting		1:24(hrs.:min) / 5:40(hrs.:min)	≥ 45 min / ≤ 10 hrs.	≥ 45 min / ≤ 375min
Compressive strength (MPa) 3 days / 7 days		17.2 / 25.6	≥ 15 / ≥ 23	≥ 12 / ≥ 19

Table 2: Properties of fine aggregate

Tests		Passing (%)	Iraqi specifications No.45/1984 (Zone 2)[8]	ASTM specification C33-[9]
Sieve size (mm)	10	100	100	100
	4.75	96	90-100	95 -100
	2.36	88	75-100	80 - 100
	1.18	67	55-90	50 - 85
	0.6	49	35-59	25 - 60
	0.3	22	8-30	5 - 30
	0.15	5	0-10	0 - 10
Material finer than 0.075mm		2.9	≤ 5	≤ 5
Sulfate (%)		0.2	Max. 0.5	-
Absorption (%)		1.09	-	-

Table 3: Properties of coarse aggregate

Tests		Passing (%)	Iraqi specification No. 45 [8] (5-20)mm	ASTM specification C33[9]
Sieve Size (mm)	37.5	100	100	-
	20	96	95-100	90-100
	10	38	30-60	20-55
	5	4	0-10	0-10
Material finer than 0.075mm		1.7	≤ 3	-
Sulfate content (%)		0.03	≤ 0.1	-
Absorption %		1.05	-	-

2.2Waste bricks, glass bottle and tile with grinding process

The raw material of waste bricks, glass bottle and tile being crushed then grinded in the Building Research Center/Ministry of construction and, it was crushed, stormed then transformed into a powder finer or equal to fineness of cement for the purpose of getting the most of their effectiveness.

The chemical analysis of the brick, glass tile powders were presented in Table 4 and the strength activity index equal to (78 and 80.5) for brick and glass respectively which was conformed to ASTM C618-12 [10] (min. =75%).

Table 4: Chemical analysis of brick, glass and tile powders.

Oxides (%)	Brick Powder	Glass Powder	Tile Powder	ASTM C 618-12 [10]
SiO_2	70.6	72.8	40.5	(SiO_2+ Al_2O_3+ Fe_2O_3) $\geq 70\%$
Al_2O_3	8.5	6.5	5.6	
Fe_2O_3	0.68	1.72	2.25	
CaO	6.57	10	21.64	-
MgO	5.5	4.37	2.5	-
SO_3	1.71	0.34	0.98	$\leq 4\%$
L.O.I	2.94	3.8	20.68	≤ 10 %

2.3 Mortar and concrete mixes

Mix proportion was prepared according to ASTM C109, 2002 as presented in Table 5. Mixing was carried out by a small laboratory mortar mixture according to ASTM C109/C109 M, 2002 [11].Thedesign of the reference concrete mix with compressive strength of 30 MPa at 28 days, was according to the ACI 211.1,1991[12].

The proportion of mix was 1:1.8: 2.65 by weight of cement, sand, coarse aggregate respectively for reference mix (CR). Nine other mixes was carried with replacement of cement (10, 20 and 30) % by weight of brick, glass and tile. The mixes details used throughout this investigation are shown in Table 6. The slump test method was carried out by ASTM C143, 2005 [13]. Mixing process of concrete was performed according to ASTM C192, 2006 [14] and we prepare the replacement of powder with (10, 20 and 30) % by weight of cement of to be used in each concrete mix.

Table 5: Mortar mix proportion –for each set (5x5x5)cm

Mix's	Cement (gm)	Brick powder (gm)	Glass powder (gm)	Tile powder (gm)
MR	988	-	-	-
MB10	899	98.8	-	-
MB20	790	198	-	-
MB30	892	296	-	-
MG10	899	-	98.8	-
MG20	790	-	198	-
MG30	892	-	296	-
MT10	899	-	-	98.8
MT20	790	-	-	198
MT30	892	-	-	296

[Sand=2712and water=205](gm)

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Table 6: Concrete mix proportion

Mix's	Cement (kg/m^3)	Brick powder (kg/m^3)	Glass powder (kg/m^3)	Tile powder (kg/m^3)
CR	380	-	-	-
CB10	342	38	-	-
CB20	304	76	-	-
CB30	266	114	-	-
CG10	342	-	38	-
CG20	304	-	76	-
CG30	266	-	114	-
CT10	342	-	-	38
CT20	304	-	-	76
CT30	266	-	-	114

[Sand=686, gravel=1010and water=205](kg/m^3)

2.4 Testing of hardened concrete

-Compressive Strength Test

The compressive strength test was made according to B.S.1881: part 116 [15] by usingcubeswith dimensions100×100×100 mm. The cubes were tested using a standard compressive strength machine with capacity of 909kN.

-Flexural Strength Test

This test was carried out by usingprism specimens with dimensions 100×100×400 mm in accordance with ASTM C293, 2006 [16] on average of two prism using (TINIUS OLESN) testing machine with capacity of 650 KN.

-Dry Density

This test was performed according to ASTM C642, 2003 [16] on average of two cubic and the dry density was calculated for ages 28-day.

3. Results and Discussion

The consistency, initial and final setting and the compressive strength results for mortar mixes are presented in Table (7). Mortar mix (MB10) showed a slight increase in compressive strength up to (3.5, 1.6 and 2.0)% while (MG20) showed the optimum increase up to (3.6,4.7 and 4.3)% compared to MR at 7,28 and 90 days respectively. Mortar mixes with replacement with tile powder showed a reduction in the compressive strength with ages, as shown in the Figure (1).

Table 7: Mortar tests results

Mix's	Consistency (%)	Initial setting (min.)	Final setting (hrs.)	Compressive strength (MPa)		
				7-day	28-day	90-day
MR	28	70	6.25	28	32	34.5
MB10	29	75	6.41	29	32.5	35.2
MB20	29.5	85	6.73	27.5	31	33.2
MB30	30	95	6.85	26	30	31.5
MG10	27	80	6.5	28	32.8	35
MG20	26.5	85	6.68	29	33.5	36
MG30	26	89	6.86	28	31.5	34
MT10	26.5	82	6.62	26	28.5	31.2
MT20	26	78	6.51	25	27.1	30
MT30	25.5	75	6.45	23.5	26	28

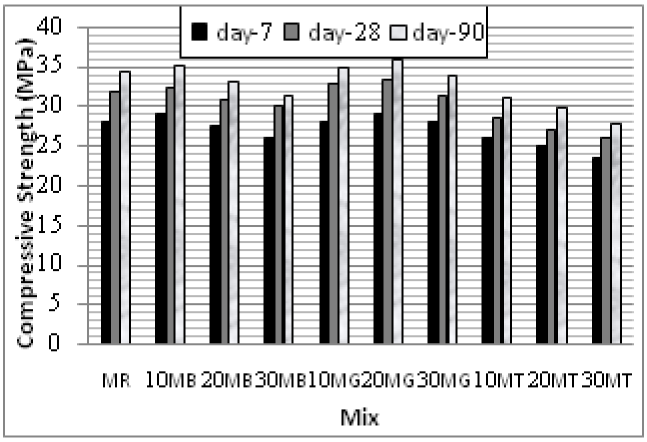
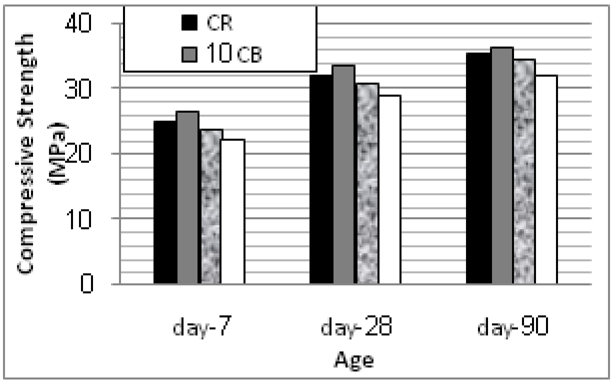


Figure 1: Compressive strength for mortar mixes

From Table (8) and Figure (2) for concrete mixes with different replacement of brick, glass and tile powder, it can be seen that the (CB10) also showed the optimum percentage increase up to (6, 4.7 and 2.0)% and MG20 up to (8, 6.3 and 4)% compared to reference mix (CR) at (7,28 and 90) days respectively. Figure (3) showed the increase and the decrees for all concrete mixes compered to CR, the mixes with tile replacement of cement showed a reduction in the compressive strength with ages.

Table 8: Concrete tests results

Mix's	Slump (mm)	Density at 28 day (kg/m^3)	Compressive strength (MPa)		
			7-day	28-day	90-day
CR	85	2380	25	32	35.5
CB10	83	2395	26.5	33.5	36.2
CB20	80	2372	24	31	34.5
CB30	76	2363	22	29	32
CG10	82	2407	26.8	33.8	36.2
CG20	77	2415	27	34	37
CG30	75	2370	24.5	31	35
CT10	80	2364	22	28	32
CT20	70	2358	21	26.2	30.5
CT30	65	2351	20	25.5	28.8



(a) Using brick powder

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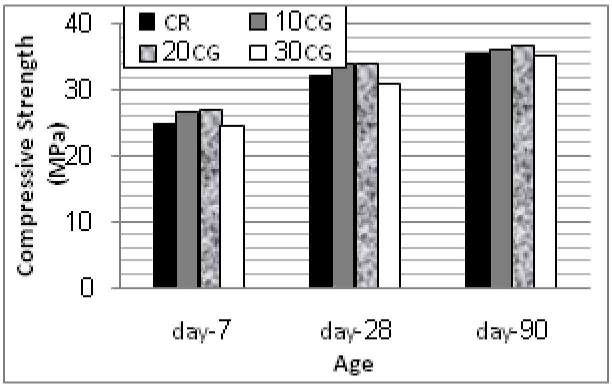
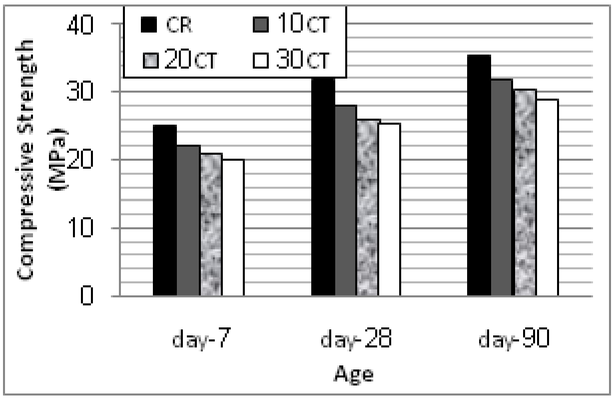


(b) Using glass powder



(c) Using tile powder

Figure 2: Compressive strength for concrete mixes

The behavior of mortar and concrete mix can be explained depending on pozzolanic reaction, since the brick and glass powder can be chemically classified as a pozzolanic powder and its strength activity index (78 and 80.5)% respectively, so the mixes using brick and glass powder showed that the possibility to replace cement with 10% of BP and 20% of GP with enhancement in the compressive strength.

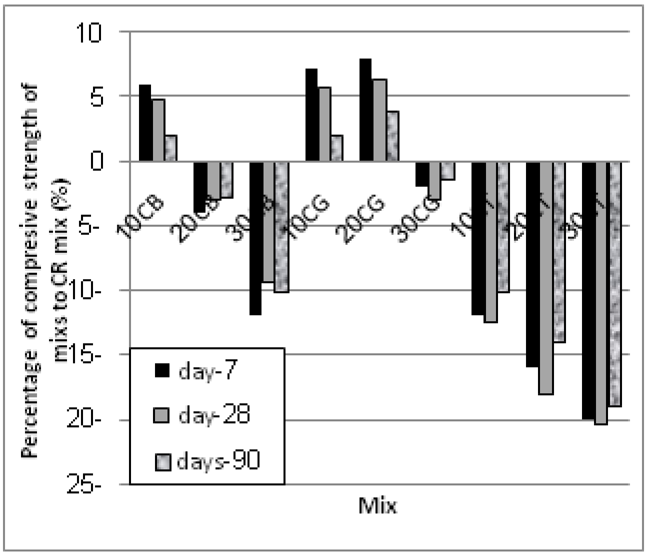
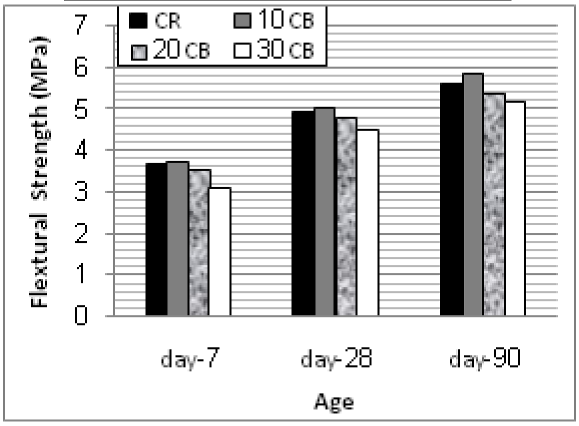


Figure 3: Percentages of compressive strength for mixes to reference mix

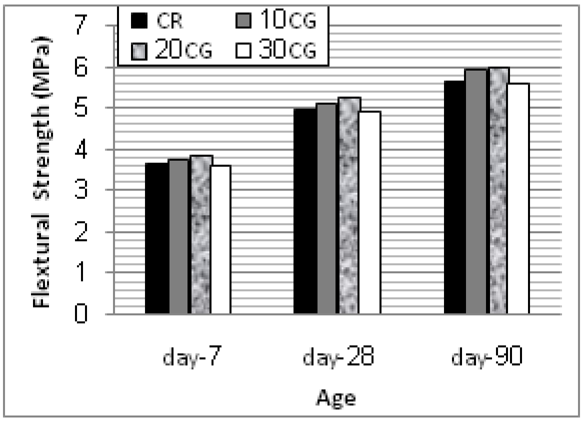
Table (9) and Figure (4) presents the flexural strength for different concrete mixes with (10, 20 and 30)% replacement of BP, GP and TP. Figure (5) showed the increase and the decrees for all concrete mixes compered to CR, for the (CB10) also showed the optimum percentage increase up to (2, 1.6 and 3.6)% and MG20 up to (6.3, 6.3 and 7.0)% at (7,28 and 90) days respectively while the mixes with TP replacement of cement showed a reduction in the compressive strength with ages.

Table 9: Flexural strength results

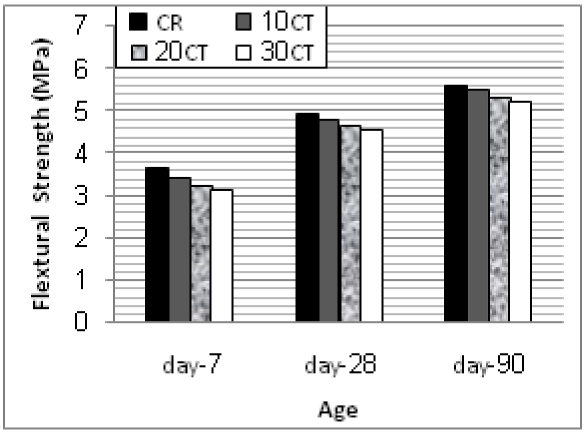
Mix's	Flexural strength (MPa)		
	7-day	28-day	90-day
CR	3.65	4.94	5.62
CB10	3.72	5.02	5.82
CB20	3.55	4.8	5.4
CB30	3.11	4.51	5.15
CG10	3.75	5.1	5.95
CG20	3.88	5.25	6.02
CG30	3.6	4.9	5.6
CT10	3.42	4.81	5.51
CT20	3.25	4.65	5.32
CT30	3.15	4.55	5.21



(a)Using brick powder



(b)Using glass powder



(c) Using tile powder

Figure 4: Flexural strength for concrete mixes

The pozzolanic reaction between silica from BP and GP with hydroxide lime liberated from C_3S and C_2S hydration in cement led to form extra gel that led to densification the structure of the cement paste, so tough the transition zone between the aggregate and cement paste with higher bond with higher density, compressive and flexural strength, while the TP inertly led to reduction the compressive and flexural strength with less density.

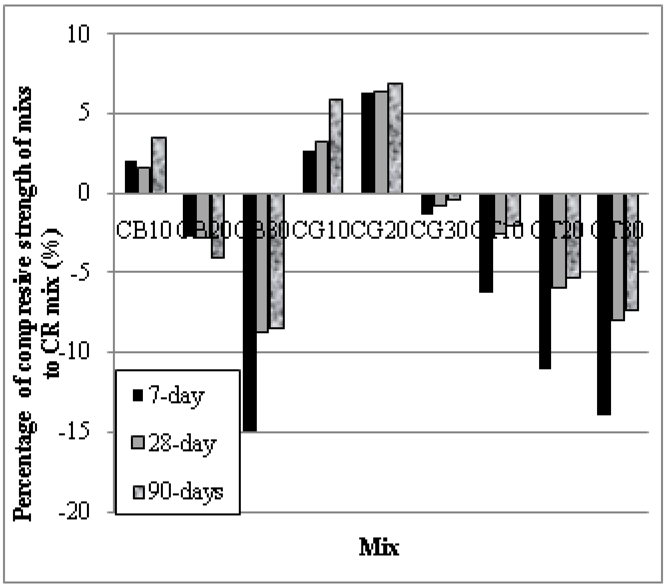


Figure 5: Percentages of flexural strength for mixes to reference mix

4. Conclusion

1) The concrete mixes using 10% brick powder as replacement of cement exhibited an enhancement in compressive and flexural strength about (6, 4.7 and 2.0)% and (2, 1.6 and 3.6)% at (7,28 and 90) days, respectively compared to thereference mix.
2) The concrete mixes using (10 and 20)% of waste glass as a replacement of cement exhibited an enhancement in compressive strength about (7.2, 5.6 and 2)% and (8, 6.3 and 4)% at (7,28 and 90)days, respectively compared to the reference mix.
3) The concrete mixes using (10 and 20)% glass powder as replacement of cement exhibited enhancement in flexural strength about (2.7, 3.2 and 6)% and (6.3, 6.3 and 7.0)% at (7,28 and 90)days, respectively compared to the reference mix.
4) The concrete mixes using partial replacement of tile powder (10, 20 and 30)% showed a reduction in compressive and flexural strength with age and less density.

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