Eng. & Technology, Vol.25, No.8, 2007

Properties of Glascrete Tiles

Shakir A. Al-Mishhadani* **Mays F. Al-Rubaie***

Received on: 2/4/2007
Accepted on: 10/9/2007

Abstract

"Glascrete" is known as a concrete in which the aggregates wholly or partially consist of crushed glass, where the glass is a unique material that could be recycled many times without changing its chemical or mechanical properties. It has been used for certain purposes where the aesthetical aspect is one of the main considerations.

This experimental work aims to evaluate the possibility of incorporating waste glass in glascrete tiles, as partial replacement for the fine aggregate. Two replacements were investigated, those are 20 and 40% by volume of fine aggregate.

The tiles are assessed with regard to the requirements of the Iraqi Standard Specification No.1042/1987, by investigating their modules of rupture and total water absorption.

The results prove that glascrete tiles with 20% and 40% of glass aggregate as partial volume replacement of natural fine aggregate are found to be acceptable with regard to the requirements of the Iraqi Standard Specification No.1042/1987.

Keywords: Glascrete, glass aggregate.

خواص بلاطات خرسانة الزجاج

الخلاصة

تعرف "خرسانة الزجاج" بانها الخرسانة التي يكون ركامها كليا اوجزئيا من الزجاج المُكسر, حيث يعتبر الزجاج مادة فريدة يمكن ان يعاد استخدامها عدة مرات من دون ان تتغير خواصها الكيميائية او الميكانيكية. وقد استخدمت لاغراضٍ محددة حيث كانت المتطلبات الجمالية تمثل احد الاعتبارات الاساسية.

تهدف هذه الدراسة العملية الى تقيم امكانية دمج المخلفات الزجاجية في بلاطات خرسانة الزجاج كتعويض عن جزء من الركام الناعم. لقد تم اختبار نسبتين تعويضيتين للزجاج المكسر , هما ٢٠% و ٤٠% كتعويض حجمي عن جزء من الركام.

لقد تم تقيم البلاطات وفقا لمتطلبات المواصفة القياسية العراقية رقم ١٠٤٢/ ١٩٨٧, وذلك من خلال اجراء فحصي معاير الكسر والامتصاص الكلي للماء.

أثبتت النتائج أن بلاطات خرسانة الزجاج الحاوية على ٢٠% و ٤٠% من ركام الزجاج كتعويض عن جزء من حجم الركام الطبيعي الناعم, كانت مقبولة وفقاً لمتطلبات المواصفة القياسية العراقية رقم ١٠٤٢/ ١٩٨٧.

* Dept. of Building & Construction Eng., University of Technology

Introduction

The safe disposal of waste materials has been always considered a major concern for the municipal facilities worldwide. But even with the heightened awareness of the importance of recycling and the restrictive legislations regarding waste disposal and landfills, the accumulation of waste materials is still uninterrupted. At that point, the idea of conversion (or recycling) waste materials into construction materials was born. It has benefits not only in reducing the amount of waste materials requiring disposal but it can also provide construction materials with significant saving over raw materials.

Glass is produced in many forms, including container glass, flat glass, bulb glass and cathode ray tube glass, all of which have a limited life in form they are produced, and need to be reused or recycled in order to avoid the environmental problems that would be created if they were to be stockpiled or sent to landfill. Glass is a unique inert material that could be recycled many times without changing its chemical properties, the efficiency of this process (i.e. recycling) is affected by several factors. Firstly, the efficiency of collecting and sorting methods for different glass colors, where, if different colors (clear, green, amber, ... etc.) are mixed, they become unsuitable for manufacturing new glass containers. Secondly, it is affected by the level of contaminates that might be presented in the stockpile, and finally the shipping costs, because not all the cities have the recycling facilities. Thus, it has been supposed that, if glass could be incorporated in concrete production, it would greatly reduce the disposal of waste glass or its use in lower valued markets such as fill or road base materials. Hence, a new material called " Glascrete " has been developed to deal with this subject. It can be defined as a concrete in which the aggregates wholly or partially consist of crushed glass, providing a particularly decorative appearance. [1] The smooth, colorful and reflective appearance of the glass aggregate makes it an attractive choice for the architectural applications, where the number of potential applications is limited only by one's imagination. To name just a few: building facade elements, partitions, floor tiles, wall tiles and panels, elevator paneling, park benches and kerbstone.

Beneficial Properties of Glascrete Tiles

As a construction material, the glass offers several advantages that could be exploited in the concrete industry. Some of these advantageous properties are given below: [2, 3]

I- The very significant hardness of glass gives the glascrete an abrasion resistance that very few natural stone aggregates can match.

II- Because glass aggregate has basically zero water absorption, it improves the flow properties of fresh concrete so that a reduction in water content can be obtained even without the use of water reducing admixtures.

III- The high chemical resistance of the glass to acidic solutions makes it suitable be applied to cases when the exposure to those chemicals is expected. This is exploited in producing anti-acidic glascrete tiles.

IV- The novel colors and pellicular reflective nature of glass aggregates give it special light reflections that couldn't be obtained with regular natural aggregate, make it very attractive for decorative concrete applications.
V- Because it is readily available to some extent, it could be considered as a low cost material.

Experimental Work

An attempt to produce glascrete tiles is carried out in this work. Two types of glascrete tiles were produced depending on their glass aggregate replacement.

Materials

1. Cement: -

Two types of cement are used to produce the glascrete tiles, these are white Portland cement, which is used for the tiles top layer. The second type is ordinary Portland cement, which is used for the tiles back layer. Chemical composition and physical properties for both types of cement are presented in Tables (1) and (2) respectively which conform to Iraqi Standard Specification No.5/1984[4].

2. Fine Aggregate: -

I- Limestone Powder (Al-Gubra): -

Fine limestone powder was used instead of natural sand to cast the top layer of glascrete tiles. The chemical composition and physical properties of the limestone powder are presented in Table (3).

II- Sand: -

Al-Ukhaidher sand was used throughout this work. The grading of sand is shown in Table (4) and illustrated in Fig. (1). The used sand is within zone 3 according to the requirements of the Iraqi Standard Specification No. 45/1984[5]. The specific gravity, absorption and sulfate content of the fine aggregate are 2.60, 1% and 0.2% respectively.

III- Glass Aggregate

Flat glass in different colors were crushed by using the Los Angeles machine and prepared to replace part of the limestone to cast tiles top layer. The next step in preparing the glass aggregate was separating each grain size after sieving, then recombining them according to Table (4). The specific gravity of glass aggregate was 2.25, while the absorption was negligible. The effect of constituents that alter the rate of setting and hardening of concrete is limited by washing the glass.

3. Coarse Aggregate: -

Crushed gravel with maximum size of 10 mm from Al-Niba'ee region was used. Table (5) and Fig. (2) show the grading of this aggregate, which conforms to the Iraqi Specification No. 45/1984[5]. The specific gravity, sulfate content and absorption of the used coarse aggregate are 2.64, 0.08% and 0.50% respectively.

2. Mix Selection: -

Two mixes were prepared to produce the top layer of the glascrete tiles. Those mixes contained 20 and 40% glass aggregate as partial volume replacement for limestone powder. The details of the two mixes are presented

in Table (6). The concrete mix of the tiles back layer was performed in accordance with ACI manual of concrete practice [6]. The mix was designed to have a min. 28-days flexural strength of 3 MPa. After many trials the mix proportions were selected and are described in Table (7).

3. Mixing, Casting and Curing of Specimens

The dry ingredients for each layer were mixed with trowel for adequate period until attaining uniform mix. Then the required amount of water was added, and the whole mix constituents were mixed until achieving a homogenous mix. Steel mold with interior dimensions of (300 × 300 × 30 mm) were used for casting. The mix of the top layer was placed in the mold and leveled by simple manual shaking. Then, the dry mix of the back layer was added, leveled and covered with the mold's cover. Locally pressing machine of 280 pound (127.3 kg) capacity was used to press the tiles. The tiles were de-molded immediately after pressing. All specimens are cured in tap water after 24±2 hours of de-molding until they reached age of 28 days.

4. Testing Methods

Two types of test methods were carried out on glascrete tiles, those are modulus of rupture test and total water absorption test. These tests were performed according to the Iraqi Standard Specification No.1042/1987 [7]. The average of three specimens has been adopted for each test at age of 28 days.

5. Results and Discussion

5.1 Modulus of Rupture Test: -

Modulus of Rupture test results for the tested tiles are presented in Table (8) and plotted in Fig. (3). These test results indicate that both types of glascrete tiles have a satisfactory modulus of rupture as compared with the Iraqi Standard Specification requirements.

It is noticed that the modulus of rupture for the glascrete tiles with 40% glass aggregate replacement is higher than the modulus of rupture for glascrete tiles with 20% glass aggregate replacement. This behavior is attributed to ability of glass aggregates to act as crack arrestors and energy absorbers in their concrete composites. In another word, the glass particles will prevent cracks from propagating through them or deflecting them when encountered.

5.2 Total Water Absorption Test: -

Water absorption test results for the tested tiles are presented in Table (9) and shown in Fig. (4). It could be observed from these results that all glascrete specimens show acceptable water absorption with regards to Iraqi Standard Specification requirements, where all the tested tiles show water absorption values lower than 8%.

Glascrete tiles with 40% glass aggregate replacement show lower water absorption relative to glascrete tiles with 20% glass aggregate replacement. This behavior is attributed to the impermeable nature of the glass aggregate.

Conclusions

The use of 20% and 40% of glass aggregate as partial volume replacement for the natural fine aggregate to produce glascrete tiles is found to be acceptable with regard to the requirements of Iraqi Standard Specification No.1042/1987. The modulus of rupture for the investigated tiles is 5.0 and 5.5 MPa respectively, and the water absorption for the investigated tiles is 5.86 and 5.15% respectively. On the other hand, those tiles are found to be acceptable with regard to the aesthetical requirements, and they exploit the special properties of glass providing colorful translucent appearance.

References

[1] Jin, W., Meyer, C., and Baxter, S. "'Glascrete'-Concrete with Glass Aggregate", ACI Materials Journal, Vol. 97, 2000, pp.208-213.

[2] Concrete Technology Unit, "Realizing a High-Value Sustainable Recycling Solution to the Glass Cullet Surplus", Guidance for the Use of Crushed or Powdered Glass in Concrete, University of Dundee, Dundee, DTI Research Contract No.GW-12.10-108. 2003, pp. 2-9.

[3] Meyer, C. "Glass Concrete", Concrete Materials Research at Columbia University, USA, 2003, pp. 55-58.

[4] المواصفة القياسية العراقية رقم (٥) لسنة١٩٨٤، "الأسمنت البورتلندي"

[5] المواصفة القياسية العراقية رقم (٤٥) ١٩٨٤، " ركام المصادر (5)لسنة الطبيعية المستعمل في الخرسانة والبناء".

[6] ACI 211.3R-97, "Guide for Selecting Proportions for No-Slump Concrete", ACI Committee 221, 1997.

[7] المواصفة القياسية العراقية رقم (١٠٤٢) لسنة١٩٨٤ " الكاشي الموزائيك".

Table (1): - Chemical composition and main compounds (Bogue's equation) of ordinary Portland cement and white Portland cement

Chemical composition				
Oxide	Ordinary Portland cement	White Portland cement	Limits of Iraqi specification No.5/1984 [4]	
			Ordinary Portland cement	White Portland cement
CaO	62.20	65.3	-	-
SiO_2	22.10	22.8	-	-
Al_2O_3	4.55	4.5	-	-
Fe_2O_3	3.34	0.4	-	-
MgO	2.32	1.0	≤5.0%	≤5.0%
SO_3	1.85	2.8	≤2.8%	≤3%
Na_2O	0.31	0.08	-	-
K_2O	0.43	0.16	-	-
L. O. I.	1.54	1.70	≤4.0%	≤4.0%
I. R.	0.45	0.52	≤1.5%	≤1.5%
L. S. F.	0.74	0.68	0.66-1.02%	0.66-1.02%
Main Compounds (Bogue's equations)				
C_3S	44.64	53.77	-	-
C_2S	29.68	24.80	-	-
C_3A	6.41	11.25	-	-
C_4AF	10.16	1.22	-	-

Table (2): - Physical properties of ordinary Portland cement white Portland cement

Physical properties	Ordinary Portland cement	White Portland cement	Limits of Iraqi specification No.5/1984[4]
Fineness (Blaine method), cm^2/gm	3100	4600	≥2300
Soundness by Autoclave %	0.24	0.4	≤ 0.8
Setting time (Vicat's method)			
Initial setting time, hrs: min.	2:10	2:25	≥45 min
Final setting time, hrs: min.	3:40	4:20	≤10 hrs
Compressive strength at			
3days, MPa	18.6	19.6	≥15
7days, MPa	27.5	28.2	≥23

Table (3): - Chemical and physical properties of limestone powder

Chemical Properties	
Oxides	Content %
CaO	56.1
SiO_2	1.38
Al_2O_3	0.72
Fe_2O_3	0.12
MgO	0.13
SO_3	0.21
L.O.I	40.56
Physical properties	
Fineness (Blaine),cm^2/gm	3100
Specific gravity	2.8

Table (4): - Grading of sand

Sieve size (mm)	% Passing by Weight	Limits of Iraqi specification No. 45/1984, zone 3 [5]
4.75	100	90-100
2.36	91.2	85-100
1.18	83.4	75-100
0.60	69.8	60-79
0.30	26.0	12-40
0.15	2.3	0-10
Fineness modulus =2.27		

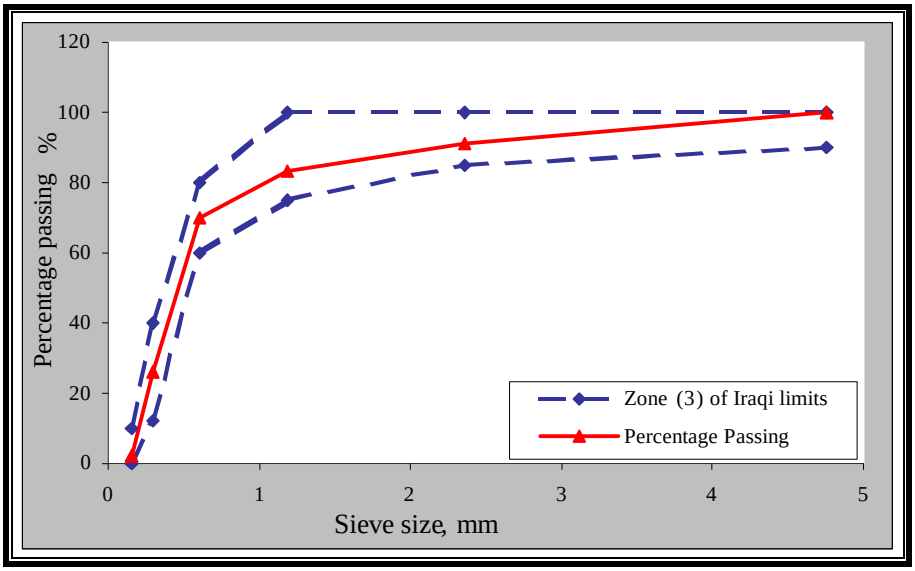

Fig. (1): - Grading curve for sand

Table (5): - Grading of coarse aggregate.

Sieve size (mm)	% Passing by weight	Limits of Iraqi Specification No. 45/1984 [5]
14	100	100
10	93.3	85-100
5	12.5	0-25
2.36	0	0-5

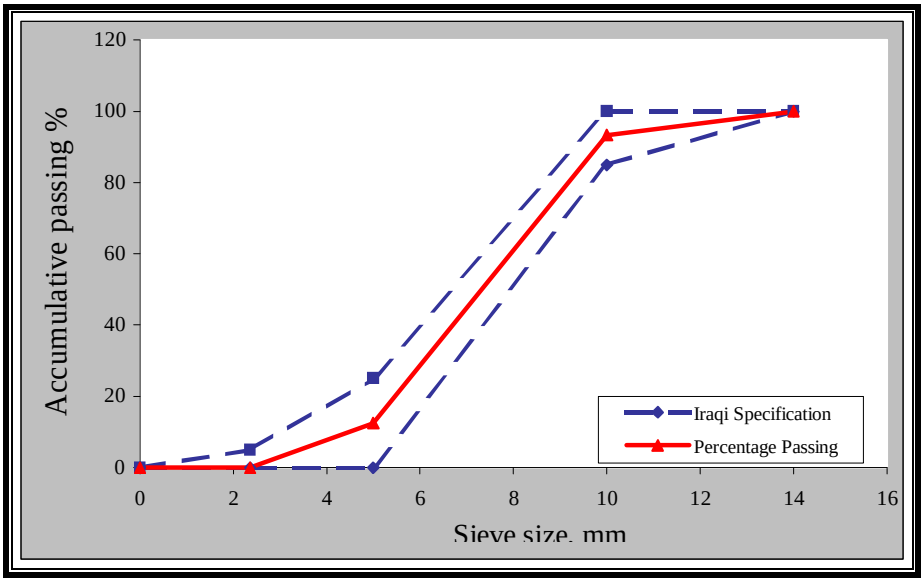

Fig. (2): - Grading of coarse aggregate.

Table (6): - Top layer proportions of tile mix.

Tiles type	Designation	White cement (kg/m^3)	Limestone powder (kg/m^3)	Glass aggregate (kg/m^3)	w/c ratio to give flow of 100±5
Glascrete tiles with 20% glass aggregate	GAT20%	550	1100	213.7	0.53
Glascrete tiles with 40% glass aggregate	GAT40%	550	825	427.4	0.51

Table (7): - Back layer proportions of tile mix.

Designation	Ordinary Portland cement (kg/m^3)	Sand (kg/m^3)	Crushed gravel (kg/m^3)	Water (kg/m^3)	w/c ratio to give zero slump
Back layer	350	500	1300	175	0.50

Table (8): - Modulus of rupture test results for glascrete tiles at 28 days age.

Tiles type	Designation	Modulus of rupture (MPa)	Limits of Iraqi Specification No.1042/1987 [7]
Glascrete tiles with 20% glass aggregate	GAT20%	5.0	≥ 3 MPa
Glascrete tiles with 40% glass aggregate	GAT40%	5.5	

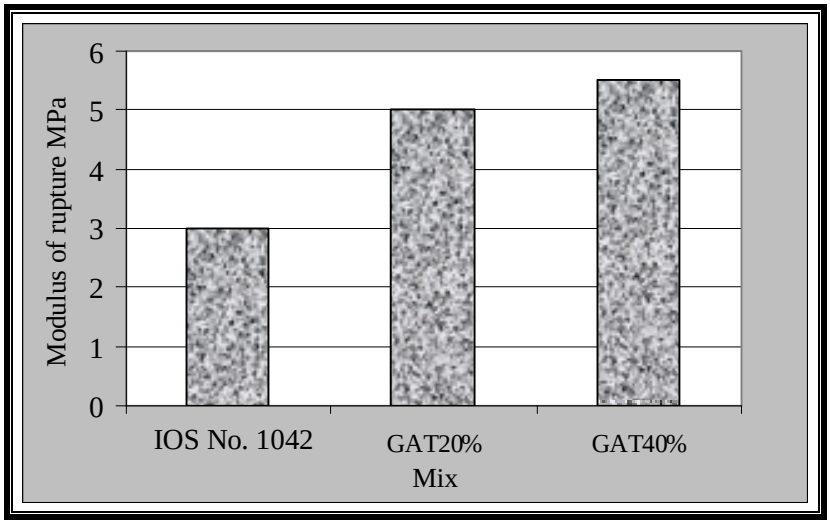

Fig. (3): - Modulus of rupture test results for glascrete tiles relative to Iraqi Standard Specification requirements.

Table (9): -Total water absorption test results for glascrete tiles.

Tiles type	Designation	Water absorption %	Limits of Iraqi Specification No.1042/1987
Glascrete tiles with 20% glass aggregate	GAT20%	5.86	≤ 8 %
Glascrete tiles with 40% glass aggregate	GAT40%	5.15	

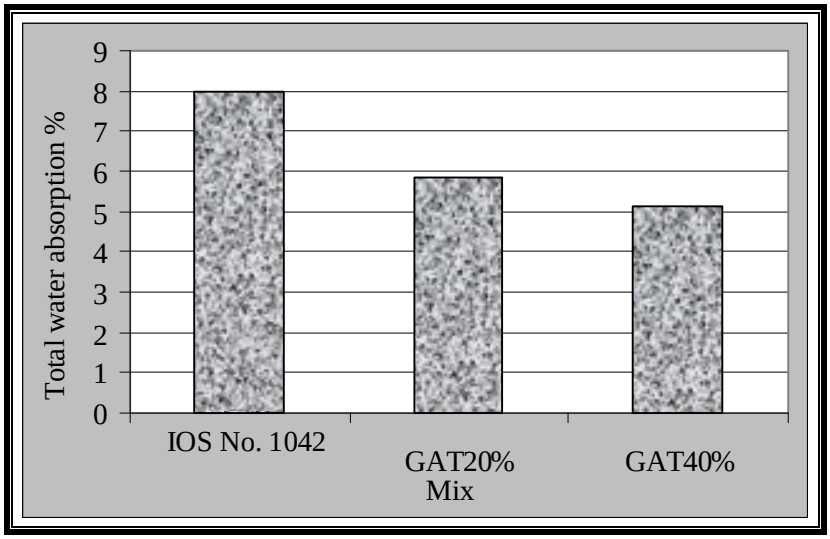

Fig. (4): - Total water absorption test results for glascrete tiles a 28 days age relative to Iraqi Standard Specification requirements.