Compressive strength measurement for cement replacement with recycled glass in concrete

Mustafa A. Mahmood, Ikram A. Al-Ajaj, Asmaa S. Khalil

Department of physics, College of Science, Baghdad University, Baghdad, Iraq

E-mail: asmaashawky67@yahoo.com

Abstract

The most important environmental constraints at the present time is the accumulation of glass waste (transparent glass bottles). A lot of experiments and research have been made on waste and recycling glass to get use it as much as possible. This research using recycling of locally waste colorless glass to turn them into raw materials as alternative of certain percentages of cement to save the environment from glass waste and reduce some of the disadvantages of cement with conserving the mechanical and physical properties of concrete made. A set of required samples were prepared for mechanical test with different weight percentage of waste glass (2%, 4%, 5%, 6%, 8%, 10%, 15%, 20% and 25%). American standard for calibration (ASTM C109 / C109M-02) to measure the compressive strength where the results showed that the Maximum compressive strength was obtained at the low weight percentage replacement 2%, 4% and 5% 6% which is 67.12, 69.24, 62.56 and 59.96 Mpa respectively. for originally mix recorded bending resistance (54.16) Mpa.

Key words

Transparent glass bottles, replacement cement, compressive strength.

Article info.

Received: Sep. 2015
Accepted: Nov. 2015
Published: Apr. 2016

قياس قوة الانضغاط للسمنت المبدل بالزجاج المعاد تدويره في الخرسانة

مصطفى عبد الكريم محمود، أكرام عطا العجاج، اسماء شوقي خليل

قسم الفيزياء ،كلية العلوم، جامعة بغداد، بغداد، العراق.

الخلاصة

ان اهم المعوقات البيئية في وقتنا الحاضر هي تكدس النفايات الزجاجية (القناني الزجاجية الشفافة) وهناك عدة بحوث وتجارب اجريت عل النفايات لمحاولة تدويرها للاستفادة منها قدر المستطاع، هذا البحث يتضمن دراسة اعادة تدوير النفايات الزجاجية وتحويلها الى مواد اولية بديلة عن السمنت لتخليص البيئة من النفايات الزجاجية وتقليل بعض السلبيات الناتجة من استخدامات السمنت وتفاعلاته والمحافظة عل الخواص الميكانيكية والفيزيائية للخرسانة. حيث تضمنت هذه الدراسة اعادة تدوير القناني الزجاجية الشفافة المحلية الاستخدام وتحويلها الى مسحوق ناعم وتبديله بنسب معينة من السمنت. تم تحضير مجموعة من النماذج المطلوبة للفحوصات الميكانيكية (مقاومة الانحناء) وبمعدل عشرة نماذج لنسب وزنية مختلفة هي (2%، 4%، 5%، 6%، 8%، 10%، 15%، 20%، 25%). تم استخدام فحص الانضغاط لحساب اعلى مقاومة انضغاط (compressive test) للنسب الوزنية السابقة حسب المواصفة الامريكية للمعايرة القياسية (ASTM (C109/C109M-02 وبينت النتائج ان النماذج (2، 4، 5، 6) ذات النسب الوزنية القليلة سجلت نتائج تحمل قوة الانضغاط هي (67.12، 69.24، 62.56، 59.96) على التوالي مقاربة للعينات الأصلية مبينة بذلك ان النسب الوزنية القليلة افضل من النسب الوزنية العالية مقارنة بالنسبة الاصلية حيث سجلت نتيجة Mpa (54.16).

Introduction

Cement (cement Portland) is ceramic materials [1]. The importance of ceramic materials in the possession of a high melting points and good mechanical properties and chemical and the provide first-hand in most parts of the world [2,3]. The most important hydraulic cement used extensively in various types of construction, as mortars, plasters grouting and concrete. The Portland cement mainly as calcium silicates and aluminates and even smaller quantities of potassium and sodium oxide may also be present[4]. Cement is one of the most cost and energy intensive components of concrete, across the world, significant environmental problems result from the manufacture of Portland cement. [5]. The heat produced by the hydration of cement may prevent freezing of the water in the capillaries of freshly placed concrete in cold weather, and a high evolution of heat is therefore advantageous[6]. Many of the world suffer from the problem of the accumulation of industrial waste and special waste resulting from the concentration of defective material because of consumer use, such as broken glass and causing other environmental and health problems that require the development of practical solutions to get rid of them through the re-use or by taking advantage of them partial substitute for some construction materials (cement, sand) involved in asphalt or concrete admixtures [7-10]. The reuse of waste glass is one of the most important issues around the world due to the increase of solid wastes in the landfill and non-degradable nature of its disposal. The use of recycled waste glass in concrete has attracted much interest worldwide and numerous researches have been carried out, showing the possibility of use of waste glass as building materials by partially replacing concrete mixtures Shi and Zheng 2007 [11]. The glass powder pozzolanic of materials that can be added to concrete or mortar (pozzolanic material) or cement paste. pozzolanic and materials are natural materials or industrial contain the active silica (amorphous) and which are the Association of properties when they interact with calcium presence of water and varying unusual heat hydroxide, (Ca $(OH)_2$) and calcium hydroxide is one of the outputs of the process of cement interaction with water Shown in the Fig. 1.

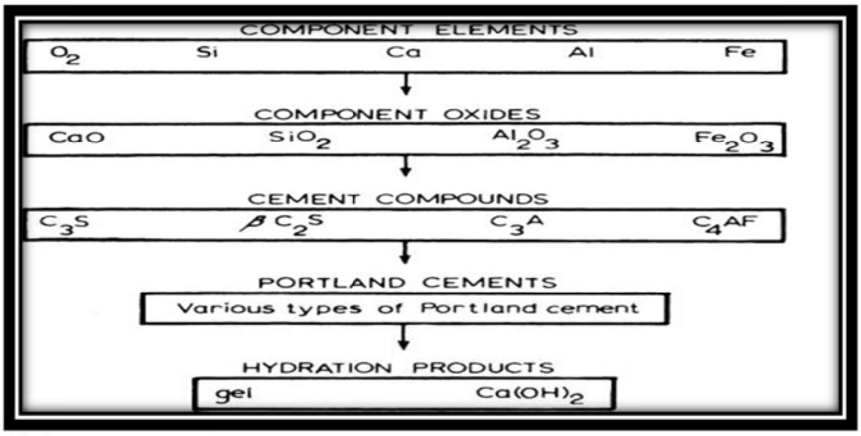


Fig. 1: Schematic representation of the formation and hydration of portland cement.

Compressive strength

Compressive strength is defined as the resistance of the rigid material to the maximum stress under the perpendicular pressure. In principle, compressive strength is the opposite of tensile strength. The tension resistance for some materials depends on the distribution of defects which act as regions of stress concentrations. Inversely to the tensile strength, The compression resistance depends upon suppressing these cracks so these materials have high compression resistance [12]. This measurement is applied widely for testing brittle materials like glass, concrete, stone, cast iron, and thermosetting polymers because these materials have toughness when compressed higher than when they are of tensile [13].

$$C.S = \sigma / A \quad (1)$$

$$N / mm^2 = MPa$$

where:
C.S: compressive strength
σ: *stress*
A: *cross section area*

Experimental work

1. Raw materials

1.1Cement

The commercially Iraqi Portland cement as known as (TASLUJA) was submitting to laser diffraction particle size analyzer tybeMastersizer 2000. The analyzer showed that the particle size have a diameter range from (5.344 µm-57.822 µm) as shown in Fig. 2.

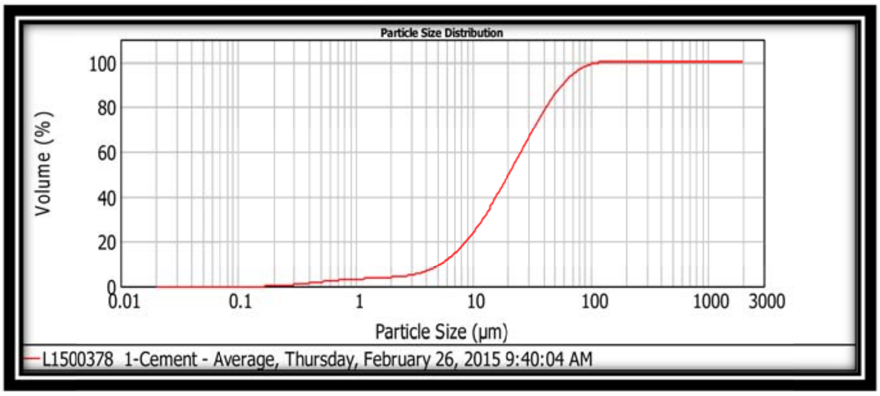


Fig.2: Partial size of cement.

Chemical analysis Portland cement was analyzed according to ASTM C150- 02a. The result agree with standard value as shown in Table 1 then calculation of potential composition of Portland cement using Bogue's Eq.[14] was shown in Table 2.

Table 1: Chemical composition of locally and standard Portland cement.

Element	Content %	Standard[15]
SO_3	2.33%	**3.0 max**
Na_2O	0.4366%	**--**
Fe_2O_3	2.611%	**6.0 max**
SiO_2	24.24%	**20 min**
CaO	60.18%	**--**
K_2O	0.698%	**--**
MgO	1.318%	**6.0 max**
AL_2O_3	2.53%	**6.0 max**
L.O.I	5.86%	**--**

Table 2: Potential composition result for Portland cement (Bogue's equations) [14].

C_3S	**39.99**
C_2S	39.33
C_3A	2.286
C_4AF	7.945

1.2 Fine aggregate (sand)

According to ASTM C33-03, proportion of salt in the sand was determined the used and to experimental and stander the result showed a good agreement as shown in Table 3. The particle size of sand was measured using different size of sieves. The process of measuring is completed according to ASTM C33-03 by sift (1kg) of sand and weight the out com sand in each sieve as shown in Table 4.

Table 3: Chemical composition of salt in sand.

Element	Expe. content %	Standard[16]
SO_3	**0.6%**	**0.5%**

Table 4: Grading of fine aggregate.

Sieve size (mm)	% Passing by weight	Specification limit[16]
9.5	100	**100**
4.75	93.2	**90-100**
2.36	84.2	**75-100**
1.18	68.0	**55-90**
0.60	37.8	**35-59**
0.30	19.6	**8-30**
0.15	8.8	**0-10**

1.3 Recycled Transparent Glass Bottles (RTGB)

The glass used in this study was waste colorless glass bottles as partial substitute of cement, in the first, all bottles washed carefully and then crushed in a mill specification. The examination of particle size was done by using Mastersizer 2000 laser diffraction particle size analyzer delivers rapid. The diameter range from was (3.733 µm- 51.938 µm) as shown in Fig. 3.

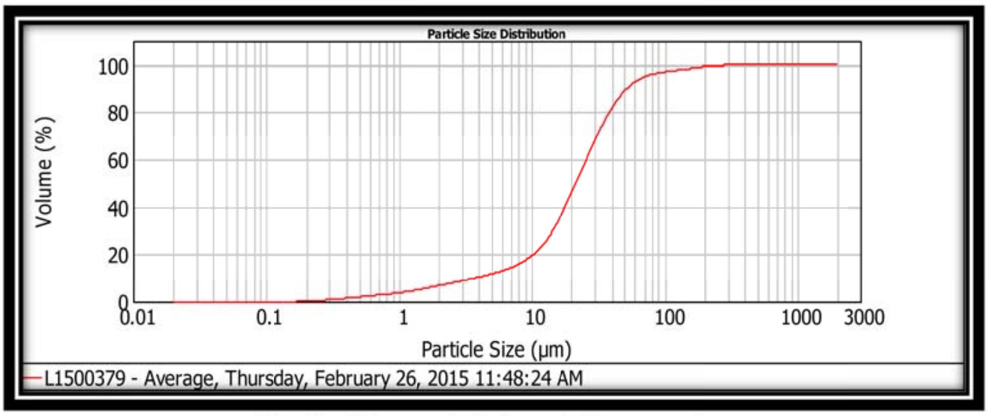


Fig.3: The partial size of glass powder.

Chemical analysis

Glass used was analyzed according to ASTM C618, and the result shown that a good agree with standard values of element as show in Table 5.

Table 5: Chemical composition of glass powder.

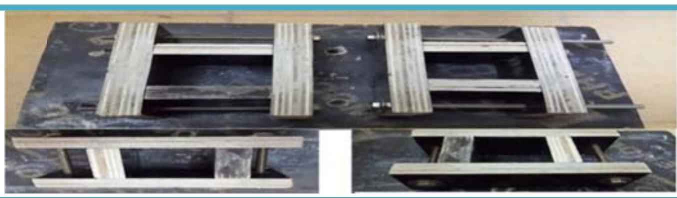
Element	Content %	stander %[17]
SO_3	0.7%	---
Na_2O	13.626%	12-15%
Fe_2O_3	1.321%	---
SiO_2	72.52%	73%
CaO	7.21%	10%
K_2O	0.227%	---
MgO	2.208%	---
AL_2O_3	1.75%	---
L.O.I	0.347%	---

1.4 Water

2. Sample preparation

The molds were made out of wood according to the ASTM (C109/C109M-02) standards which determines the volume of the sample as shown in Table 6.

Table 6: For used molds.

Test	ASTM	mold Shape
Compression	(50*50*50)mm	

The weight percentages the concrete components are cement, sand and water (1:2.75:0.485) respectively according to ASTM C109/C109M. The details and proportions of mixes was shown in Table 7.

Table 7: Descriptions of Investigated Mixes.

Set No.	symbols	Mix Description
1	C	Mix with cement and natural sand only
2	CG2	C and 2% by volume of Glass powder as partial replacement of cement
	CG4	C and 4% by volume of Glass powder as partial replacement of cement
	CG5	C and 5% by volume of Glass powder as partial replacement of cement
	CG6	C and 6% by volume of Glass powder as partial replacement of cement
	CG8	C and 8% by volume of Glass powder as partial replacement of cement
	CG10	C and 10% by volume of Glass powder as partial replacement of cement
	CG15	C and 15% by volume of Glass powder as partial replacement of cement
	CG20	C and 20% by volume of Glass powder as partial replacement of cement
	CG25	C and 25% by volume of Glass powder as partial replacement of cement

Mixing process was carried out using 0.1 m^3 rotary type mixer for all batches. To prepare the basic mix, sand and cement were initially mixed for 2 to 5 minutes, then required amount of water was added and mixed for additional 2 minutes until achieving a homogenous mixes. In order to prepare homogeneous, fine glass was add in a different weight percentages were mixed with cement before adding to mixer. Finally, it mixed with the basic component for 10 minutes until achieving a homogeneous mixes.
To prepare samples with dimension as shown in Table 6 all the molds were cleaned and thoroughly oiled before casting process. A vibrating table was used in a sufficient period to extract the air from voids. The top surfaces of the molds were leveled and covered with nylon sheets to prevent evaporation. All samples surfaces were cleaned and polish as show in Fig. 5.

Compressive measurement

Electronic universal test mechanical WDW-200E. (maximum load is carrying device 200 kN).
Mold samples was prepared according to ASTM C109/C109M-02 for compression measurement as shown in Table 8, with dimensions 50mm as shown in Fig. 4.

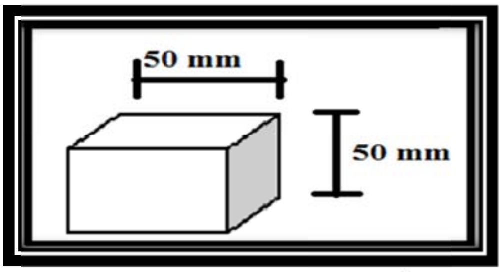


Fig. 4: Compression test specimen.

After the completion of homogeneity mixing process, mixture was pour in the mold which was prepared by measuring the pressure of cubic concrete samples, as shown in Fig. 5.

Fig. 5: Concrete samples for compression measurement.

The data is record as stress – strain curve.

Results and discussion

Compressive strength were calculated using Eq.(1) Figs. 6-15 show the effect of waste glass addition on this property. It can conclude that the compressive strength increased with decreasing weight percentage of waste glass. Also, the compressive strength for sample have small amount of waste glass is close to the control mix as shown in Table 8 and this can be attributed to reactions material pozzalanic ground glass that appear to speed up the time sclerosis with the passage of time and help to improve the madder bending. Similar behavior was reported by Bajad 2013 replacement of cement by waste glass powder and he concluded that a considerable improvement in the compressive strength was seen at 10% replacement of cement [18].

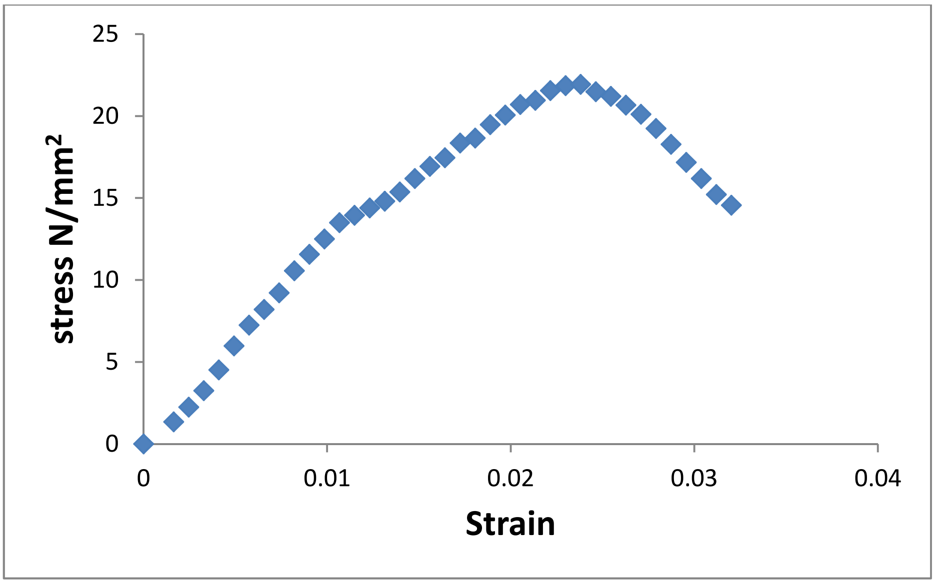


Fig. 6: Stress vs Strain curve for sample 1.

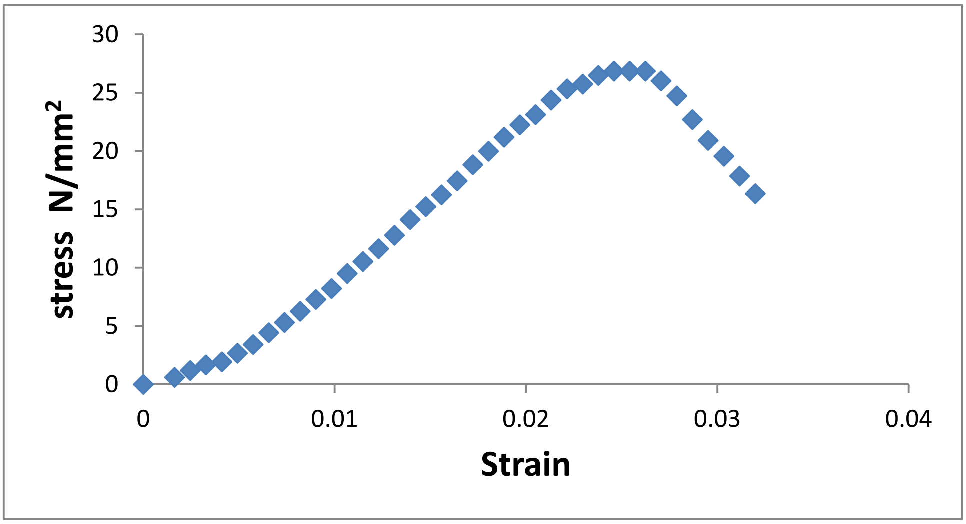


Fig. 7: Stress vs Strain curve for sample 7.

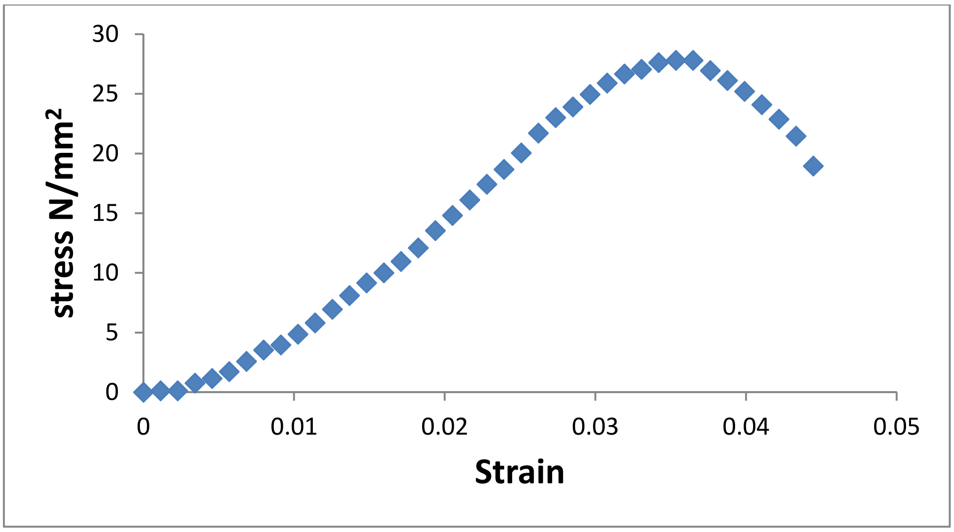


Fig. 8: Stress vs Strain curve for sample 8.

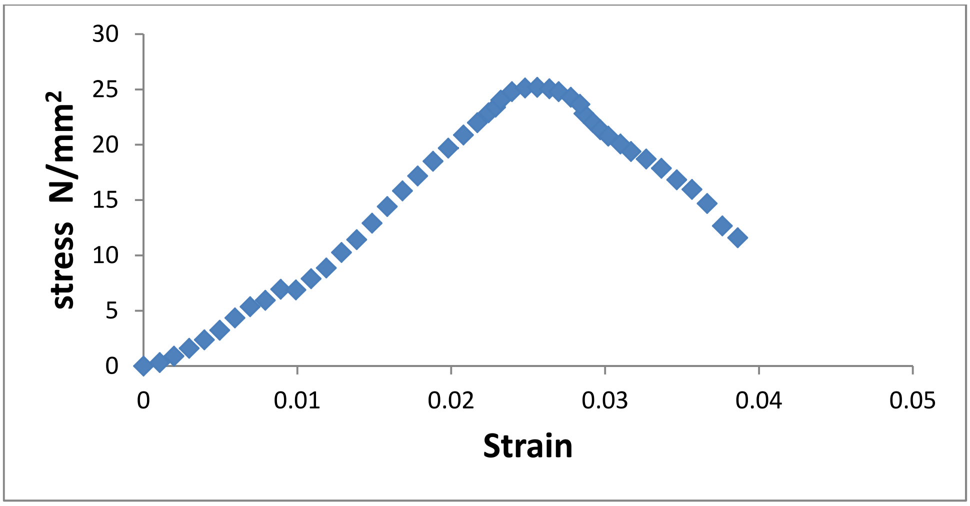


Fig. 9: Stress vs Strain curve for sample 2.

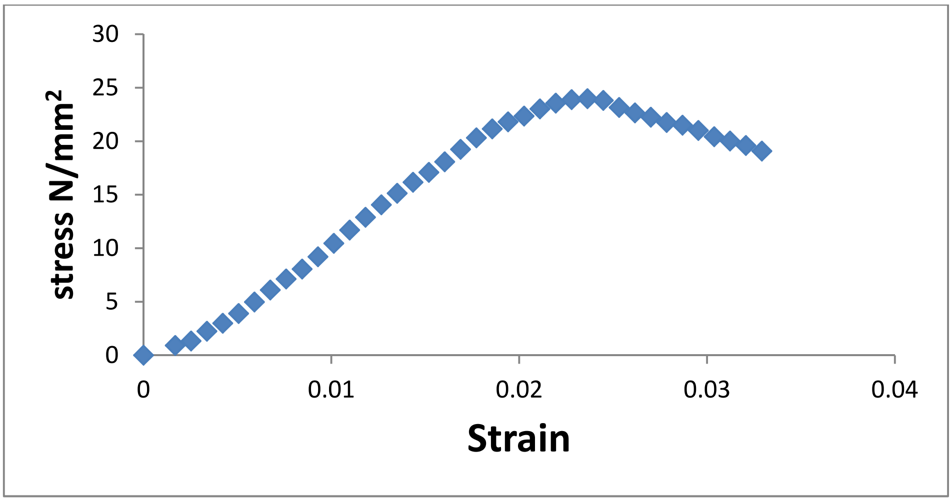


Fig. 10: Stress vs Strain curve for sample 9.

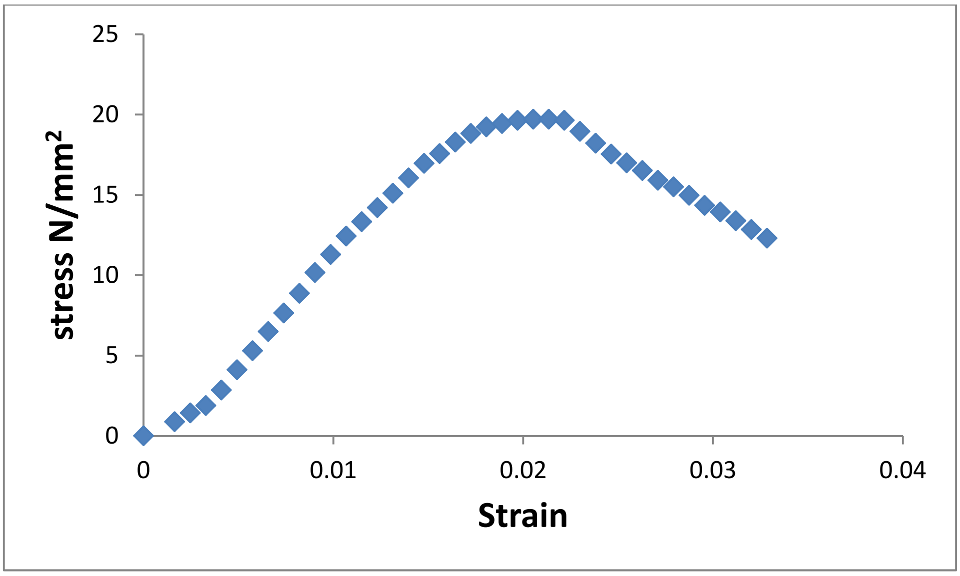


Fig.11: Stress vs Strain curve for sample 10.

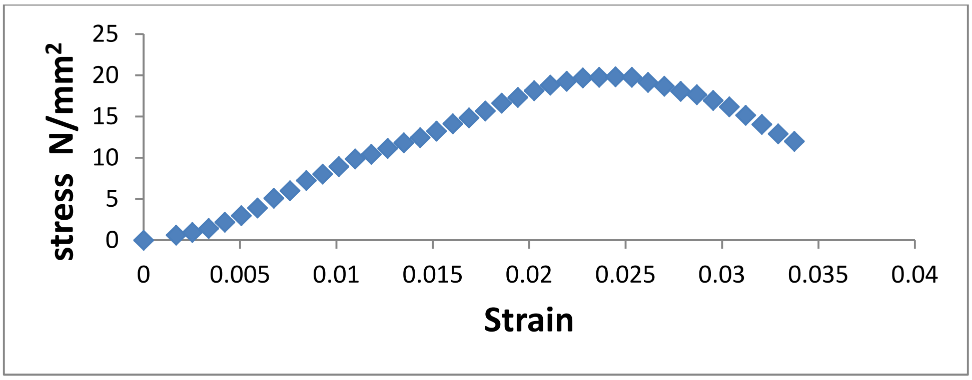


Fig. 12: Stress vs Strain curve for sample 3.

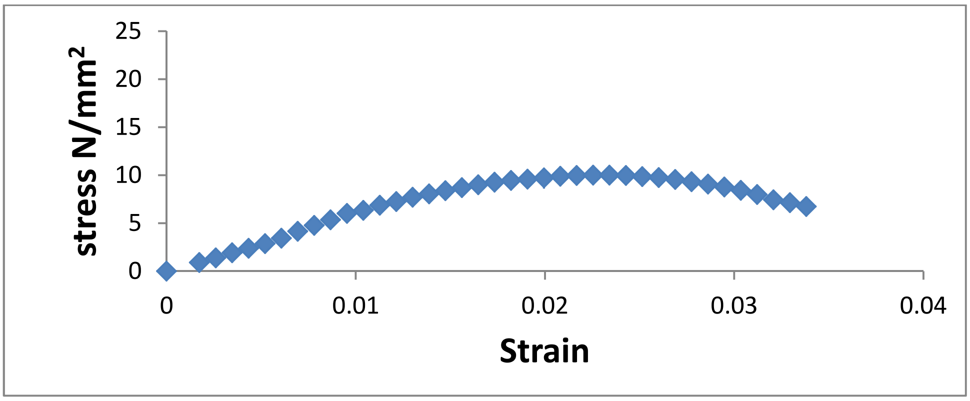


Fig. 13: Stress vs Strain curve for sample 4.

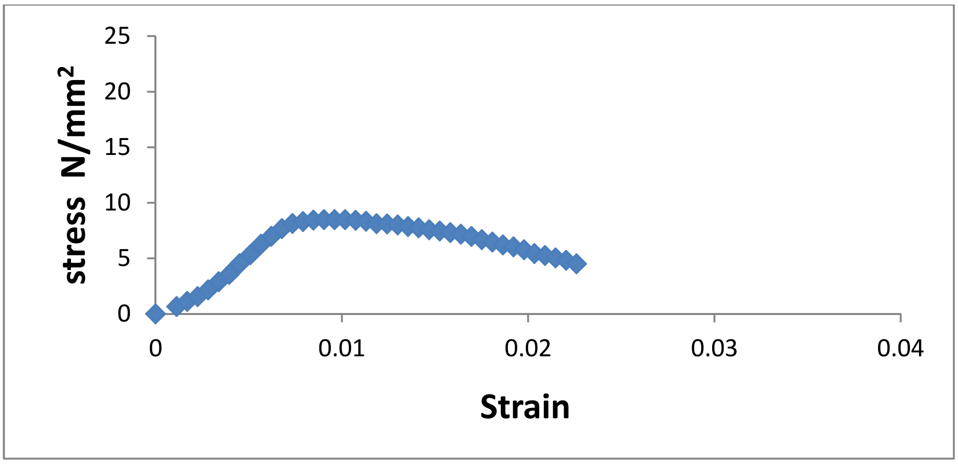


Fig. 14: Stress vs Strain curve for sample 5.

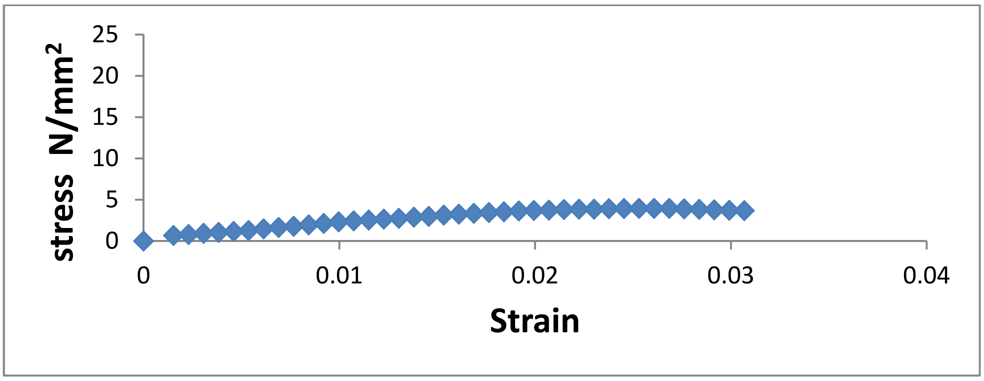


Fig. 15: Stress vs Strain curve for sample 6.

Table 8: Compression results for concrete samples.

Sample	Details	Designation	Max load (kN)	%increase or decrease from C for Max load	Compressive strength (Mp_a)	%increase or decrease from C for Compressive strength	Toughness (N/mm^2)	%increase or decrease from C for Toughness
1	Control concert	C	21.66	--------------	54.16	------------------	0.459	-----------------
2	Replacement of cement by (2%)of waste glass	CGP2	26.84	+ 23.91	67.12	+23.92	0.474	+3.26
3	Replacement of cement by (4%)of waste glass	CGP4	27.69	27.83+	69.24	+27.84	0.678	+47.71
4	Replacement of cement by (5%)of waste glass	CGP5	25.02	+15.51	62.56	+15.50	1.119	+143.79
5	Replacement of cement by (6%)of waste glass	CGP6	23.98	+10.71	59.96	+10.70	0.496	+8.06
6	Replacement of cement by (8%)of waste glass	CGP8	19.28	-10.98	49.56	-8.49	0.424	-7.62
7	Replacement of cement by (10%)of waste glass	CGP10	19.47	-10.11	49.36	-8.86	0.398	-13.28
8	Replacement of cement by (15%)of waste glass	CGP15	9.96	-54.01	24.92	-53.98	0.238	-48.14
9	Replacement of cement by (20%)of waste glass	CGP20	8.46	-60.48	21.16	-60.93	0.135	-70.58
10	Replacement of cement by (25%)of waste glass	CGP25	3.96	-81.71	9.92	-81.68	0.0841	-81.69

Conclusion

Comparison between basic sample and sample contain replacement of glass. It can be concluded the following:

1. It is Possible to produce concrete by replacement part of the cement by waste glass powder after grinding to the approximate size of the cement.

2.The results showed that the replacement of part of the cement by powder glass gives resistance to compression greater or nearest Resistance of the control mixture (C).

3. In economic terms, waste glass there is advantage to use waste glass in concrete with good production properties.

Acknowledgement

The Authors are very greet full to Prof. Dr. Raad A. Radhi to his assistance for provide the original copy of his two codes of calculation of form factors and residual interaction.

References

[1] C. Suchicital, "Ceramic processing", MSE-4424, 1998.

[2] M. W. Barsoum, "Fundamentals of Ceramics" McGraw – hill, Singapore, (1997).

[3] W.Ryan and C.Fric, “Properties of Ceramic Raw Materials“, John Wiley and Sons, Inc., New York (1967).

[4] G. Kenneth and G. Michael, "Engineering materials: Properties and selection" Prentic Hall India, pp. 763, (1999).

[5] Jackson, Neil, Dhir, Ravindrak, "Civil Engineering Materials" 5th edition, Hong Kong, (1996).

[6] A.M Neville "Properties of Concrete". Fifth Edition, pitman -1 publishing limited, London, UK, 1981.

[7] C. Shi, Y. Wu, C. Riefler, H. Wang, "Characteristics and Pozzolanic Reactivity of Glass Powders "Cement and Concrete Research, 2004.

[8] Ahmad Shayan, "Value-added Utilisation of Waste Glass in

Concrete", Iabse Symposium Melbourne, 2002.

[9] N. N. Eldin and A. B. Senouci, Journal of Materials in Civil Engineering, ASCE, (1993) 478-496.

[10] W. Chesner, "Waste Glass and Sewage Sludge Ash Use in Asphalt Pavement", Utilization of Waste Materials in Civil Engineering Construction, American Society of Civil Engineering, 1992.

[11] C. Shi and K. Zheng, A review on the use of waste glasses in the production of cement and concrete. Resources, Conservation and Recycling, 52 (2), (2007) 234–247.

[12] M. S. Shetty, (1982) Concrete Technology Thoery and Practice, S Chand and Company LTD.

[13] R. B. Seymour "Polymeric Composite" Alden Press, London, (1990).

[14] ASTM: C 150-02a, Standard Specification for Portland Cement.

[15] ASTM: C 33-03, Standard Specification for Concrete Aggregates.

[16] ASTM: C 150-02a, Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

[17] Caijun Shi, Keren Zheng, Resources, Conservation and Recycling 52 (2007) 234-247, China.

[18] M. N. Bajad, C.D. Modhera Journal of Information, Knowledge And Research In Civil Engineering, 1, Issue 1 (2015) 1-168.