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Investigation and Comparison of the Strength Properties of Lightweight Concretes Containing LECA and Waste Glass

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ABSTRACT

Industrial development and the trend toward industrialization have contributed to the economical growth of countries. However, they have yield other problems such as increased waste left over from industrial productions, lack of attention to which has brought serious destructive effects on the environment. An example of these problems is the waste left over from glass products. Glass is produced in various types and the need for reusing and recycling it, is a requirement in order to prevent environmental problems caused by its melting or burying. The main aim of environmental laws is to reduce glass wastes as far as possible, to take them to the landfills, and to chemically analyze them. Moreover, substantial space, which can be used for other purposes, is needed to bury these wastes. The main focus of this paper was to study the effect of different amounts of glass on the concrete strength. To this end, laboratory studies were conducted in 6 stages. Using cement type 1, sand, super plasticizer, and water, the glass splinters with substitution ratios of 0, 5, 10, 15, 20, and 50 percent were substituted with a portion of LECA particles. Furthermore, to compensate for the effect of strength reduction caused by the use of lightweight aggregates, the same percentage of Metakaoline Pozzolan was used in all designs. The samples made in 7 and 28 days were tested, the results of which showed that the highest increase in strength was related to the 5 % glass substitution.
KEYWORDS: Lightweight concrete, glass splinters, metakaoline pozzolan, compressive and flexural strength.

1. INTRODUCTION

Chemical characteristics of glass may have determinant effects, such as making gradual changes in the concrete mix properties. Due to rich silica nature and non-crystalline structure, glass is sensitive to chemical attacks under severe alkaline conditions which is created in hydrated cement phase in concrete [1]. The chemical attack can lead to the formation of ASR gel. Figure 1 shows an example of this gel formation. Generally, glass powder has influence on reducing the effect of ASR reaction in accelerated mortar test, such as the effect of fly ash, microsilica, and slag. This shows that glass powder can cease ASR-induced expansion in sensitive aggregates and coarse glasses. Therefore, glass can be used in three forms in concrete: coarse grained soil, fine grained soil, and glass powder. Coarse grained soil may cause ASR to react in the concrete. However, glass powder reduces their ASR effect [2]. This reaction can be very dangerous for the durability of the concrete, therefore; appropriate preventive actions should be done in order to reduce the impact of this reaction. One of the best preventive ways is using appropriate Pozzolanic materials, such as microsilica or Metakaoline, which should be combined in a proper ratio to the concrete mix [3]. Thus, in this paper Metakaoline with a 10 % substitution, which is the best percentage to increase compressive strength of concrete at all ages, has been replaced to the cement [4].

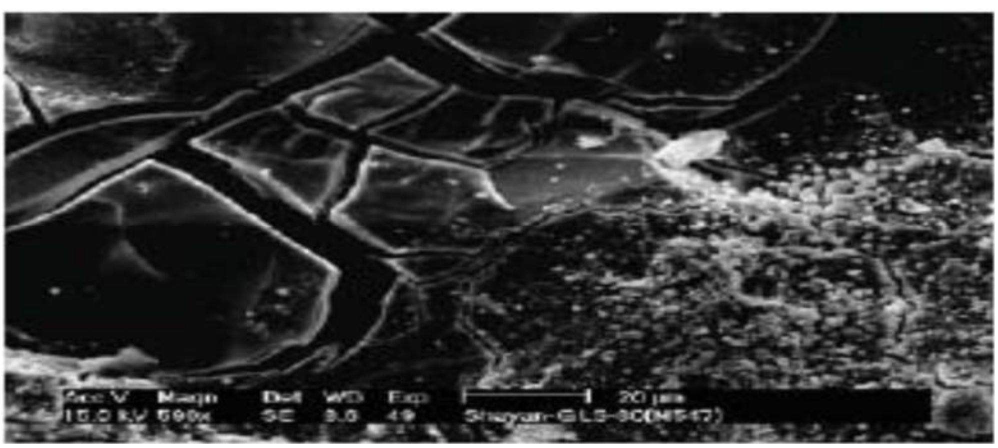

Fig. 1. Formation of ASR gel in concretes containing glass

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2. Test Plans:

The aim of this study is to investigate the effect of substituting different percentages of coarse grained glasses including 0, 5, 10, 15, 20, and 50 percent with about the same size of lightweight LECA particles on the compressive and flexural strength properties of lightweight concretes. However, studying these properties is considered to be investigated in highly efficient concretes with a water-cement ratio of 0.4, since a minor change in the water-cement ratio leads to considerable changes in the strength properties. In this test, 6 cube samples of 10 × 10 × 10 were made from each design, three of which were tested at 7 days and three other at 28 days in order to examine their compression strength, then their average was presented as the result of the work. In addition, three samples of 10 × 10 × 50 were made from each design at the age of 28 days in order to examine the flexural strength.

2.1 Raw Materials:

2.1.1 Cement

The cement used in this study is an ordinary Portland cement type 1 of Isfahan having Iran standard (ISIRI). The physical properties and chemical composition of cement is presented in Tables 1 and 2 respectively.

Table 1. Physical properties of cement used in this study

Properties	Density (g/cm3)	Specific level Blaine (cm2/g)	28-day compressive strength (MPa)	Cumulative density (g/cm3)
Amount	3.05	3420	44.5	1.07

Table 2. Chemical analysis of cement

constituent oxides	SiO2	Al2O3	Fe2O3	CaO	MgO	SO3	Na2O+K2O	LOI
Portland cement	21	4.6	3.2	64.5	2	2.9	1	1.5

2.1.2 Metakaolin

Metakaolin is an amorphous aluminum silicate with pozzolanic properties which is put into the category of class N of pozzolans (raw or calcined natural pozzolans) based on ASTM C618 standard, and like other pozzolans reacts with calcium hydroxide created by cement hydration and produces hydrated calcium silicate (C-S-H) [5]. Metakaolin is a tiny white clay mineral that has been used traditionally in porcelain production (Figure 2). Table 3 presents physical characteristics of metakaolin:

Fig. 2.

Table 3. Physical characteristics of Metakaolin

Particle size	10.5 t0 2.0 microne
Special level	10000- 29000 (Kg/m2)
Special weight	6/2 (gr/cm3)

2.1.3 Lightweight Aggregate (LECA)

The word LECA is taken from the expression of “Light Expanded Clay Aggregate” (Expanded Clay Particles). Raw materials used for producing these lightweight aggregates are composed of deposits of natural materials such as clay, shale and slate which contain a large amount of silica. These aggregates are prepared using two rotary furnaces and sedimentation methods. In both methods, the raw materials are heated till they are expanded. In the process of expansion, heating is continued till the internal gases of materials are released and the materials took a soft and flexible form, but not melted completely. At this stage, the bubbles of internal gases created some pores in the doughy materials, therefore; expanded raw materials and aggregates with a special lower weight are obtained [6]. The special weight of LECA concrete (made purely from LECA) in dense and non-condensing modes are 950 Kg / m³ and 700 Kg / m³ respectively. The density of lightweight aggregates has been presented separately in Table 4. The low weight of grains is due to the empty space inside the grains which have occupied 73 to 88 percent of the total space based on their gradation. The LECA used in this research was directly prepared from Iran LECA Company located in Saveh.

Table 4. Density of lightweight LECA particles

type of sample	LECA with 0-4 gradation	LECA with 4-10 gradation	LECA with 10-19 gradation
density	0.99	0.67	0.5

2.1.4 Sand

The type of sand used in this study is of river sand 0-5 which is prepared from Isfahan Sofe mine. The special weight of this sand is 2590Kg / m³ and its fineness modulus is 2.81.

2.1.5 Super Plasticizer

The super plasticizer used in this study is the Polycarboxilate with 40% solid material and actual special mass of 1081.73 produced in Abad Gran Company. The percentage of super plasticizer was regulated with regard to the fluidity and high efficiency level of concrete in mixture design.

2.1.6 Water

Tap water is used in this research.

2.1.7 Safety Glass Wastes

Glass is a non-organic material which is frozen during the cooling process without crystallization in the molten phase. Using glass splinters in expanded concrete is dangerous and larger size may cause significant expansions. Therefore, the size of expansion depends on the amount of glass, the size of particles, and the amount of mixed alkali [7]. In this article, glass splinters are made from safety glass and the size of particles are between 4 to 9.5 mm**.**

3. MIXTURE METHOD

The type of mixer used in this study is a rotary mixer with the maximum volume of 50 litres. The method of mixing the materials is as follows: First, dry materials were completely mixed in the mixer for 2 minutes. Then 50% of the water and the whole cementitious materials were put into the mixer and mixed for 3 minutes. Finally a solution was made from the combination of the rest of the water and super plasticizer and was added to the concrete and completely mixed with other materials for 5 minutes. Then concrete was flowed into the intended molds and after 24 hours the samples were brought out of the molds and placed in a pool of water with 23 degrees temperature.

3.1 Mixture Design

The details of mixture design are shown in Table 5. The ratio of water to cementitious materials is considered to be 0.4 percent for all commixtures. For each design, using mass scale, a portion of glass splinters was replaced to the 4-10 lightweight LECA particles. Five different percentages of glass splinters (5%, 10%, 15%, 20%, and 50%) were selected. Furthermore, in order to reach an accurate comparison of compressive strength, Metakaolin, the ratio of water to cementitious materials, and the percentage of super plasticizer were kept constant in all designs.

Table 5. Mixture design

Name of mixture	S0	S1	S2	S3	S4	S5
percentage of glass splinters	0	5	10	15	20	50
percentage of Metakaolin	10	10	10	10	10	10
glass splinters (kg/m3)	0	7.6	15.2	22.8	30.4	76
cement (kg/m3)	450	450	450	450	450	450
Metakaolin (kg/m3)	50	50	50	50	50	50
LECA sand	231	231	231	231	231	231
4-10 LECA	152	144.4	136.8	129.2	121.6	76
10-19 LECA	66	66	66	66	66	66
natural sand	800	800	800	800	800	800
water (kg/m3)	200	200	200	200	200	200
super plasticizer	5	5	5	5	5	5
water/ cementitious materials	0.4	0.4	0.4	0.4	0.4	0.4
super plasticizer/ cementitious materials	1%	1%	1%	1%	1%	1%

4. Compressive Strength Test

Six cube samples of 10 cm were built for each mixture design. All samples were brought out of the molds after 24 hours and were placed in a pool of water with a temperature of 23 ℃ and were tested at the ages of 7 and 28 days. Then the average of three samples was recorded as the compressive strength. The compressive strength test was carried out on the samples using standard mangle with the load control of 3.00 Mpa /s. In addition, to perform flexural strength test, a prismatic sample of 10 × 10 × 50 cm was built and tested at the age of 28 days.

5. Experimental Results and Discussion

The results of compressive and flexural strength tests are presented comparatively in Table 6 and in Figures 1, 2, 3 and 4.

Table 6. The results of compressive and flexural strength tests

	0%	**5%**	**10%**	**15%**	**20%**	**50%**
7 days	18.68	21.76	18.18	14.65	16.92	21.06
28 days	19.36	22.67	19.58	13.04	20.65	22.59
flexural	1.69	1.893	1.49	1.442	1.46	1.531
the average of the total density of dried samples	1670	1660	1592	1604.4	1665.9	1669.3

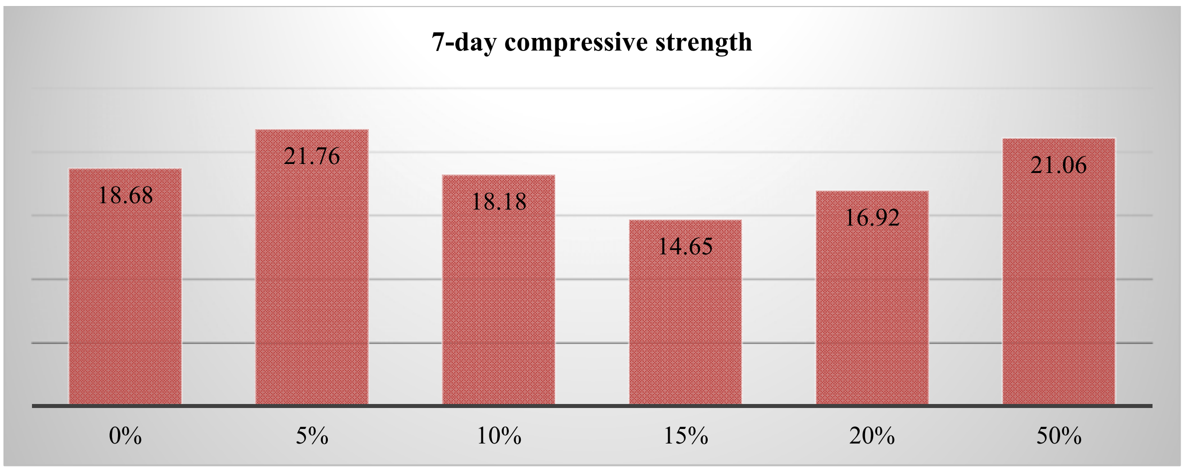

Chart. 1. The results of strength (comparison of different percentages of substitution in bar chart)

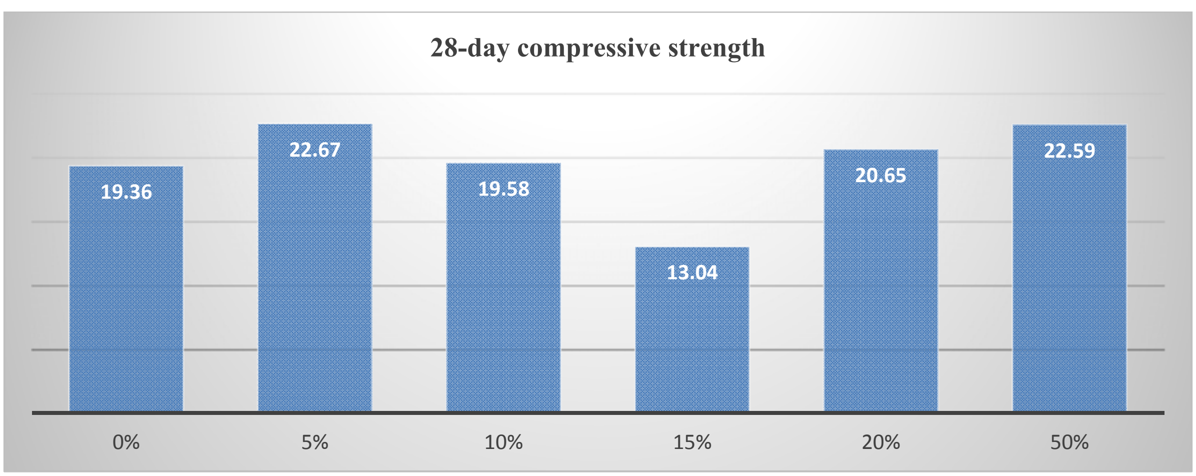

Chart. 2. The results of strength (comparison of different percentages of substitution in bar chart)

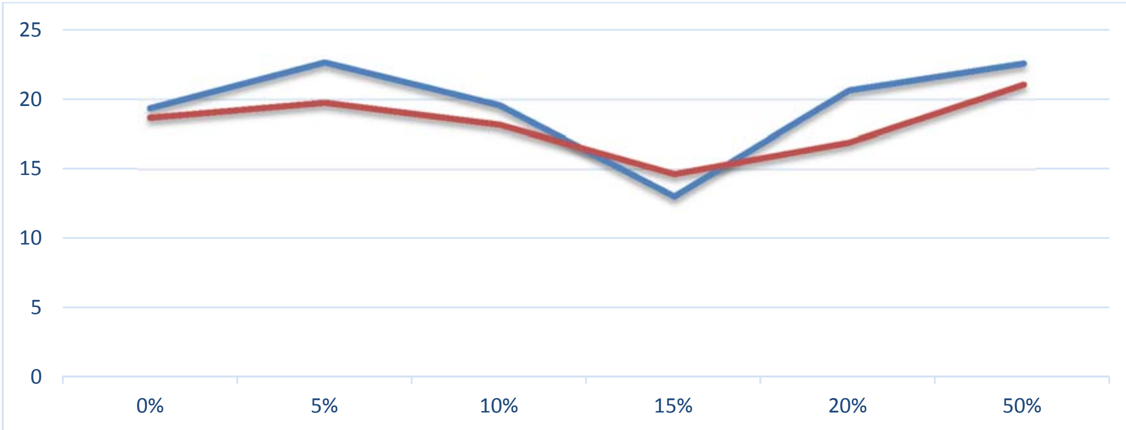

Chart. 3. Results of strength (comparison of concrete in different ages with different percentages of glass splinters substitution)

To determine the flexural strength of concrete [8] Simple Beam with Second–Point Loading method was used, the result of which is presented comparatively in Figure 4.

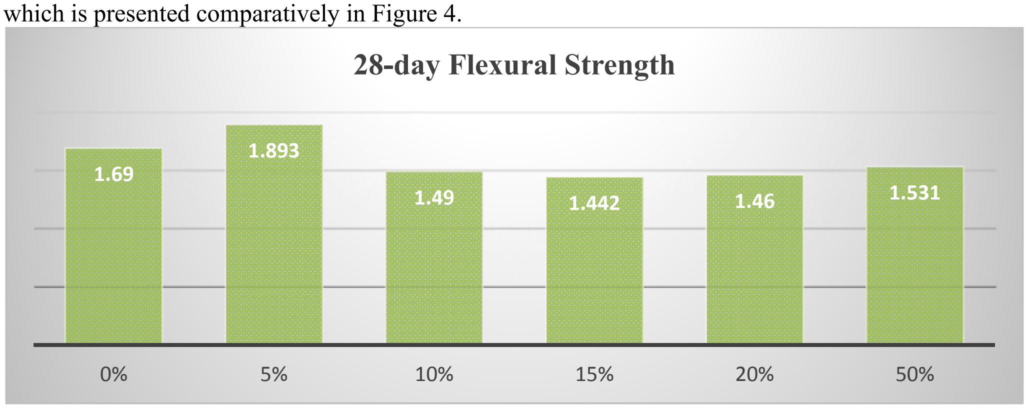

Chart. 4. The results of flexural strength

6. Discussion

As it is clear from the charts, the greatest increase in strength is at 5% substitution; the 7-day strength has an increase of about 16.4% and the 28-day strength has an increase of about 9.17%. This increase has also occurred for its flexural strength which is about 12.01. The experiments showed that at 15% substitution there was a sharp decline on the compressive and flexural strength which was about 27.5 percent.

7. Conclusion

The following conclusions are drawn from this study:

The concretes made from glass splinters have lower density than ordinary concretes and ,therefore; are lighter than ordinary concretes. The greatest reduction of compressive and flexural strength has occurred at 15% substitution.

In this article, the greatest increase of strength has occurred at 5% substitution. There was also another increase of strength which was occurred only in the compressive strength at 50% substitution.

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