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Jabbarova N.E., Abdullayeva M.Y., Asadova I.B. Properties of concrete with the addition of ash residues from the processing of household waste

Jabbarova N.E.,
Abdullayeva M.Y.,
Asadova I.B.
Azerbaijan State University of Oil and Industry

Abstract. *In this article studied the impact of solid remnants (ash residues) on cement and concrete. It also should be noted that the increase in the amount of added ash residues from 10 to 20%, 60 mPa continuously increases and at the end of the observation period, it increases evenly. There are have been studied the influence of various factors on the strength of concrete (strength of the binder-alkaline solution, temperature and length of curing, etc.).It was observed that amidst increasing in the concentration of the binder - sodium hydroxide and silicate - the strength of concrete increases as well. The mixture containing an ash residue with a mass ratio of sodium silicate solution to the alkali solution of 2.0. was chosen as the optimal one. Temperature and length of curing of ash cement also showed positive dynamics of concrete compressive strength*

Keywords: *municipal solid waste, ash residues, cement, concrete, strength, bonding, time and temperature of curing.*

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1. Introduction

Today, for the time being, the disposal of household and industrial waste is a valid environmental issue.

In the reason for the exponential growth of urbanization and industrialization, the amount of municipal solid waste (MSW) is increasing rapidly. In addition, disposal of municipal solid waste (MSW) is becoming a frequently serious obstacle for many urban municipalities because of the increasing volume of generated municipal solid waste, increasing costs of landfill operations or due to a lack of landfills. Every year, land plots are allocated for the storage of household and industrial waste, which can be used for agricultural land, as well as for the constructions. With increasing awareness of the environment andits potentially hazardous consequences, the use of these materials has become an attractive option of recycling alternative. The use of various wastes for these purposes is a practical implementation of the concept of industrial metabolism, which consists in the use of waste from one industry as a raw material for another.

The main guiding principle of SWM is the rule of 3R's (waste reduction, reuse and recycling), which gradually began to be carried out starting from the 20th century in EU countries [1]. The waste management system was first developed in the EU countries, due to the early and rapid development of the economy, the lack of resources and irrational usage of an area in numerous European countries [2,3]. The way to manage above-mentioned types of waste includes landfilling, composting, incineration, etc.

Fig. 1 reveals that landfill was the dominant SWM method in 1995 in these countries, but this figure has been steadily declining since then, while incineration and waste packaging in the waste management process increases dramatically with significant increases in waste recycling. [3].

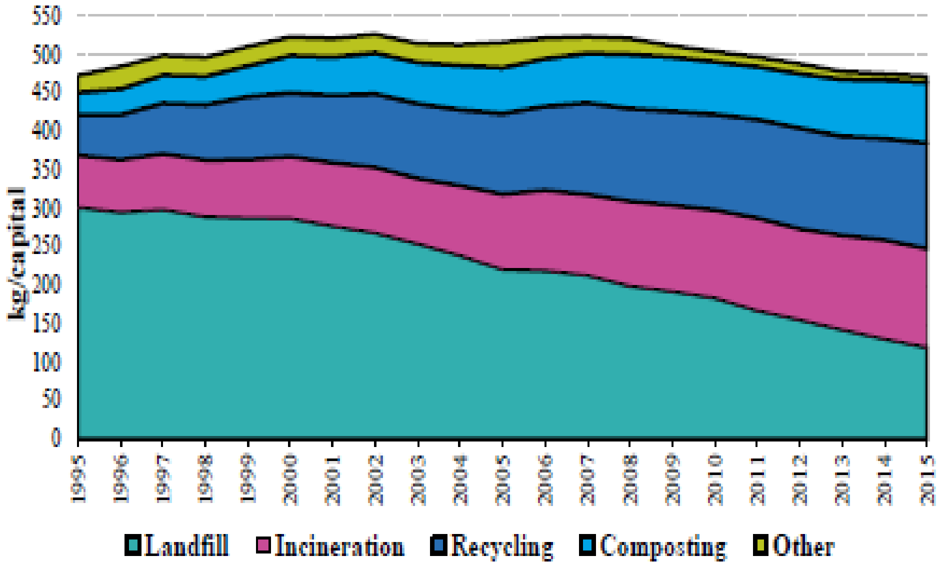

Figure 1. Household waste treatment in the period of years 1995-2015 (Eurotat 2017)

The global production of cement is growing annually (in 2018 it reached about 5 million tons per year and is growing annually by 5-10%). Concrete mixes with ash have greater cohesion, less water separation and delamination. Concrete has high strength, density, water resistance, resistance to sulfate corrosion, and lower thermal conductivity [3-7].

In connection with the increase in the amount of household waste in Azerbaijan on the territory of the former Balakhani landfill for waste disposal, by the order of the President of Azerbaijan Ilham Aliyev dated December 28, 2011, the “Balakhani industrial zone” with a total area of 7 hectares began its activity. The Balakhani industrial zone concentrates on the production in the field of waste processing. The management company of the industrial park is "Tamiz Shahar" JSC

Balakhani Industrial Park includes two plants on sorting and incineration. This is the largest waste processing station in Eastern Europe and the CIS. The plant is built adopting 4G technology and fully complies with local and European environmental protection standards.The enterprise's capacities allow to process up to 200 thousand t. of municipal solid waste (MSW)from which up to 40% of secondary raw materials are extracted: metals, glass, cardboard, plastic and other materials [14].

The ash of incineration plants contains oxides of CaO, SiO_2, Fe_2O_3 and Al_2O_3, similar to the composition of raw materials for cement production, this may become a possible substitute for raw materials in the production of cement [3-5, 8-13]. The incineration of waste generates a large amount of fly ash and bottom ash, which can be used as a filler additive in building materials for road construction and other fields.

2. Metod

Compression tests were performed on a YAW-300D computerized bend-ing-compression machine with a maximum bending and compressive force of 300 and 10 kN, respectively. Samples for compression tests were prepared in special molds with dimensions 40:40:40 mm. After holding in the mold and special heat treatment, the samples were brought to a state corresponding to the standards for a day at room temperature. After holding in the mold and special heat treatment, the samples were brought to a state corresponding to the standards for a day at room temperature. The compressive strength of concrete samples is calculated by the formula:

$\sigma = F / S$; where, σ - compressive strength, MPa; S- cross-sectional area of concrete sample, mm2, F- maximum compressive force, N.

The arithmetic mean of the three experiments was taken as the desired test result

3. Results and discussions

In this article presents the results of studying the effect of various factors, such as the amount of ash, an activator-binder alkaline solution, temperature and time of curing, etc. on the strength of ash concrete.

The ash concentration varied from 10-30%, and the activators from 5-10%. The kinetics of changes in the strength of concrete with different ash content was determined experimentally. The results of the observation are given in Figure 2.

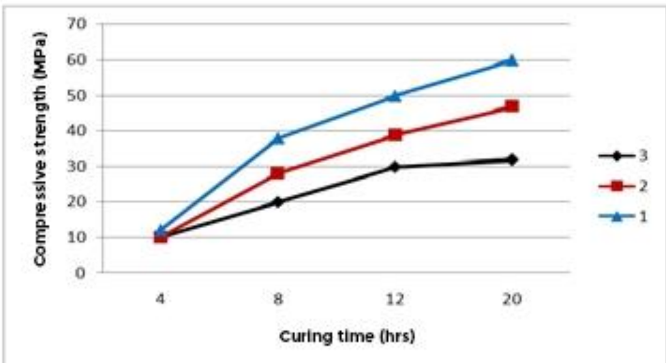

Figure 2. Kinetics of changes in concrete strength
Curves: 1 - 10%, 2 - 20% and 3 - 30% ash.

The results showed that the highest strength, about 60 MPa, is possessed by concretes with an ash content of 10-20%. which strngth increases uniformly on the 20th day and later. An increase in the amount of ash from 25% and more with the same amount of activator tends to decrease the compressive strength of concrete.

The concentration of sodium hydroxide (NaOH) solution.

Mixtures produced to analyse the effect of sodium hydroxide solution on the compressive strength of concrete. The test cylinders were left at ambient conditions for approximately 30 minutes prior to the initiation of dry cure in the oven. The curing time was 24 hours at various temperatures.

Resulted measurements on day 7 of the compressive strength of the test cylinders are shown in Table 1.

In Table 1, the difference between mixture 1 and mixture 3 is the concentration of the NaOH solution in terms of molar (second column). Blend 3 with a higher concentration of NaOH solution gives higher compressive strength than blend 1. A similar trend is observed for blenders 2 and 4.

The ratio of dissolved sodium silicate to dissolved sodium hydroxide. The effect of the ratio of dissolved sodium silicate to NaOH solution in bulk on strength in concrete can be seen by comparing the results of mixtures 1 and 2, as well as mixtures 3 and 4 in the table. For mixtures 1 and 2, although the concentration of NaOH solution (in terms of molarity) is the same, in mixture 2 the ratio of sodium silicate to the solution of NaOH is higher than in mixtures 1. This change increases the compressive strength of mixture 2. A similar trend is also observed in the results of mixture 3 and 4. The results are shown in the table. Mixtures 2 and 4 with a mass separation of sodium silicate solution with NaOH dissolution 2.0.

Table 1

Change in the strength of concrete depending on the amount of activator – alkali and sodium silicate

Mixture	Concentration of NaOH liquid (in Molars)	Ratio of sodium silicate to NaOH solution (by mass)	Comressive strength at 7th day (MPa)
			Cured for 24 hours at 60 ° C
1	5 M	0,5	15
2	5 M	2,0	47
3	10 M	0,5	40
4	10 M	2,0	58

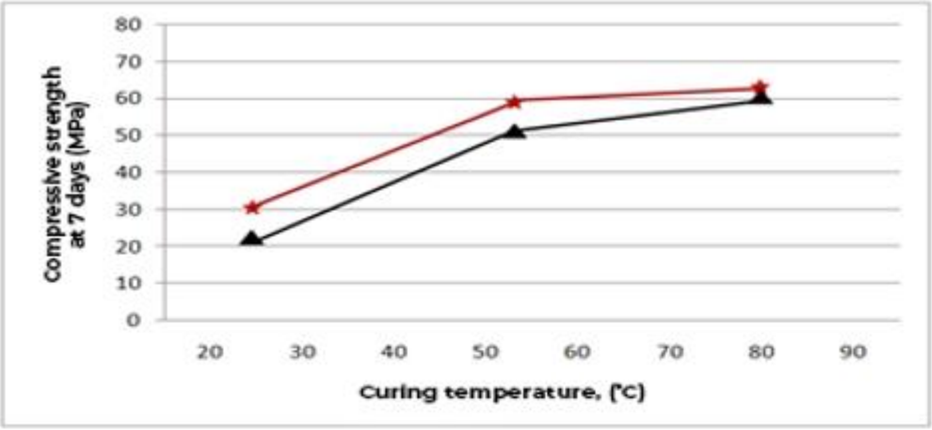

Figure 3. Impact of temperature on compressive strength
Curves: mixture 4; - mixture 2

Curing temperature. Figure 3 shows the effect of cure temperature on compressive strength for mix 2 and 4 after dry curing of test cylinders in an oven for 24 hours. All other test variables were constant. A higher cure temperature resulted in greater compressive strength, although raising the cure temperature above 60 ° C did not significantly increase the compressive strength.

Figure 4 demonstrates the effect of curing temperature for different oven holding times. Five different curing temperatures were used, i.e. 30 ° C, 45 ° C, 60 ° C, 75 ° C and 90 ° C.

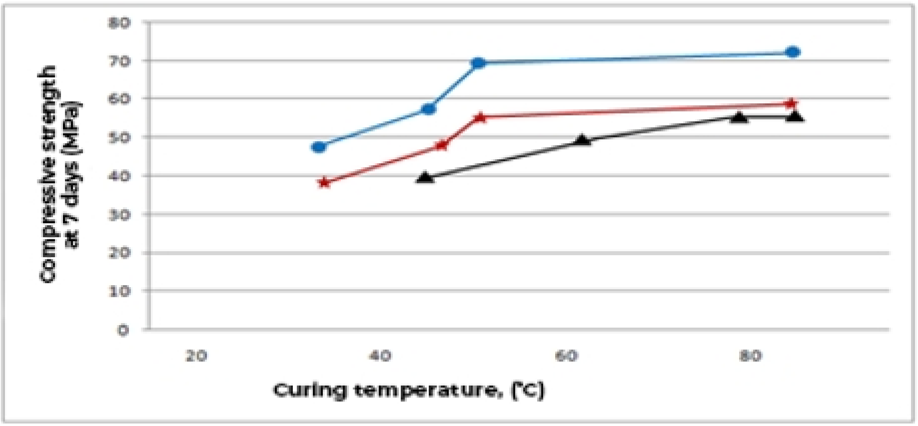

Figure 4. Effect of curing temperature on compressive strength
Curves: mixture 4 – 24 h., - mixture 2 – 24 h.,
- mixture 2 – 6 h.

The cure was carried out in an oven for 24 hours for mix 2 and 4 and 6 hours for mix 2 only. The results revealed in Figure 4 confirm that higher cure temperatures resulted in higher compressive strengths for both 6 hours and within 24 hours of curing.

Curing time. Geopolymer concrete can be obtained by adopting the generally accepted technologies used in the manufacture of Portland cement concrete. In the laboratory, fly ash and aggregates were first dry mixed together in a container for about three minutes. An alkaline NaOH liquid was mixed with water. The liquid component of the mixture was then added to the dry materials and mixing was continued for another four minutes. Fresh concrete can be processed for up to 120 minutes without any signs of setting and without any decrease in compressive strength. Fresh concrete was cast into special moulds and compacted using conventional methods. The compressive strength and workability of geopolymer concrete also depend on the wet mixing time. As the wet mixing time increased, the compressive strength of the hardened geopolymer concrete increased with a slight loss of workability in the fresh concrete.

Although low calcium ash-based geopolymer concrete can be cured under ambient conditions, thermal curing is generally recommended. Heat curing contributes significantly to the chemical reaction that takes place in the geopolymer paste. Both the curing time and the curing temperature affect the compressive strength of geopolymer concrete.

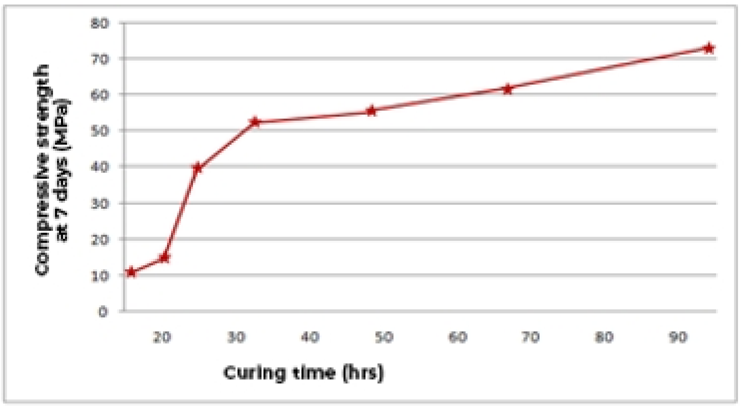

Figure 5. Influence of curing time on compressive strength for
- mixture 2

To investigate the effect of cure time, tests were prepared using Mix 2. Test cylinders were cured for various cure periods from 4 hours to 96 hours (4 days).

Figure 5 presents the results of these tests at the temperature of 60 °C. Longer cure times improved the polymerization process, resulting in higher compressive strength. The rate of increase in strength was rapid up to 24 hours of cure.

Impact of the mass ratio of water to geopolymer mass and sodium oxide on the strength of concrete.

The test specimens were cylinders with a size of 100–200 mm, thermoset in an oven at various temperatures for 24 hours. The results of these tests, presented inFig. 5, show that the compressive strength of geopolymer concrete decreases with an increase in the ratio of water mass to geopolymer by mass.

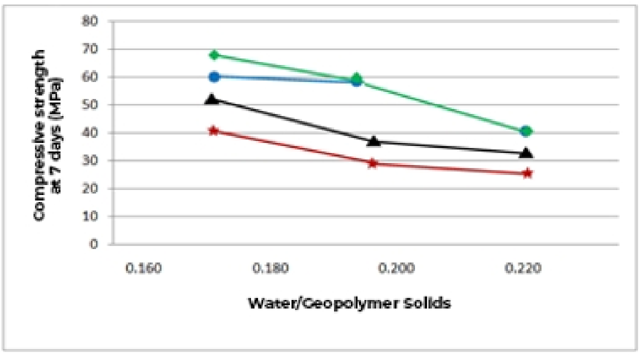

Figure 6. Effect of water-to-geopolymer solids ratio by mass on compressive strength of geopolymer concrete

Curves: - 90 °C; - 75°C; - 45 °C; - 30°C

As can be discerned from the above, the interaction of various parameters in terms of compressive strength and workability of geopolymer concrete is complicated. To support in the development of low calcium ash-based geopolymer concrete mixes, a single parameter has been developed called the "water to geopolymer ratio" by weight. For this parameter, the total mass of water is the sum of the mass of water contained in the sodium silicate solution, the mass of water in the sodium hydroxide solution, and the mass of additional water, if any, added to the mixture. The mass of the geopolymer solids is the sum of the mass of ash, the mass of sodium hydroxide solids and the mass of solids in a sodium silicate solution (i.e., the mass of Na_2O and SiO_2).

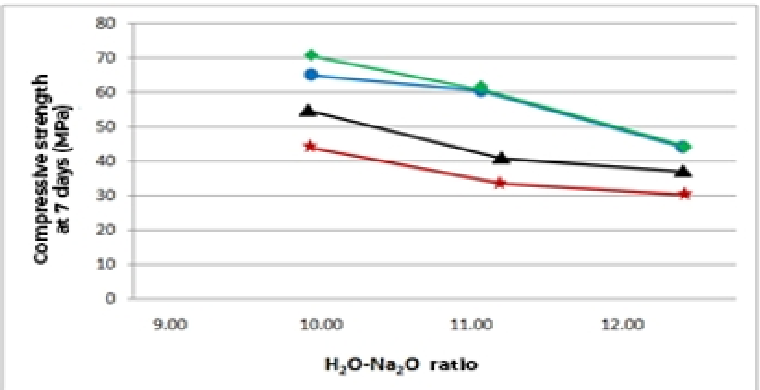

Figure 7. Effect of H_2O-to-Na_2O molar ratio on compressive strength

Curves: - 90 °C; - 75°C; - 45 °C; - 30°C

The test cylinders were cured for 24 hours at various temperatures. Figure 7 shows the effect of the H_2O-Na_2O molar ratio on the compressive strength of geopolymer concrete at different curing temperatures. An increase in this ratio provides the decreasing of the compressive strength of the concrete.

4. Conclusions

As a result of the study of the effect of ash residues of solid waste on the properties of cement and concrete based on it:

A method has been developed for obtaining concrete samples with the addition of bottom ash from MSW processing, activated with an alkaline solution. The results showed that the highest strength, of the order of 60-70 MPa, is possessed by concretes with an ash content of 10-20%, and on the 20th day and at a later date, the strength gradually increases. An increase in the amount of ash from 25% and more with the same amount of activator, there is a tendency for the compressive strength of concrete to decline.

The optimal concentration of the alkaline solution was chosen - 5M. A higher concentration (in terms of molar) of sodium hydroxide solution leads to a higher compressive strength of geopolymer concrete based on bottom ash.

It has been established that the higher the ratio of the mass of sodium silicate solution to sodium hydroxide solution by weight, the higher the compressive strength of concrete. The optimal mixture was chosen containing an ash residue with a mass ratio of sodium silicate solution to the alkali solution of 2.0 and was used as the main mixture to study the influence of other parameters.

It was revealed that the curing temperature affects the strength of ash concrete. A higher curing temperature leads to a higher compressive strength of concrete, although an increase in temperature above 60 ° C does not significantly increase the compressive strength.

The molar ratio of H_2O-Na_2O and Na_2O-SiO_2 showed that only the range from 10.0 to 14.0 is possible. When the molar ratio H_2O-Na_2O is less than 10.0, concrete mixtures are difficult to process; on the other hand, when the value is exceeded 14.0, there is a significant separation of the ingredients of the mixture due to the presence of excess water. With an increase in the ratio of the mass of H_2O to the mass of concrete, its compressive strength also decreases.

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