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STUDY OF THE USE OF GLASS WASTE IN THE PREPARATION OF CONCRETE

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Abstract:*The presented article describeds the results of scientific research on the use of waste glass in concrete production. In accordance with the research topic, it was studied that glass waste can be used as fine and coarse aggregate in concrete production and its feasibility as a sand substitute was confirmed. According to the topic, glass cullet was replaced in concrete material in the amount of 20%, 40% and 60% of the sand raw material, and the technological, physical and mechanical properties of the resulting samples were evaluated through tests. Based on traditional concrete production, samples were prepared and stored in a standard environment for hardening. Thus, density tests along with slumping are carried out for fresh concrete and, at the same time, analyses are carried out to determine the compressive strength, resistance to impact, and water absorption capacity for the hardened finished sample. According to the research topic, the application of 40% glass cullet as a sand substitute has a positive effect on the mechanical and physical properties of concrete. However, at 60% substitution, the adhesion of the mixed cement raw material in the interfacial layer decreases, and as a result, the indicative values of the mechanical properties of the product weaken. According to the scientific research, the use of glass waste as a sand substitute was considered more efficient and expedient from both ecological and economic points of view.*
Keywords: *waste glass, concrete, sand substitute, density, durability, water absorption.*

INTRODUCTION

The production of construction materials is one of the main industries that consumes excessive amounts of natural raw materials and emits harmful substances that are considered a source of danger to the environment in modern times. One of the most widely produced materials in the construction industry is concrete, and negative phenomena such as dust particles released into the air during the product preparation process, wastewater, etc. have a serious impact on the environment. One of the main raw materials of the process is sand, and in recent years, a decrease in the reserves of this component has been observed, as well as an increase in production costs. Due to the aforementioned problems, enterprises are currently focused on researching alternative filler materials [1].

The use of recycled materials as an alternative filler component has become relevant in modern times. Thus, the rapid increase in the volume of glass waste from industrial and household waste currently makes it necessary to recycle them [2].

Since the high proportion of glass waste is composed of silica, its mechanical durability and chemical stability are extremely high. The listed properties make it advisable to use this waste as a promising and efficient filler material in concrete production. In the process, glass waste is used in two ways, both as a cement and as a sand substitute. When used as a cement substitute, an alkali-silica reaction occurs in the chemical composition of concrete, creating stress within the product and causing it to crack. At the same time, from an economic point of view, this method of use requires grinding glass cullet to a finely dispersed form and is considered an additional process stage for these enterprises [3]. Thus, the fine grinding process causes negative situations such as high energy consumption, an increase in the amount of dust particles emitted into the environment, and a longer completion time of the production process.

The optimal use of glass waste as a sand substitute is fully consistent with the production of the required quality product [4]. The main advantages of this application method include the fact that the production process does not require an additional stage, saving energy consumption, as well as reducing the volume of harmful waste emitted into the environment and protecting natural sand resources [5].

The presented research topic focuses on the use of glass waste as a sand substitute in concrete production [6].

EXPERIMENTAL PART

In the production of concrete using glass waste as a sand substitute, cement with a specific surface area of 562 m^2/kg, as well as natural coarse and fine sand with a grain size of 5mm and 2mm were used [7]. Waste glass, a mixed-color soda-lime material, was used in the production process. Before entering the process, glass waste is processed in three main stages: crushing, crushing, and grinding. Equipment with rotating blades installed inside is used for the crushing operation. After that, after the operation is completed, the large grains of the particles sent for crushing are removed from the process. The next operation is performed in a grinding device with a rotating grinding shaft [8]. According to the topic, fine-grained waste glass crumb with a size of 3mm is used for concrete production.

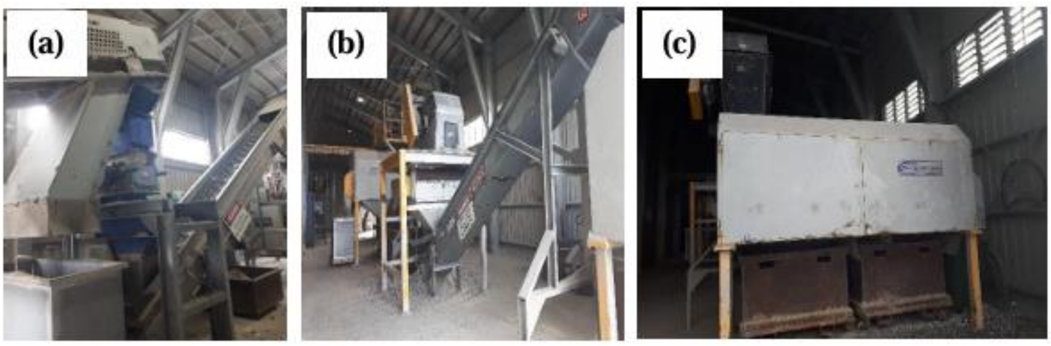

Fig.1. Waste glass processing stage.a- Mil-tek GC600 Glass Crusher, b- Retsch AS 200 Vibratory Sieve Shaker, c- IKA MF 10 Basic Analytical Mill

A visual image of the scrap obtained after the processing processes is shown in figure 2.

Fig. 2. Colored and 3 mm glass crumb

The concrete sample prepared for the study showed a strength of 32 MPa at 28 days. The overall study consists of 3 separate experiments. These experiments include tests conducted initially on the raw materials used, then on the fresh concrete material, and finally on the hardened product.The listed tests include particle size distribution tests, slump tests, density tests, and also compression, tensile, and strength tests [9].The results of the experimental study are shown graphically in figure 3.

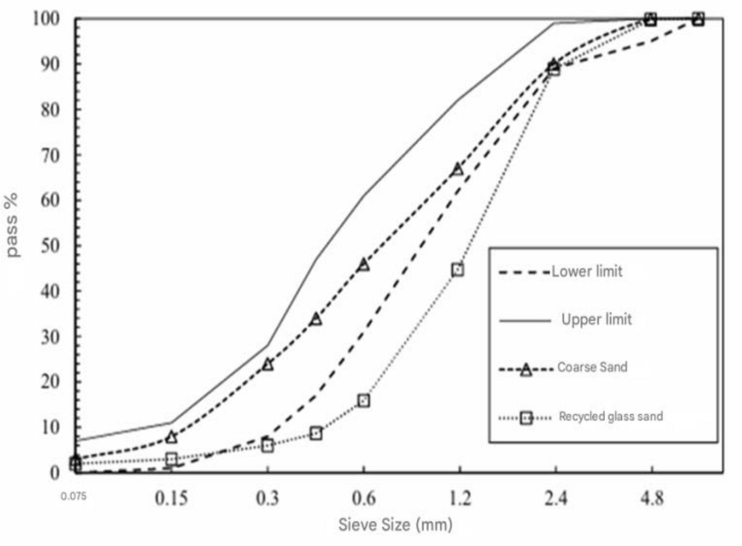

Fig. 3. Graphical results of the particle size experiment

To check the presence of undesirable components in the chemical composition of glass cullet, 100 g of glass cullet is placed in a 250 ml beaker and 50 ml of 1N hydrochloric acid is added and boiled. After boiling, litmus paper is used to detect the precipitate, and in case of acidity, neutralization is carried out using 1N sodium hydroxide. Then, 3 ml of Fehling's solution, a copper-based chemical reagent, is added to the mixture and heated in a water bath. If the mixture does not form a red-brown precipitate after heating, the result is acceptable. A description of the test performed is shown in figure 4. The laboratory equiment complex used for sample preparation, mixing, filtration and pH determination in chemical analysis processes is shown in figure 4.

The particle size determination for the materials was performed by sieving. Then, for the prepared fresh concrete sample, during the density tests with subsidence, a cone shape with a height of 300 mm, a bottom diameter of 200 mm, and a top diameter of 100 mm was used [10].

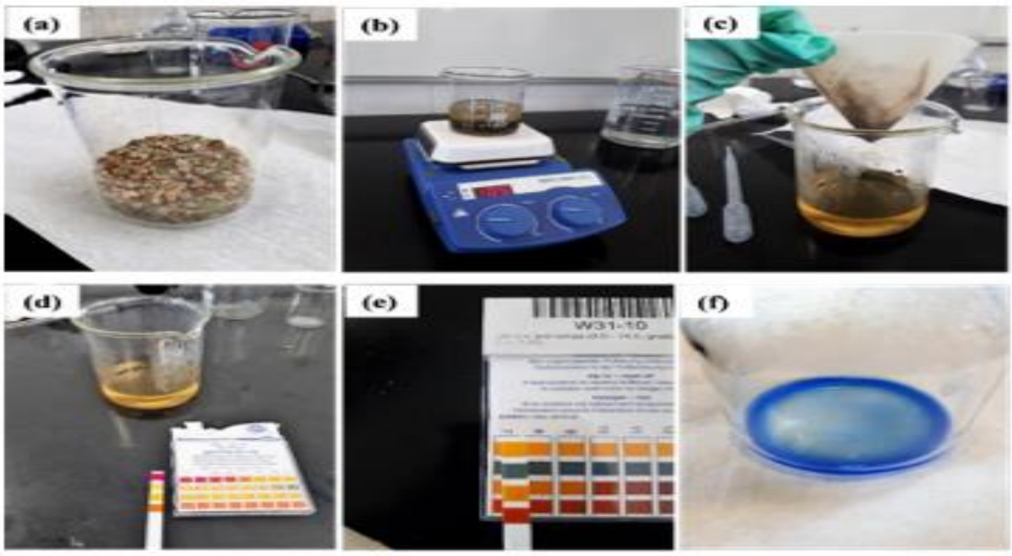

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Fig. 4. Test for checking the chemical composition of glass cullet for undesirable components. a-DURAN Borosilicate Glass Beaker (250 ml, Griffin type), b-IKA C-MAG HS 7 Hot Plate, c-Borosilicate Glass Funnel + Whatman Grade 1 Filter Paper, d and e-MColorpH Indicator Strips (pH 0–14), f-DURAN Glass Petri Dish

RESULTS AND DISCUSSION

The difference between the height of the cone and the subsidence of the concrete is accepted as the experimental result. For the density test, a sample is poured into cylindrical molds.

Then, the results obtained are substituted into the standard expression and the result is determined. The results obtained for the density test are given in table 1.

The first test is the compressive strength test on the hardened sample. The test was conducted on cylindrical specimens for 28 and 56 days. Before the test, the sample was kept in water, hardened, and then analyzed. The test equipment used for the test is presented in figure 5.

An experiment was conducted with a Universal Testing Machine (UTM) and is shown in figure 5.

A graphical representation of the density test results of a hardened concrete sample conducted at two separate times is presented in figure 6.

Table 1

Density test results of fresh concrete

Replacement interest rates	Sliding (mm)	Density of freshly mixed concrete (kg/m³)	Density of hardened concrete (kg/m³)		
			7 days	28 days	56 days
Control	90,2	2395	2407	2400	2398
20%	61	2378	2388	2373	2379
40%	66	2366	2362	2370	2383
60%	41	2351	2359	2357	2362

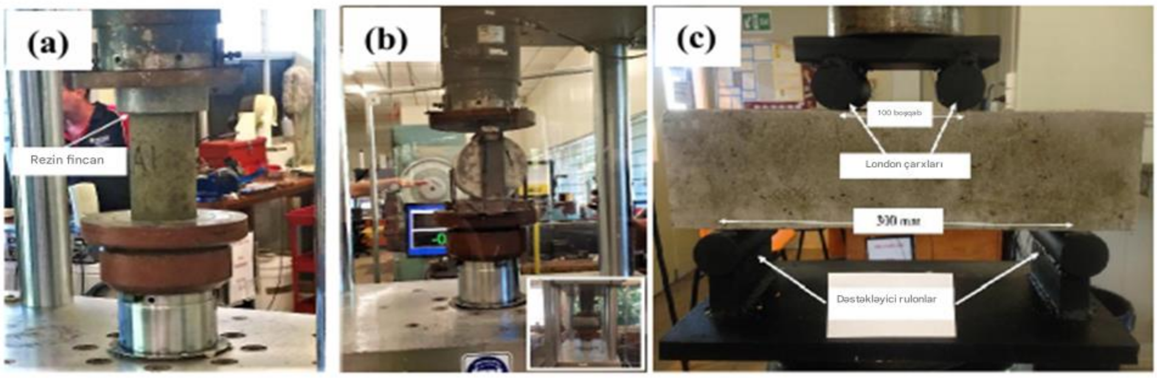

Fig. 5. Compression test setup Universal Testing Machine (UTM). a-Compressive strenght, b-Tensile strenght, c-Flexural strenght

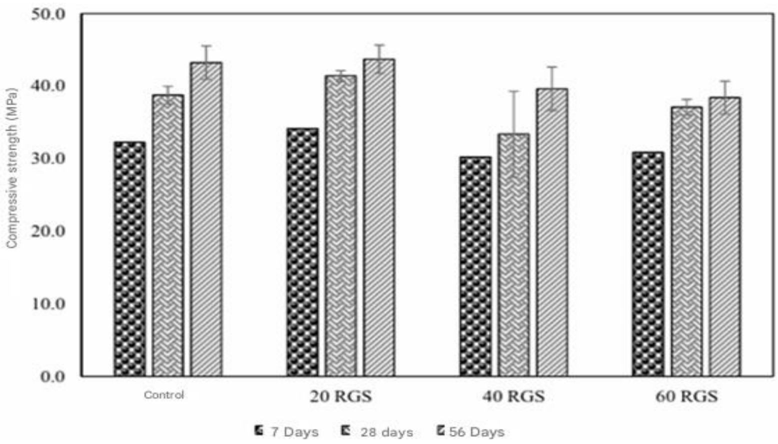

Fig. 6. Graphical result of the density test

A chloride penetration experiment is carried out to measure the durability of concrete. The sample is cut according to the required standard dimensions and coate.

The sample is cut according to the required standard dimensions and coated with an epoxy layer. The prepared sample is placed between two cells filled with 0.3 N sodium hydroxide on one side and 3% sodium chloride solutions on the other. A 60V direct current is applied to the sample placed between the two solution layers. Thus, the experiment is carried out at least three times with an interval of 30 minutes throughout the test. A real description of the experiment is depicted in figure 7. The Specimen Preparation Apparatus is shown in figure 7, option a. The Hydraulic Conductivity Setup is shown in figure 7, option b. The Electrochemical Cell System is shown in figure 7, option c.

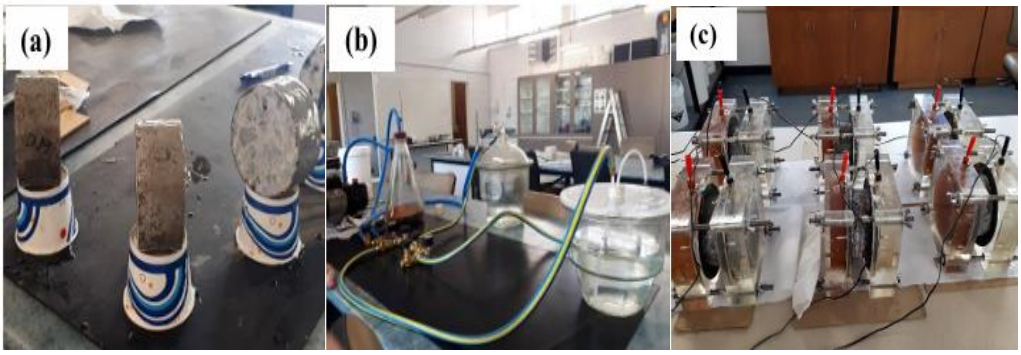

Fig. 7. Chloride penetration test. a-Specimen Preparation Apparatus, b-Hydraulic Conductivity Setup, c-Electrochemical Cell System.

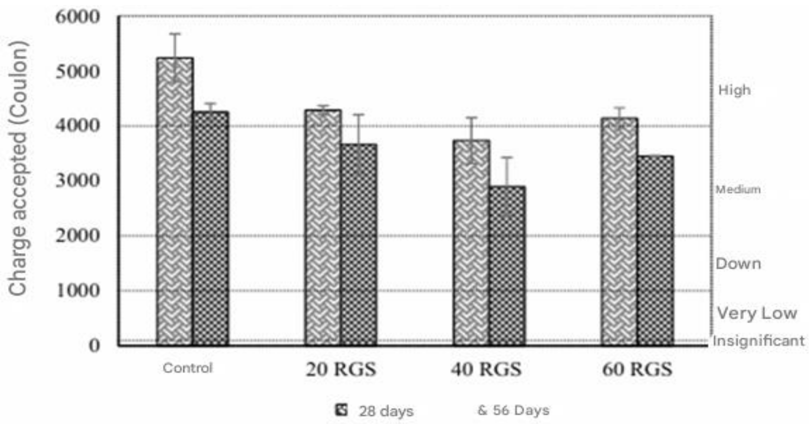

Fig. 8. Graphical representation of the results of the chloride penetration test

In the test conducted for 56 days, the chloride penetration of the concrete was 19% less than that at 28 days. However, the result obtained was considered to be in the high permeability range and a graphical representation of the test is shown in figure 8.

CONCLUSION

Various tests were conducted on a sample of freshly prepared concrete mix and a hardened product using glass cullet. Although the result obtained from the density test of the concrete mix prepared on the basis of glass waste cullet was low, the hardening time analysis was within the required time intervals. Other test results also prove that the prepared concrete is of the required quality.

The results show that the use of recycled glass waste cullet as a sand substitute of up to 40% in concrete production is more appropriate. However, changing the substitution ratio can reduce the workability of the concrete product, and in this case, additional components must be included in the process.

If the correct application ratio is determined based on the tests conducted, a very high quality concrete product can be produced, and thus the amount of natural raw material resources used is reduced and conserved, and also a reduction in various capital costs of enterprises, along with energy consumption, is observed. The overall result is that the recycling of glass waste is successful.

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