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2nd International Conference on Engineering, Natural and Social Sciences

April 4-6, 2023 : Konya, Turkey

https://www.icensos.com/

Investigation of Electrical Conductivity of Fly Ash Based Waste Aluminum Chips Reinforced Alkalis Activated Mortars

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Abstract – In this study, the effect of waste aluminum reinforcement on electrical conductivity was investigated in the alkaline activated mortar samples produced using fly ash. In the preparation of the mortar samples, aluminum waste was substituted at 0%-10%-15% and 20% by weight of the binder ratio. It is seen that the use of substitute aluminum waste as additive waste according to cement weight has a negative effect on both the workability and strength of the concrete. It was found that the added material did not improve the overall quality of the concrete. It was also revealed that it is a weaker and less machinable material. However, it has been observed to be quite good in terms of electrical conductivity. It has also been found that the use of these materials leads to some reduction in machinability or strength. However, it is thought to have some benefits in terms of sustainability or cost effectiveness.

Keywords – Electrical Conductivity, Electrical Resistivity, Aluminum Waste, Flow Diameter Test, Unit Weight

I. INTRODUCTION

The properties of concrete containing aluminum wastes have been investigated in previous studies in terms of both fresh and hardened conditions. Instead of cement, aluminum wastes can be used as supplementary cementitious material (SCM) [1],[2]. Calcium hydroxide in the cement reacts to form calcium aluminate hydrates, which contribute to the strength and durability of the concrete. Also, using aluminum waste as an SCM can reduce the carbon footprint of concrete production. In addition, studies in the literature have investigated the use of aluminum waste instead of sand in concrete. It has been found that aluminum waste can be crushed and used as a fine aggregate in concrete. In addition, it has been shown to have good strength and durability properties. Generally, the use of aluminum waste in concrete is a promising area of research with the potential to improve the performance of the material while reducing the environmental impact of concrete production.

The development of new technologies for the cost-effective conversion of various wastes into usable raw materials is an important area of research. The use of pozzolanic materials in concrete production is a well-established technique that has been used for thousands of years. Many pozzolanic materials used in concrete production are by-products of various industries. These materials can be mixed with cement to improve the strength and durability properties of concrete. However, there is much research to be done on the development of pozzolanic materials that can be specifically designed and optimized for use in concrete production. There has been some research on the development of new pozzolanic materials, such as geopolymers, which are synthesized from industrial by-products and may have improved mechanical and chemical properties compared to conventional pozzolanic materials. However, more research is needed to optimize the production and use of these materials in concrete production. The development of new pozzolanic materials is an important area of research with the potential to improve the performance of concrete while reducing the environmental impact of concrete production using waste materials.

Elinwa and Mbadike 2011, investigated the use of aluminum waste instead of cement in concrete production [3]. In the study, concrete samples containing varying levels of aluminum waste ranging from 5% to 40% were produced instead of cement. The setting time, tendency strength and compressive strength of concrete samples were investigated. As a result of the study, it was found that the addition of aluminum waste to the concrete mix caused an increase in the setting time of the concrete. They also showed that higher levels of aluminum waste resulted in longer setting times. In the study; It was found that the tendency and compressive strengths of concrete decreased with increasing aluminum waste levels. However, even at the highest level of aluminum waste (instead of 40% of cement), the concrete samples showed acceptable strength levels.

Arimanwa et al, examined the replacement of cement with waste aluminum chip at varying rates ranging from 0% (control group) to 20% in 2012 [4]. The compressive strength of the obtained concrete samples was measured and compared with the estimated values obtained from the Scheffe theory [4]. It has been found that the compressive strength of concrete decreases with increasing waste aluminum chip level. It has also been shown that the laboratory results for compressive strength are compatible with Scheffe's model and the model can be used to predict the compressive strength of cement concrete formed by aluminum waste. It has been reported that the use of waste aluminum chip leads to a reduction in the workability of the concrete mix due to the absorption of water by the aluminum waste chips.

The development of alternative binders such as alkali-activated mortar or concrete is a very important issue in terms of sustainability in the construction industry [5]. The production of conventional cement systems is a significant contributor to greenhouse gas emissions and energy consumption, and alternative binders can help reduce these impacts [6]. Alkali activated materials are a class of binders that can be produced from a variety of waste materials such as fly ash, slag and natural pozzolans [7],[8]. These materials can be activated by alkali activators such as sodium hydroxide or potassium hydroxide to form a cement-like binder [9]. Alkali activated materials have several advantages over conventional cement systems, such as lower carbon dioxide emissions and energy consumption during production [10]. They also have the potential to use waste materials that would not be used, reducing the environmental impact of waste material [11], [12]. Generally, the development of alternative binders such as alkali-active materials is an important area of research with the potential to significantly reduce the environmental impact of the construction industry [13].

The aim of this study is to emphasize that producing alkali-activated mortar or concrete using alternative binders in cement systems is very important in terms of sustainability. In this study, unlike the literature, it was aimed to examine the electrical conductivity and some mechanical properties of mortars that were activated with high alkalis and added aluminum sawdust.

II. Materials and Method

A. *Materiel*

The standard sand used in the study is the CEN reference sand specified in TS EN 196-1 [14] standards, produced at the Limak Trakya Cement factory. Chemical and physical properties of Fly Ash are given in Table 1. Fly ash was used directly without grinding as it left the factory.

Table 1. Physical and chemical properties of Fly Ash

Chemical Properties (%)	**Fly Ash**
SiO_2	30,02
Al_2O_3	12,52
Fe_2O_3	5,42
CaO	38,78
MgO	1,75
SO_3	0.69
Na_2O	0.41
K_2O	0,66
Physical Properties	
Blaine's thinness (cm^2/g)	2345
Specific gravity (g/cm^3)	2.68

The digital camera image of the fly ash used in the production of the test sample mortars and the waste aluminum chip are shown in Figure 1.

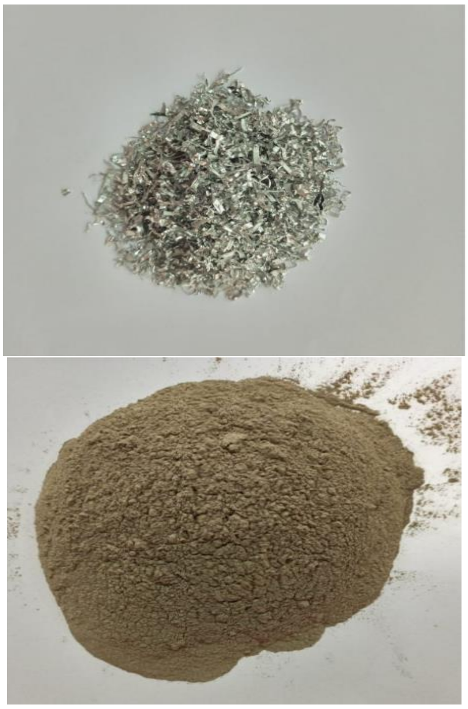


Figure 1. Waste aluminum (a) digital camera, (b) Fly Ash

Solid potassium hydroxide (KOH) and sodium silicate solution (Na_2SiO_3) with 98% purity were used as alkali activators in the experimental study. The chemical composition of the Na_2SiO_3 solution (% by weight) consists of SiO2 (26.5), Na_2O (8.3) and dH_2O (6.2). Sodium hydroxide and sodium silicate used as activators are shown in Figure 2.

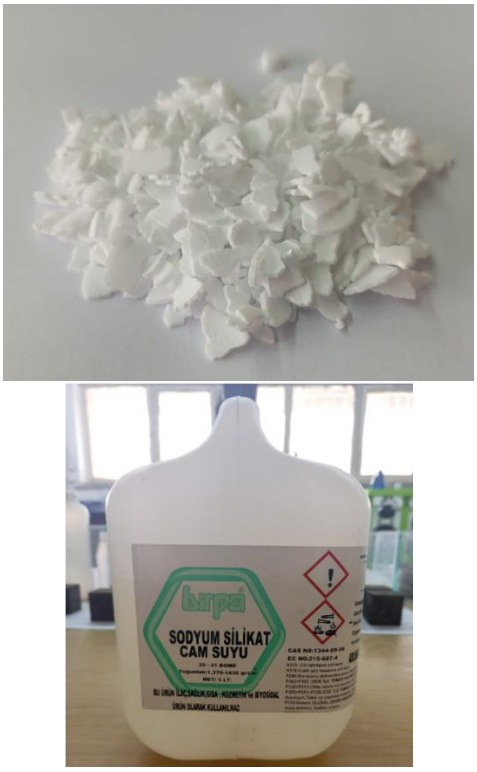


Figure 2. Potassium hydroxide (a) sodium silicate (b)

Potable tap water was used in the experimental study.

B. Experiment Design

The mixing ratios of the alkali-activated mortars produced in this experimental study are given in Table 2.

. Table 2. Mortar mixing ratios

Sample	UK (g)	KOH (g)	Na2SiO3 (g)	Sand (g)	Water (g)	Al Waste Chip (g)
UAO ŞAHİT	450	32	127	1350	146	0
UA5	450	32	127	1350	146	22,5
UA10	450	32	127	1350	146	45
UA20	450	32	127	1350	146	90

Samples of AAC mortar with aluminum chip are shown in Figure 3.

Figure 3. Samples of AAC mortar with Additive Aluminum Chip

C. Unit Weight Test

The dry density of the produced composite material was calculated using the formula in equation 1.

Dry Density = (Dry Sample Mass / Sample Volume) (1)

D. *Flow Diameter Experiment*

The spreading diameters of all fresh mortars were obtained according to the TS EN 1015-3 standard and are shown in Figure 4 [15].

Figure 4. Flow diameter experiment (a) Control (b) 5% UA (c) 10%UA and (d) 20% UA

E. *Electrical Conductivity Experiment*

A DC power source and two digital multimeters were used in the experimental setup prepared for electrical conductivity measurement. A fixed voltage value is given to the material produced through the power supply. The power supply is set to 32V. One of the digital multimeters was connected in series to the established circuit and the current passing through the circuit was measured. The other multimeter is used to measure the voltage value supplied from the power supply. The currents passing through the circuit are calculated by taking measurements from at least 5 different parts of the material. The reason for this is that the material produced is not homogeneous.

The resistance value of the material was calculated according to the measured voltage and current values. The resistance value is found by considering Ohm's law. After the resistance value was found, the electrical resistivity and conductivity values of the material were calculated. The measured resistance value varies according to the size and area of the material. For this reason, 40x40x40 mm dimensions were used to ensure equal conditions in every material produced. The electrical conductivity expression of the material is calculated after the resistivity is found.

III. RESULTS

A. *Unit Weight*

While the dry density of the control concrete was 2415 kg/m3, the densities of the samples with 5, 10% and 20% aluminum slag waste replacement by weight of the cement were respectively found to be 2295, 2255, and 2095 kg/m3. When the increased aluminum waste content is compared with the control concrete, it is seen in Figure 5 that the unit weight decreased by 4.96%, 6.62% and 13.25%, respectively. This decrease in density can be attributed to the chemical reaction that occurs between the aluminum waste and the alkali present in the cement concrete. This reaction causes the release of hydrogen gas and the formation of small bubbles that rise to the top surface of the concrete, leading to an increase in voids and a decrease in the overall density of the material.

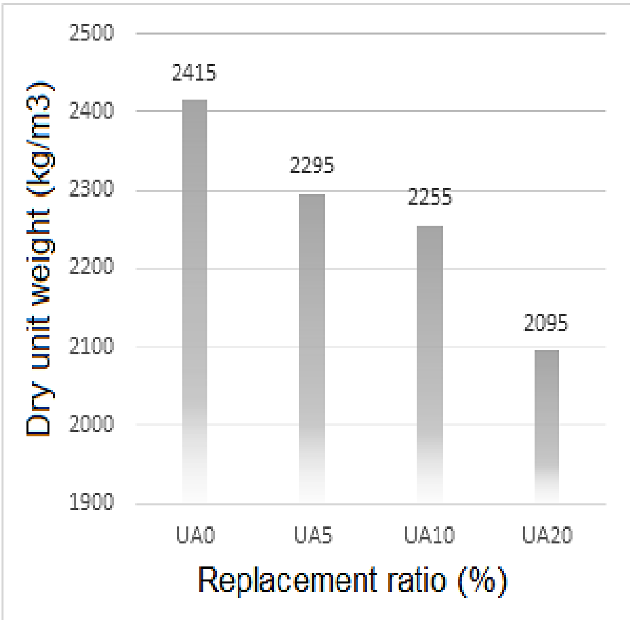


Figure 5. Unit weights of mortar samples

B. Flow Diameters (mm)

The flow diameters of the control concrete and the waste aluminum chip of 5, 10%, and 20% by weight of the cement were respectively found to be 152, 143, 135 and 122 mm. Flow diameter results are shown in Figure 6. When compared to the control concrete, the reduction in flow diameter was respectively calculated as 5.9%, 11.18%, and 19.73%.

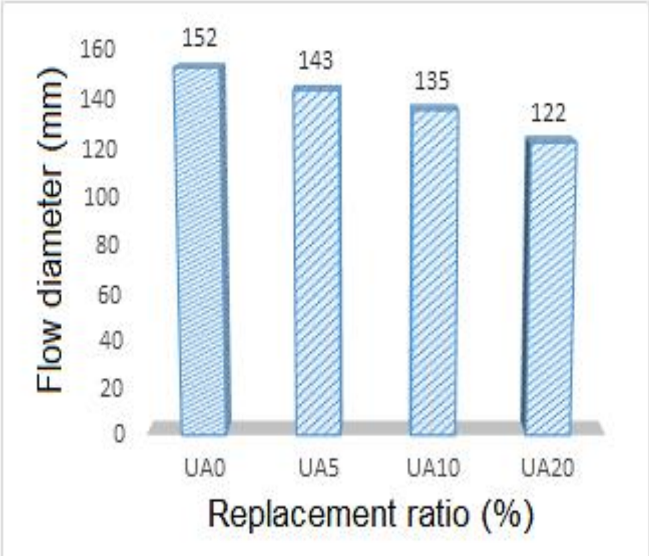
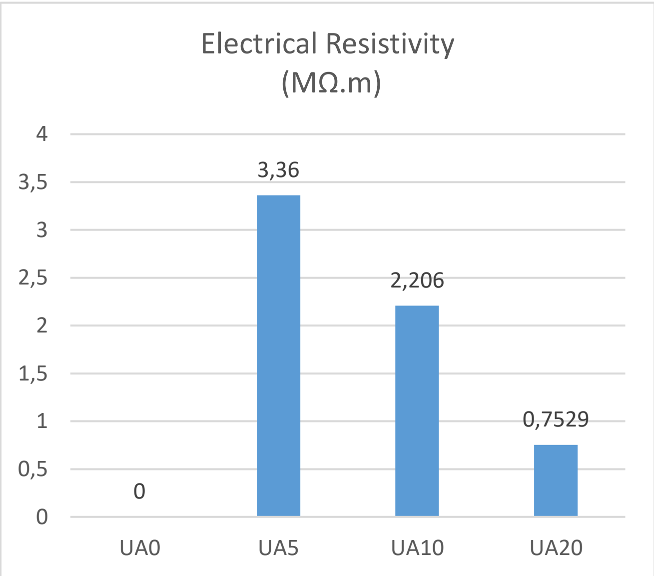


Figure 6. Flow diameter results of mortar samples

C. *Electrical Resistivity Experiments Results*

The resistivity and electrical conductivity values obtained by adding different amounts of waste aluminum to the samples are shown in Figure 7.



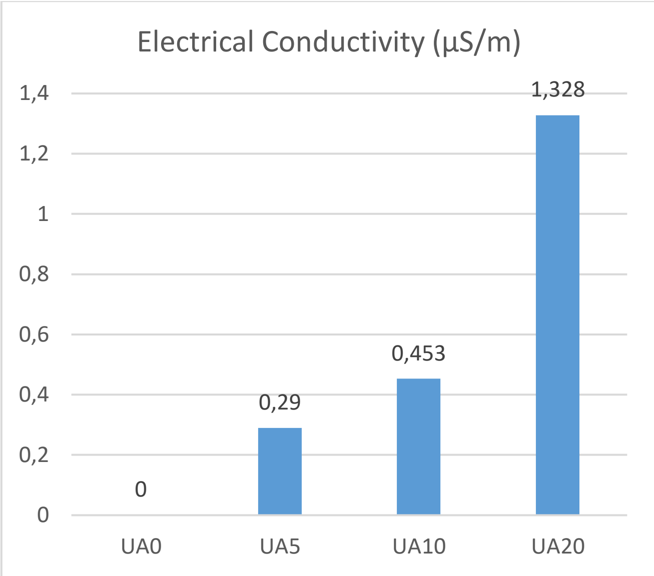


Figure 7. Resistivity and electrical conductivity values of mortar samples

When the resistivity and electrical conductivity graphs obtained in Figure 7 are examined, the electrical conductivity of the sample formed by adding 20% AL increased by 457.9% compared to the sample formed by adding 5% AL. The electrical conductivity of the new material produced has been increased thanks to the added aluminum. This ratio also showed that aluminum was dispersed homogeneously in the produced mortar. It has been observed that the positive effect on the material in terms of conductivity increases as the density of aluminum is increased. Since aluminum is a very good conductor, it is expected that the resistance to electric current will decrease. The decrease in the resistivity value caused the electrical conductivity value to increase at the same rate.

IV. DISCUSSION

It is seen that the use of waste aluminum chip instead of some of the cement in the concrete causes a decrease in the dry density of the concrete. It is seen that the decrease in dry density increases with the increasing amount of waste. A maximum decrease of 13.25% was observed in 20% waste content. While this reduction in density may have some adverse effects on the strength and durability of concrete, it appears that the use of waste aluminum chip as a cement substitute can still have other benefits such as reduced environmental impact or cost saving. It has been observed that the electrical conductivity increases as the aluminum content added to the produced concrete increases. The gaps formed in the material are filled with aluminum. As a result, AAC composites produced as conductors for various applications have a good potential for structural health monitoring systems, highway bridge decks, parking lots, sidewalks, driveways and airport runways, covered snow melting system, smart structures.

V. CONCLUSION

As a result of this experimental study, it was observed that the electrical conductivity property of the mortars in which waste aluminum chip was substituted increased due to the increase in the substitution rate. In addition, it was determined that waste aluminum chip substituted into the mortar had a reducing effect on the flow diameter of the mortar and the dry mortar density amounts.

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