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An Evaluation of the Effect of Waste Aluminum Sawdust on the Carbonation of Concrete

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Abstract
The aim of this study is to examine the effect of replacing waste aluminum sawdust (AS) with fine aggregate on the strength and durability properties of concrete. For this, concrete mixtures with a cement dosage of 400 kg/m^3 and water/cement (W/C) ratio of 0.40-0.50-0.60 were prepared. AS obtained from Elazig industrial site was added to the concrete mixtures by replacing 0%, 0.5% and 1% fine aggregate by volume. After curing in the curing pool for 28 days, the produced concrete samples were subjected to accelerated carbonation test in the carbonation tank at three different time periods the 1st, 3rd and 7th days. Compressive strength test and carbonation depth measurement test were performed on the samples before and after carbonation. In addition, the microstructure of AS concrete was investigated using scanning electron microscopic images (SEM). In the microscopic images, larger cracks, openings and interfacial voids were observed in the concrete matrix with the addition of AS. In addition, it has been observed that the carbonation effect contributes to the compressive strength.

1. Introduction

In recent years, there has been a rapid increase in the emergence of waste materials and by-products due to population growth, the development of industry and technology, and the increase in consumption. When these waste materials are not disposed of properly, they cause environmental pollution [1], [2]. Therefore, it is necessary to ensure the disposal of solid wastes by minimizing the damage to the environment.

The expansion of construction has an important role in the increase in environmental problems. Buildings produce harmful emissions and wastes by consuming natural resources and energy during their lifetime. As a result, they create environmental pollution [3], [4]. It is estimated that around 11 billion tons of aggregate are consumed every year around the world. Approximately 8 billion tons of this aggregate amount are used in concrete production [5].

Exposed and unprotected concrete structures cause corrosion damage [6]. In Turkey, it was observed that corrosion damage occurred in all of the structures damaged in the earthquake. There is also a risk of corrosion in our existing structures. The most important factor causing corrosion is carbonation [7]. Carbonation also causes deterioration of the durability of the structures. As a result of carbonation, the pH value of the concrete decreases from 12-13 to 8-9, weakening its basic feature. For this reason, rusting of the reinforcements in the concrete becomes easier. The reinforcement in the carbonation region becomes susceptible to corrosion. As a result of corrosion, the adherence between the concrete and the reinforcement weakens and the strength of the concrete decreases [8].

Many studies have been conducted on the effects of using wastes in concrete, such as wood chips, glass dust, and marble powder [9]. However, there are hardly any studies on the use of aluminum

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sawdust in concrete production. The aim of this study is to examine the effects of carbonation on the mechanical properties of these sawdust-added concretes by experimentally measuring the mechanical properties of concrete as a result of carbonation at different times. In addition, by ensuring that aluminum sawdust, which is an industrial waste, is used in concrete production, it is aimed to improve the properties of concrete and to bring more environmentally friendly concrete types to the economy by recycling the wastes.

2. Material and Method

In this study, CEM I 42.5 R Portland cement obtained from Elazig Çimentaş cement factory was used [10]. Aluminum sawdust (AS) was used as a waste material. AS was supplied from Elazig industrial zone. In the experiments, the largest grain diameter (D_{max}) obtained from Palu District of Elazig was selected as 8 mm, and stream aggregate was used. Aggregates are used in three classes: 0-2 mm, 2-4 mm and 4-8 mm. The physical properties of the aggregate are given in Table 1, and the granulometry curve of the aggregate is presented in Figure 1. Also, The chemical properties of the materials used in the study are given in Table 2.

Table 1. Physical properties of aggregate

Aggregate Properties	(0-2) mm	(2-4) mm	(4-8) mm
Loose Unit Weight (gr/cm^3)	2.44	2.71	2.81
Water Absorption (%)	3.53	1.71	1.31

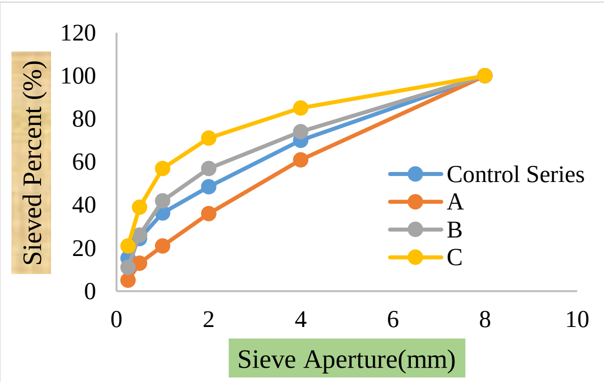


Figure 1. Gradation curve of the aggregate

Table 2. Chemical properties of materials used in the study (%).

Chemical Composition	Cement (C)	Chemical Composition	Aluminium Sawdust (AS)
CaO	63.33	Al	89.96
SiO_2	19.07	Zn	4.97
Fe_2O_3	3.72	Mg	2.11
Al_2O_3	4.82	Cu	0.26
SiO_3	2.83	Mn	0.25
Na_2O	0.39	Fe	0.24
K_2O	0.65	Si	0.15
MgO	1.10	Cr	0.025
Cl	0.009	Ti	0.012
Insoluble residue	0.20	Pb	0.005
Loss of ignition	2.70	Sn	0.003

The waste aluminum sawdust used is aluminum sawdust that became inactive as a result of processing aluminum sheets and profiles and was obtained from the Aykü aluminum workshop operating at the Elazig industrial site. Chip sizes are mixed. The specific gravity of the AS used is 2.7 gr/cm^3. The view of the AS used in the study is shown in Figure 2.

Figure 2. Aluminium sawdust sample used in the study

2.1. Sample Preparation and Mixing Ratios

Before beginning the study, an extensive literature review on mixing ratios was conducted. The trial mixes were then poured. Reference mixtures were determined using the data obtained as a result of these trial mixtures. In this study, 9 different concrete mixtures were prepared in accordance with the mixing principles specified in TS 802. In order to examine the variation range of strength properties of AS reinforced concretes at fixed cement dosage at different ratios, 9 concrete mixtures with cement dosage of 400 kg/m^3, W/C ratio of 0.40-0.50-0.60, respectively, were prepared. In these mixtures, 0.5% and 1.0% AS were used by replacing the fine aggregate by volume. A superplasticizer was not used since it has a consistency within the workability limits. A total of 9 different concrete series were prepared, 3 for the control series without AS and 6 for the series containing AS. Details of mixing ratios are summarized in Table 3. In the table, naming is done by giving the W/C ratio first and then the AS ratio used in the series names.

Table 3. Proportions of the concrete mixtures (kg/m^3)

Mixture Code	W/C	Cement	Water	AS	Fine aggregate (0-2) mm	Fine aggregate (2-4) mm	Coarse aggregate (4-8) mm
0.40AS0	0.40	400	160	0.00	562	544	659
0.40AS0.5	0.40	400	160	3.11	559	544	659
0.40AS1.0	0.40	400	160	6.21	556	544	659
0.50AS0	0.50	400	200	0.00	528	512	620
0.50AS0.5	0.50	400	200	2.92	526	512	620
0.50AS1.0	0.50	400	200	5.85	523	512	620
0.60AS0	0.60	400	240	0.00	495	480	581
0.60AS0.5	0.60	400	240	2.74	493	480	581
0.60AS1.0	0.60	400	240	5.48	490	480	581

2.2. Production of Samples and Test Schedule

Within the scope of the study, 9 series with and without AS were prepared to investigate the effect of AS on the measurement of compressive strength and carbonation depth before and after carbonation. The samples were kept in standard water cure for 28 days in order to reach the standard compressive strength. Then, the samples were subjected to carbonation test separately for 1 day, 3 days and 7 days in order to determine the carbonation effect. The flow chart of the study is shown in Figure 3.

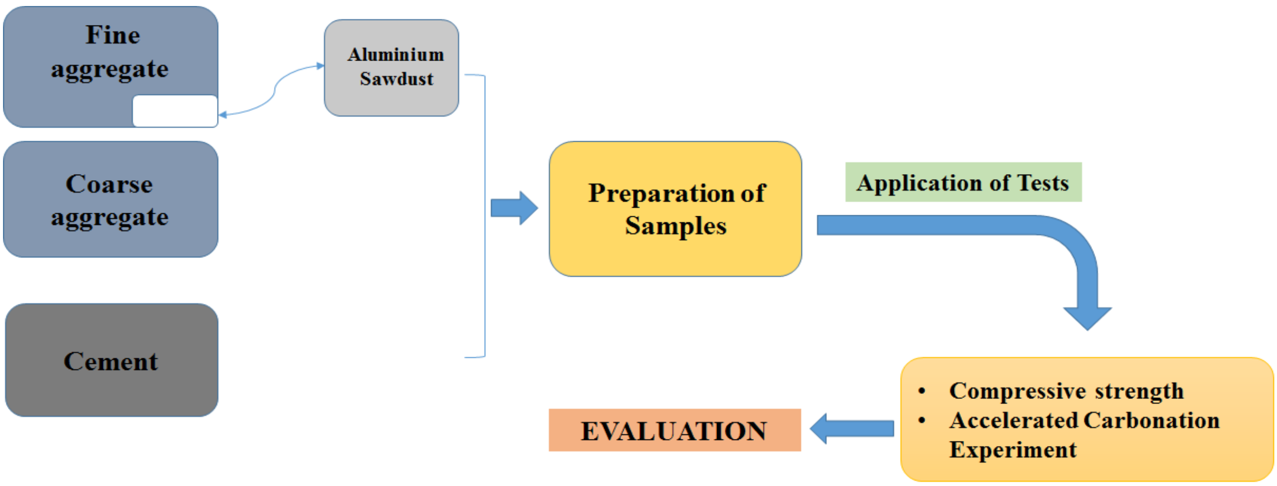


Figure 3. Flow chart of the study

3. Results and Discussion

3.1. Validation and evaluation of experiments

3.1.1. Compressive strength

The compressive strength test of concrete samples was determined according to TS EN 12390-3 standard [11]. The 100x100x100 specimens were placed in the compression testing machine and loaded at 3 kN/sec. The average compressive strength of three cube specimens of each concrete mixture was termed as the compressive strength of that concrete mixture (Figure 4).

Figure 4. Compressive strength test

The compressive strength of the prepared series, with and without AS was determined according to the different curing times before (control series) and after the carbonation test (Figure 5).

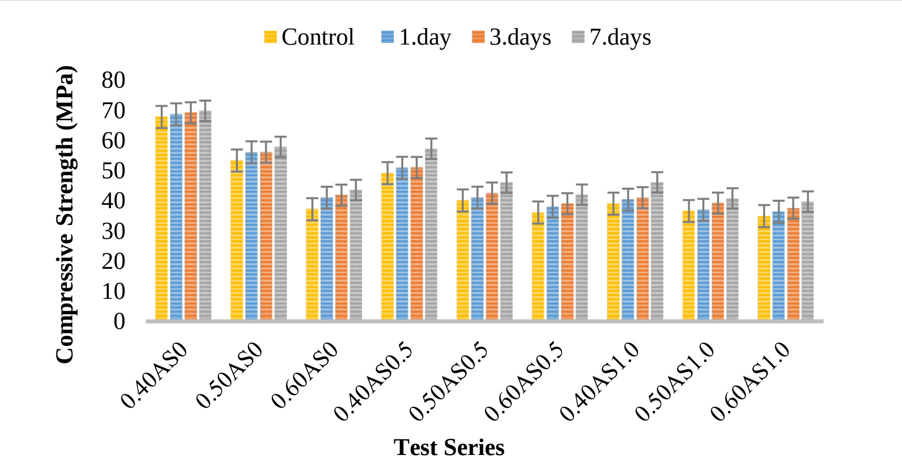
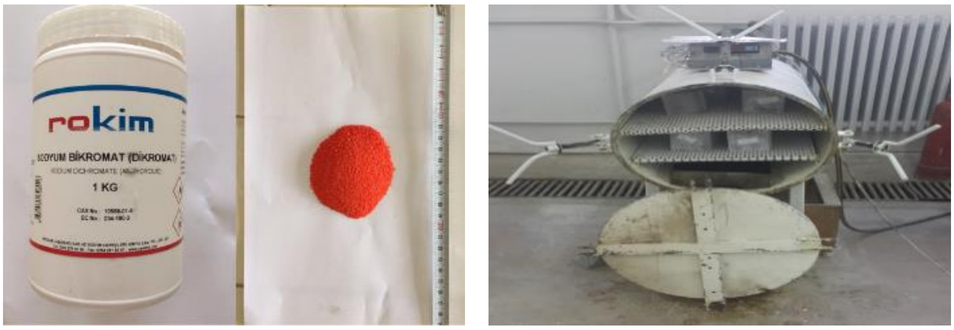


Figure 5. Relationship between compressive strength-carbonation curing age

The compressive strength results of all concrete series before and after carbonation are shown in Figure 4. According to this; the compressive strength values of the concrete samples exposed to carbonation for 1 day increased between 1.29% and 10.26% when compared to the control samples. Among the samples exposed to carbonation for 1 day, the highest compressive strength is seen in the 0.4AS0 series, and the lowest in the 0.60AS1.0 concrete samples. It is seen that the most suitable ratio among the concrete series containing aluminum sawdust exposed to carbonation for 1 day is 0.4AS0.5 concrete series. Likewise, when the 3-day and 7-day concrete series are examined, the highest compressive strength was seen in the 0.4AS0.5 series, similar to the results of the 1-day series. Therefore, these results show that carbonation positively affects the compressive strength of concrete. With the emergence of $CaCO_3$, which is the product of the carbonation reaction in concrete, an increase in density occurred in the carbonated parts, and this increase in density on the surface made itself felt with a slight increase in strength [10], [11]. This situation is also compatible with the literature. Because the water released as a result of the carbonation event, helps the hydration of the cement and causes some increase in strength. This has a positive effect on the compressive strength. [14], [15].

3.1.2. Accelerated carbonation test

Carbonation depth was measured in accordance with the BS EN 13293-2004 standard [16]. For carbonation to take place, sodium dichromate was chosen for 55% humidity at 20 ºC. The saturated solution of sodium dichromate was placed in the water container inside the tank and the temperature of the water was kept at 20 ºC throughout the experiment. The samples were placed in the tank at regular intervals and with no surfaces touching each other, and the lid of the tank was tightly closed so that there would be no gas leakage. 40% CO_2 was given into the tank from the CO_2 filled tube via a one-way valve (Figure 6).



(a) (b)

Figure 6. (a) Sodium bichromate salt (b) Gas-leakproof tank used for carbonation test

For the carbonation test, the concrete samples were exposed to carbonation according to different time periods as 1, 3 and 7 days. For this, after the samples were separated into two and cleaned of dust and particles on the surface, 1% phenolphthalein ($C_2OH_{14}O_4$) - 70% ethyl alcohol solution was sprayed. It reacted with Phenolphtalein and its hydration product, $Ca(OH)_2$, and dyed that area pink, and no color change was observed in the carbonation parts of the samples. The depths of the parts that do not change color on the concrete samples were measured from 8 different places as seen in Figure 7, and the carbonation depth was determined by using Equation 1.

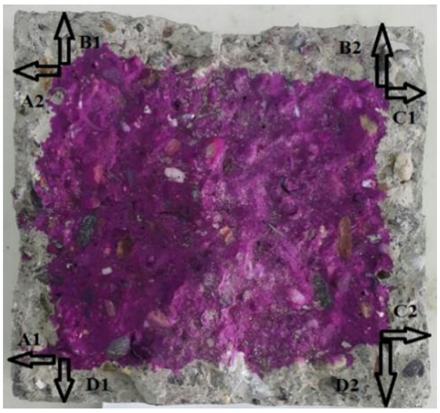


Figure 7. Depth of carbonation measured on the sample surface

$$D = \frac{A_1+A_2+B_1+B_2+C_1+C_2+D_1+D_2}{8} \quad (1)$$

D : Average depth of carbonation (mm)
A,B,C,D : Depth of carbonation of each surface

The data obtained as a result of the carbonation depth measurement are shown graphically in Figure 6. A comparison was made by measuring the carbonation depth of concrete series with and without AS. It is seen that the carbonation depth of the concrete mixtures containing AS is higher than the concrete mixtures without AS, and the carbonation depth increases as the amount of AS increases (Figure 8). AS could not fully settle in the concrete paste due to its grain sizes and formed voids. These voids made it easier for the CO_2 in the tank to enter the concrete. In addition, the carbonation depth increased as the carbonation day time increase

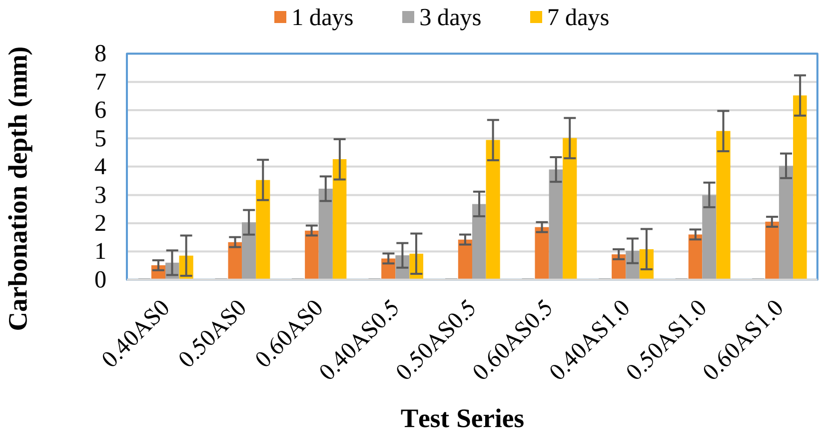
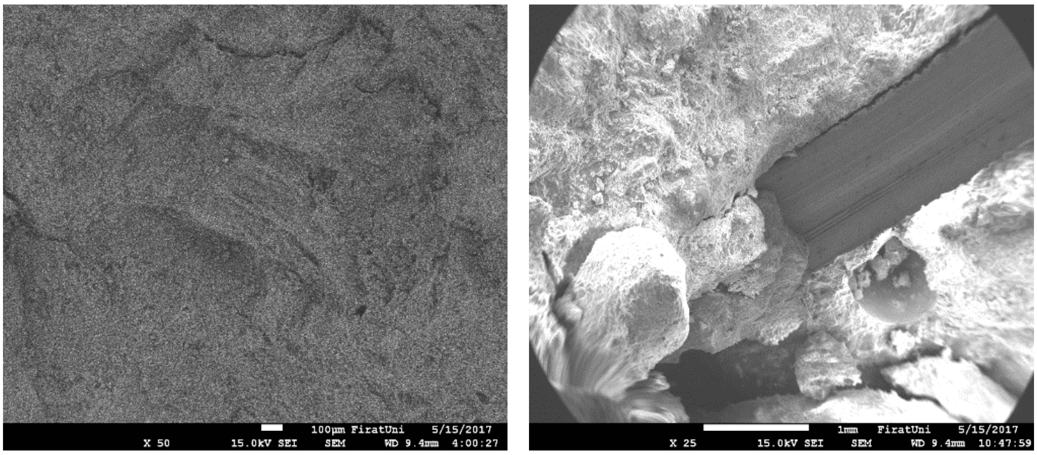


Figure 8. Relationship between carbonation depth-carbonation curing age

3.1.3. Microstructure

The structure of concrete samples obtained by substituting aluminum sawdust with fine aggregate was investigated using scanning electron microscopic images (SEM). SEM images of concrete samples are shown in Figure 9.



(a) (b)

Figure 9. SEM image of the sample (a) without AS (b) with AS

When Figure 8 (a) is examined, despite the x50 magnification, no obvious cracks were observed in the micro image without AS. When Figure 8 (b) is examined, it is understood from the micro-image of the sample that the adherence due to the use of sawdust is not complete, and from the trace left by the AS peeling off. In addition, microcracks are clearly visible.

4. Conclusions

In this study, the changes in the mechanical properties of the concrete series produced using different AS ratios in 3 different carbonation time periods were investigated. The findings obtained as a result of the study are given below in the articles:

1-Since mixtures with a high W/C ratio were prepared, concrete with an appropriate consistency within the workability limits was obtained. However, although the mixture was poured and placed, the workability decreased as the AS ratio increased. This had a negative impact on the strength of concrete

2-After a certain amount of AS, there was a decrease in the compressive strength, and an increase in the depth of carbonation.

3-The highest increase in the compressive strength value after carbonation is observed in the 0.4AS0.5 series, and this increase value is approximately 16%.

4-In all series, as the number of days exposed to carbonation increased, the compressive strength values increased in parallel with the depth of carbonation.

Since waste aluminum sawdust negatively affects the workability of concrete, it is seen that it is not suitable to be used in concrete. In future studies, it can be aimed to reduce concrete production costs by contributing to recycling by using a different industrial waste.

Contributions of the Authors

In the study, Tuba Demir, Melek Öztürk are related to the subject. literature review, data acquisition, Tuba Demir, Bahar Demirel numerical study titles, evaluation of the results; Bahar Demirel forming the idea, obtaining the data, finding and review of results, spelling and content. They contributed in the titles of checking the article.

Conflict of Interest Statement

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The study is complied with research and publication ethics.

References

[1] A. K. Parashar and R. Parashar, "Utility of wastage material as steel fibre in concrete mix M-20," *Int. J. Adv. Res. Technol.*, vol. 3, pp. 2–8, 2012.

[2] I. Martínez-Lage, P. Vázquez-Burgo, and M. Velay-Lizancos, "Sustainability evaluation of concretes with mixed recycled aggregate based on holistic approach: Technical, economic and environmental analysis," *Waste Manag.*, vol. 104, pp. 9–19, 2020.

[3] H. Binici, A. H. Sevinç, and H. Geçkil, "Durability properties of waste iron powder added mortars and concretes," *Çukurova University Faculty of Engineering and Architecture Journal*, vol. 30, no. 1, p. 1–16, 2015.

[4] A. A. Thakare, A. Singh, V. Gupta, S. Siddique, and S. Chaudhary, "Sustainable development of self-compacting cementitious mixes using waste originated fibers: A review," *Resour. Conserv. Recycl.*, p. 105250, 2020.

[5] G. L. Golewski, "Green concrete based on quaternary binders with significant reduced of CO_2 emissions," *Energies*, vol. 14, no. 15, p. 4558, 2021.

[6] Y. Liu, "Modeling the time-to corrosion cracking of the cover concrete in chloride contaminated reinforced concrete structures." Virginia Tech, 1996.

[7] T. Gönen and S. Yazıcıoğlu, "Carbonation and Activity Degrees in Concretes," *Stand. econ. and Single. Journal*, publication, no. 497, pp. 84–88, 2003.

[8] A. Tafraoui, G. Escadeillas, and T. Vidal, "Durability of the Ultra High Performances Concrete containing metakaolin," *Construction and Building Materials*, vol. 112, 2016.

[9] V. M. Sounthararajan and A. Sivakumar, "Effect of the lime content in marble powder for producing high strength concrete," *ARPN J. Eng. Appl. Sci.*, vol. 8, no. 4, pp. 260–264, 2013.

[10] P. and C. C. Cement - Part 1: General Cements, Composition, "TS EN 197-1," Turkey, 2012.

[11] Turkish Standards Institute, Concrete-Hardened Concrete Tests-Part 3: Determination of Compressive Strength of Test Samples, "TS EN 12390-3," Turkey, 2019.

[12] N. Cauberg, O. Remy, and J. Pi√©rard, "Evaluation of durability and cracking tendency of Ultra High Performance Concrete," in Creep, Shrinkage and Durability Mechanics of Concrete and Concrete Structures, Taylor & Francis, 2010, pp. 695–700.

[13] M. Alwaeli and J. Nadziakiewicz, "Recycling of scale and steel chips waste as a partial replacement of sand in concrete," *Constr. Build. Mater.*, vol. 28, no. 1, pp. 157–163, 2012.

[14] T. Erdogan, Concrete. Ankara: METU Press, 2003.

[15] H. Binici, H. Temiz, A. H. Sevinç, E. Mustafa, K. Mehmet, and Z. Şayir, "Investigation of High Temperature Effect of Concretes Containing Aluminum Sawdust, Pumice and Aerated Concrete Powder," *Yapı Teknol. Electron. Journal*, vol. 9, no. 1, p. 1–15, 2013.

[16] M. Safiuddin and N. Hearn, "Comparison of ASTM saturation techniques for measuring the permeable porosity of concrete," *Cem. Concr. Res.*, vol. 35, no. 5, pp. 1008–1013, 2005.