USABILITY AS A POZZOLAN IN CONCRETE PRODUCTION OF NUTSHELL BRIQUETTE ASH

MURAT OZOCAK[1*] , CAN BURAK SİSMAN[2]

[1]*Istanbul University - Cerrahpasa, Forestry Vocational School, Irrigation Tecnology Program Department, Istanbul/Turkey*
[2]*Tekirdağ Namık Kemal University, Agriculture Faculty, Biosystem Engineering Department, Tekirdağ/Turkey*

The depletion of traditional energy sources and environmental problems have increased the orientation to new and renewable energy sources. In this context, studies have intensified on the use of wastes generated in different sectors for energy production. As a result of these studies, fuel briquettes were produced from hazelnut shells and put into use for heating purposes in different structures. In this study, it was aimed to prevent environmental problems caused by the ash formed as a result of burning the briquettes produced from hazelnut shells and to investigate its usability as a pozzolan in the production of economical and durable concrete with high insulation properties in the construction sector. In this way, it will be possible to convert ash, which is the waste of a useful product produced from an agricultural waste, into a product with high added value in the construction sector. For this purpose, the effects were investigated on the physical, mechanical and thermal properties of concrete of using briquette ash in different proportions (0, 5, 10, 15 and 20%) as a substitute for cement in concrete production. As a result of the research, it is recommended to use briquette ash up to 5% in order to produce concrete with sufficient strength and good insulation, as it is possible to use briquette ash as a pozzolan in concrete production.

Keywords: *Briquette ash, nutshell, agricultural wastes, concrete, pozzolan material*

1. Introduction

Biomass, which is a renewable, economical and environmentally friendly energy source, has become an alternative fuel in meeting the increasing energy need today [1]. Biomass is formed by plants converting and storing solar energy into chemical energy through photosynthesis. Agricultural, forestry, industrial, animal and domestic wastes can be shown as biomass sources. Solid biofuels obtained from these sources are divided into two groups as traditional and modern biofuels. Traditional biofuels are wood, tree branches, etc. plant parts that are burned directly in stoves or boilers without any treatment. Modern biofuels, on the other hand, are fuels whose shape and structure are changed by processing [2]. Modern biofuels are pellets or briquettes produced by grinding the biomass into smaller pieces and compressing them under high heat and pressure, using adhesive when necessary [3,4].

Among the biofuels produced in the form of pellets or briquettes, agricultural wastes constitute an important potential. Turkey has a very important potential in terms of agricultural wastes and different agricultural wastes are used as raw materials in the biofuel sector in different geographical regions [1]. The shell of the hazelnut fruit, which is grown in 16 different regions of our country, is an agricultural waste that is used intensively in the production of briquettes as biofuel. Hazelnut shell constitutes approximately 50% of the hazelnut produced and the annual amount of shell released in our country is around 300,000 tons [5]. The fact that the hazelnut shell has a caloric value of 4,100-4,400 cal/gr has made it widespread to use it directly or as briquettes [6].

As a result of the burning of hazelnut shell briquettes, ash, which is a waste that creates important environmental problems, is released. The amount of this waste that is released every year in our country is between 8,000-10,000 tons. Disposing of this waste and reducing environmental problems is only possible by converting the ash into a useful product. Ash is a material that can be used as a pozzolan in the concrete industry, as it exhibits pozzolanic properties thanks to the high amount of silicate and alumina it contains [6, 7].

Pozzolan materials are defined as silicate or silicate alumina materials that have little or no binder but gain binding property by chemical reaction with calcium hydroxide when finely ground [8]. Pozzolans can be used directly during cement production or as a replacement for cement in concrete production. In concrete, pozzolan increases the strength by reducing the amount of calcium hydroxide, which is formed as a result of the setting and hydration of the cement and adversely affects the concrete strength. In addition, the use of pozzolan increases the plasticity of the concrete [9].

In this study, it was aimed to investigate the usability of briquette ashes, which are formed by the combustion of briquettes produced from hazelnut shells as biofuel, as pozzolans in concrete production.

*Autor corespondent/*Corresponding author*,
E-mail: muratozocak@iuc.edu.tr

2. Material and Method

In this study, constituted the material of the research concrete samples produced with cement, aggregate, (sand, gravel) water and ash obtained as a result of burning of the briquette produced from hazelnut shell

Hazelnut shell briquette ash, which constitutes the aim of the research and is used interchangeably with cement, was obtained from houses and poultry houses that use hazelnut shell briquettes for heating purposes in Düzce (Fig. 1.). The physical and chemical properties of the briquette ashes used are given in Table 1.

Fig. 1 - Briquette produced from hazelnut Shell

According to the TS-25 [10] standard of the Turkish Standards Institute, the total content of $SiO_2 + Al_2O_3 + Fe_2O_3$ in natural pozzolans should be at least 70%. A material below this value cannot be considered as a pozzolan. In this respect, XRD (X-Ray Diffraction) analysis was performed to examine the pozzolanic property and mineralogical structure of the briquette ash used in the study (Fig.2). As a result of the analysis, was determined to be approximately 71% the quartz (SiO_2), alumina (Al_2O_3) and iron oxide (Fe_2O_3) content of the briquette ash (Table 1). This situation shows that the briquette ash produced from hazelnut shells is pozzolanic properties in terms of quartz (SiO_2), alumina (Al_2O_3) and iron oxide (Fe_2O_3) content.

The cement constituting the research material is CEM I A-LL 42.5 portland cement in accordance with TS EN 197-1 [11] supplied from Bartın Cement factory. In order to achieve the aim of the study, CEM I cement without any pozzolanic additive was preferred. Chemical and physical analysis results of cement are given in Table 2.

Aggregates with the largest grain diameter of 22 mm were used in the study, which were obtained from the quarries in the region and in order to keep the concrete composition high. The grain diameters of the aggregates used in concrete production were selected in three different grain sizes as 0-5 mm, 5-12 mm and 12-22 mm, and their physical and chemical properties are given in Table 3. In order to determine the amount of aggregate in different particle sizes to enter the concrete mix, the

Table 1

Physical and chemical properties of briquette ash

Chemical properties		**Physical properties**		
SiO_2	28.93	Specific gravity (g/cm³)		2.8133
Na_2O	3.23	Remaining ower sieve (%)	90 µm	4.8
Al_2O_3	23.74		200 µm	0.4
Fe_2O_3	18.26	Specific surface area (cm²/g)		22,513
K_2O	1.42			
B2O	3.58			
CaO	1.46			
MgO	3.2			
Loss on ıgnition	7.6			

Table 2

Chemical and physical properties of cement

Chemical Properties		**Physical Properties**		
Total SiO_2	18.80	Specific gravity (g/cm³)		3.10
SiO_2	18.29	Volume expansion (mm)		1.0
Al_2O_3	5.29	Water/cement		28.80
Fe_2O_3	2.89	İnitial setting time (min)		172
CaO	62.82	Final setting time (min)		235
MgO	2.44	Blaine specific surface (cm²/g)		4271
SO_3	3.29	45µm sieve(%)		4.7
Cl	0.076	90µm sieve(%)		0.2
Na_2O	1.21	Compressive strength (MPa)	2 day	36.3
İnsoluble residue	0.51		7 day	44.9
Loss on ıgnition	3.34		28 day	54.2

Table 3

Physical and chemical properties of aggregate

	Aggregate grain size (mm)		
	0-5	5-12	12-22
Aggregate Flatness Index	-	9	10
Aggregate Figure Index	-	8	7
Methylene Blue Test (g/kg)	1		
Los Angeles Coefficient (%)	27- LA30		
Grain Density (g/cm^3)	2.40 2.51 2.69	2.46 2.55 2.70	2.48 2.56 2.70
Water Absorption (%)	4.5	3.5	3.4
Freeze- Thaw Resistance (%)	10		
Alkali Silica Reactivity (%)	0.013		
Chloride Ratio (%)	0.004		
Acid Soluble Sulfate (%)	0.094		
Total Sulfur (%)	0.426		

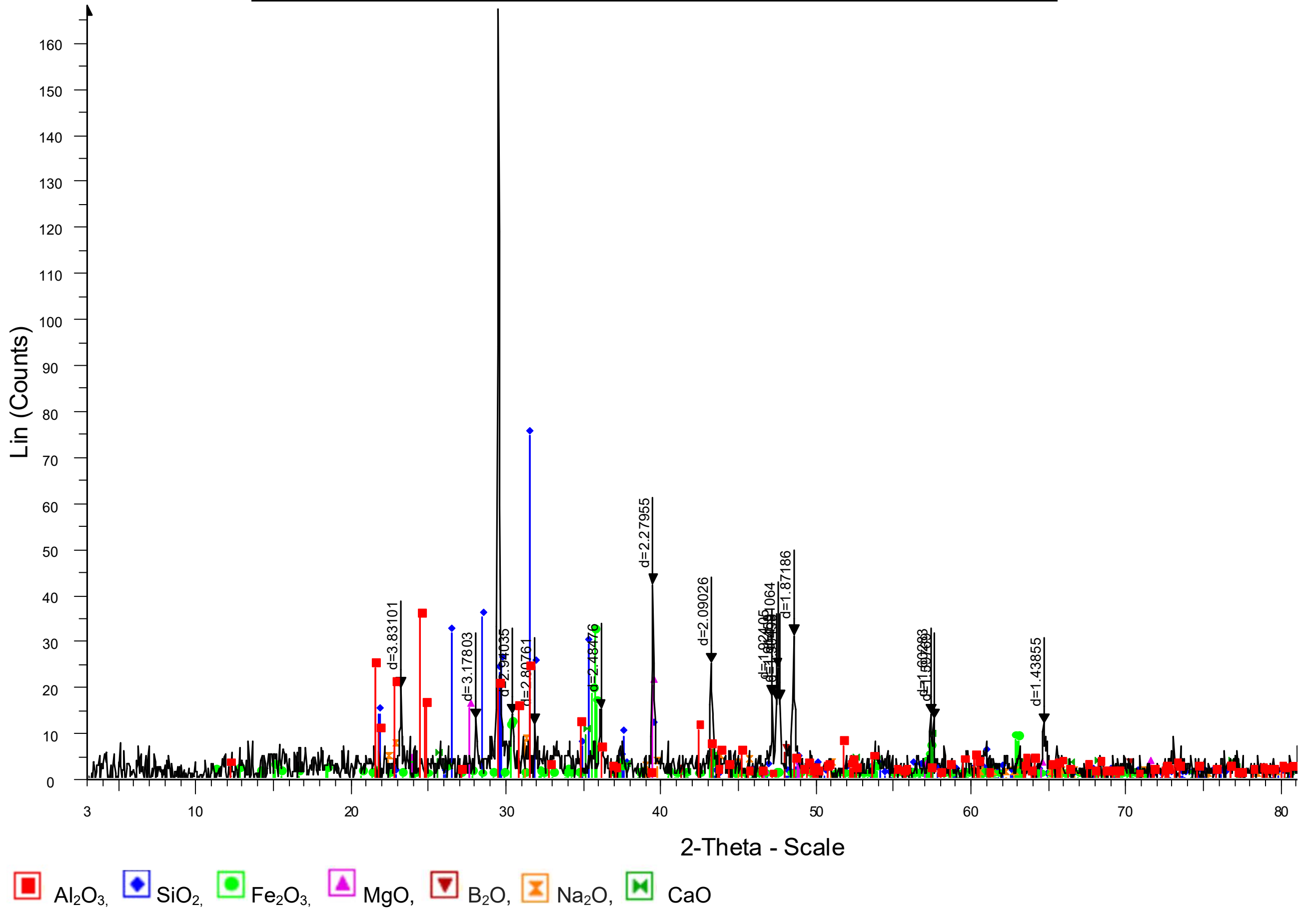

Fig. 2. Briquette Ash XRD Analysis

granulometry curve was drawn as a result of the sieve analysis performed according to TS EN 933-1 [12] and given in Fig. 3.

In the pouring of the concrete samples, tap water in accordance with TS-1008 was used as the mixing water entering the mixture [13].

In this study, which was carried out to determine the usability of hazelnut shell briquette ash as a pozzolan in concrete production, 300 kg/m³ of C25 concrete class were targeted in determining the amount of material to be added to the concrete mix. Nutshell briquette ash, which constitutes the aim of the research, was used as replacement with cement at the rates of 0%, 5%, 10%, 15% and 20% of the cement weight determined for the target concrete.

All the materials determined by the mixing calculations in the concrete castings were weighed

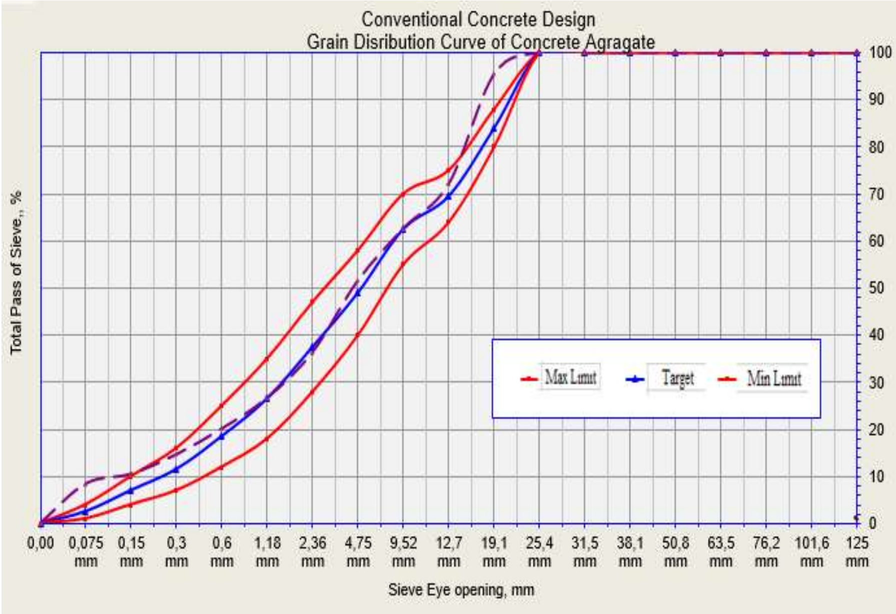

Fig. 3 - Aggregate grain-size curve

on the basis of weight under laboratory conditions and placed in the concrete mixer machine. A homogeneous mixture was created by mixing all the materials before the mixing water was put into the machine chamber, then fresh concrete was prepared by adding the mixing water.

Since the net water/cement ratio of the concretes produced using pozzolan could not be determined with sufficient accuracy, the amount of water in the concrete mixture calculations was determined according to the targeted concrete consistency. For this purpose, a series of test mixtures was made and the target slump value was taken as 13±1 cm for all samples and the experiment was continued until this value was achieved [14].

The air content of the produced fresh concrete samples was determined according to the methods given in TS EN 12350-7 [15] and the unit weights were determined according to the methods given in TS EN 12350-6 [16].

In the study, the fresh concretes prepared for the hardened concrete tests to be carried out with 3 recurrence were filled in standard cube molds (15*15*15 cm^3) in accordance with TS EN 206-1 [17]. Concrete samples, which were kept in the molds for 1 day, were removed from the molds and kept in 20 ± 2 ºC water in the curing pool until the end of the determined test periods [18].

Compressive strength on hardened concrete samples kept in the curing pool for 7, 28 and 90 days is in TS EN 12390-3 [19], splitting strength is in TS EN 12390-6 [20], sound transmission rate is in TS EN 12504-4 [21], the unit weight was made in accordance with the methods specified in TS EN 12390-7 [22]. In addition, water absorption in 28-day samples was made according to TS EN 12390-7 [22], in 28-day and 90-day samples, the freeze-thaw test was performed according to Ekmekyapar and Örung [23], and the thermal conductivity of 28-day samples was made with the QTM 500 device and all concrete samples were tested. SEM images were prepared to examine the microstructures of the produced concrete samples.

3. Research Findings and Discussion

3.1. Fresh Concrete Test Results

According to the results of the air content test conducted in all ash groups, it was determined that the air content increased with the increasing amount of ash in the concrete, in other words, the void ratio increased (Fig. 4.). The air content, which was 2.1% in the blank samples without ash additive, increased to 2.9% in the samples with the most ash (20%).

The unit weight change of fresh concrete depending on the amount of ash entering the mixture is given in Figure 5. When the results are examined, it is seen that the unit weights decrease depending on the increase in ash percentage and air content. It varies between 2121 - 1709 kg/m³. The amount of highest change in unit weight according to the amount of ash entering the mixture was 19.4%, and as the amount of ash increased, the decrease in unit weight increased.

Both the increase in air content and the decrease in unit weight are the result of the lower specific gravity of the ash used than the cement, as expected. In a different study on the relaterd to effect on concrete of pozzolanic additives , it was observed that the unit weights of fresh concretes decreased with the increase in the additive ratios. [24] Similarly, in the concrete samples produced with briquette ash produced from hazelnut shells,

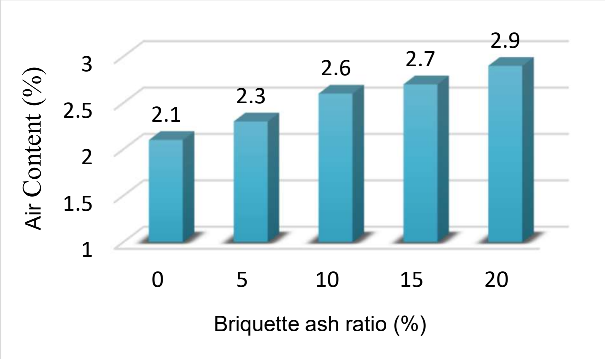

Fig. 4 - Variation of fresh concrete air content

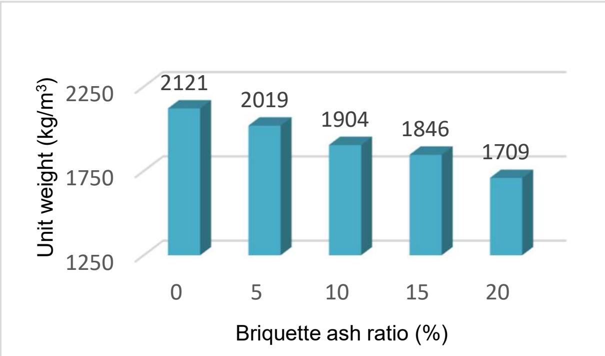

Fig. 5 - Fresh concrete unit weight variation

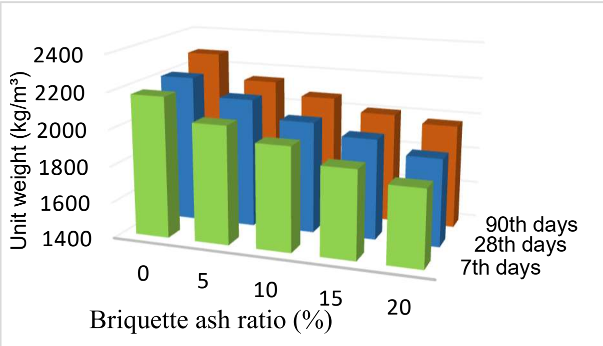

Fig. 6 - Unit weight variation of hardened concrete samples

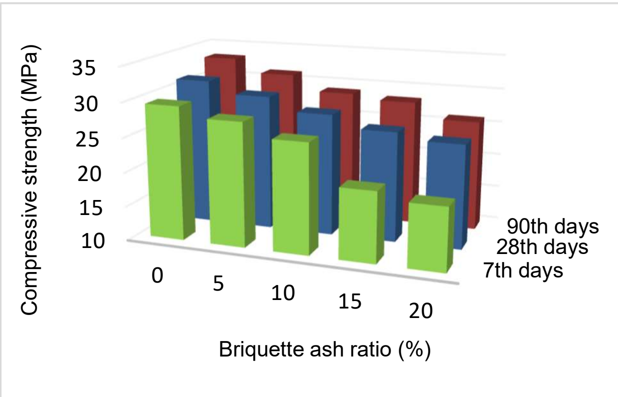

Fig. 7 - Compressive strength variation

there was a decrease in unit weights as the additive ratio increased.

3.2. Hardened Concrete Tests

The unit weight test results on the 7th, 28th and 90th days on concrete samples produced using different amounts of ash are given in Fig. 6. In parallel with the increase in the ash content in the mixture for all curing periods, the unit weights decreased and decreased from 2210 kg/m³ to 1880 kg/m³ in 28-day samples. İn the case of using 20% ash in 28-day-old samples was determined, it was found to be the highest of decrease ratio in unit weight and this ratio as 14.9%. Depending on the curing time, an increase in unit weights was observed in all ash additive ratios.

In a different study, in which instead of cement of rice husk ash was used , it was determined that the void ratio in the concrete increased with the addition of ash [25]. Similarly, briquette ash produced from hazelnut shells increased the voids in the concrete samples produced within the scope of the research and a decrease in unit weights was experienced.

The results of the compressive strength test performed on the hardened concrete samples at 7, 28 and 90 days are given in Fig. 7. In parallel with the increase in the amount of ash used in the mixture, the compressive strengths decreased and according to the test times, the maximum loss was 35% in 7-day samples, and the maximum loss was 21% in 90-day concretes. This showed that the negative effect of the use of ash on the compressive strength of concrete was higher in early strengths and less in late strengths. Different researchers have stated that pozzolans used in concrete production reduce the effect of sulfate in concrete, reducing pressure losses in the late ages of concrete and even showing a positive effect [26-29].

The 28-day compressive strengths of the concrete samples varied between 31.3 MPa and 25.0 MPa, and respectively decreased depending on the amount of ash (0, 5, 10, 15 and 20 percent) entering the mixture, 5.4%, 11.5%, 17.1% and 20.1%. When the amount of ash entering the mixture is used up to 5%, values close to the C25 class concrete strength predicted as the target concrete in the study were obtained, but in the case of using a higher amount of ash, only C20 concrete could be produced.

In a similar study, hazelnut shell ash was used directly as a pozzolan [29]. As a result of the study, C25 class concrete properties were obtained up to 10% admixture according to 28-day compressive strength. This situation shows that briquette ash produced from hazelnut shell can be used as a pozzolan in addition to hazelnut shell ash. With the research, it has become possible to use as pozzolan of a new ash sourced from hazelnut shell, other than hazelnut shell ash.. Briquette ash produced from hazelnut shells can be used as a pozzolan up to 5% in carrier elements that require high strength.

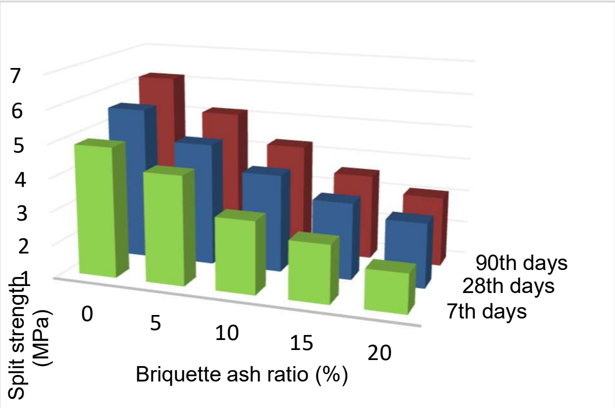

Fig. 8 - Variation in splitting strength

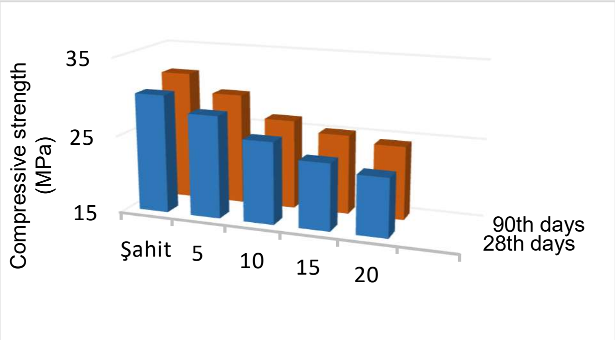

Fig. 9 - Compressive strength variation after freeze-thaw repetitions

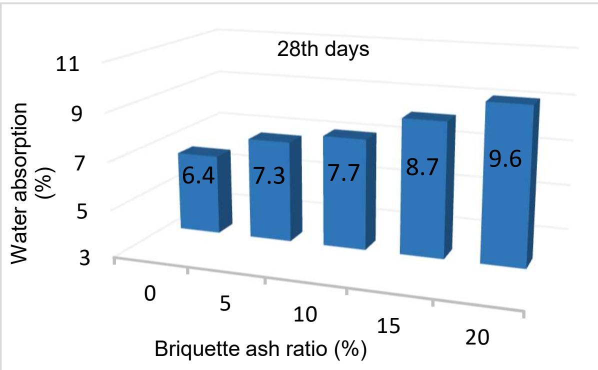

Fig. 10 - Variation in water absorption rate

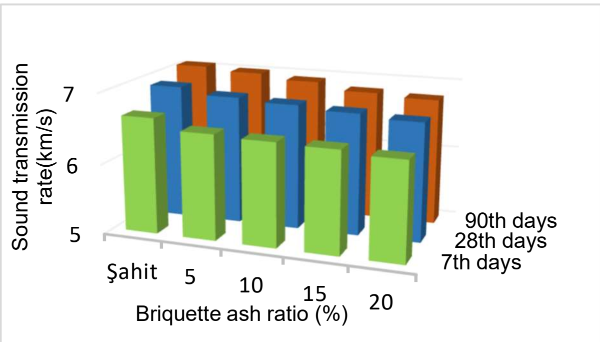

Fig. 11 - Sound transition rate variation

When the split strength results on the produced concrete samples are examined (Fig.8.), it can be seen that the split strengths for all curing times decrease according to the ash percentages. Depending on the amount of ash at the rates of 0, 5, 10, 15 and 20 % entering the mixture, determined the respectively decrease in the splitting strength is 12.8%, 35.3, 44.3 and 55.7% for the 7-day samples, 16.1%,29.4, 40.7 and 47.4%, for the 28-day samples and 16.2%, 30.3, 42.1 and 49.7% in 90-day samples. For all curing times, increasing concrete age increased the split strength.

In order to determine the freeze-thaw resistance of the concrete samples, the 28th and 90th-day samples were subjected to compressive strength after the freeze-thaw cycle and the results are shown in Fig.9. has also been given. According to the witness sample, depending on the amount of ash entering the mixture, It was realized as the compressive strength losses are 6.8%, 15.5, 22.0 and 25.4 for 28-day samples, respectively, and 7.3, 16.2, 20.2, 22.7% for 90-day samples. Ekmekyapar et al. [23], Erdoğan [30] and Şişman et al. [31] stated that concretes are considered frost resistant if their compressive strength loss after freeze-thaw is below 20%. Therefore, it can be said that up to 10% of briquette ash can be added to the concrete mix as a pozzolan in terms of frost resistance, and these concretes can also be used in cold climate conditions.

When the water absorption rates of 28-day concrete produced using hazelnut briquette ash are examined (Fig. 10.), it can be seen that the water absorption rates increase in parallel with the amount of ash entering the mixture. The least increase in water absorption rate was determined as 14% in concrete with 5% ash additive. The highest increase was determined as 50% in 20% ash additive.

In a study investigating the effect of using ash additive as a pozzolan material on water absorption values, they concluded that although ash additives increase the water absorption rate intensively in early curing times, it has a positive effect on the water absorption rate as the curing time [32]. Likewise, it was determined that the briquette ash produced from hazelnut shells positively affected the water absorption rate in all additive ratios and it decreased during the increasing curing time.

In order to evaluate the sound insulation properties, sound transmission velocities were measured in all concrete samples and the results are given in Figure 11. Sound transmission velocities decreased with increasing ash content and increasing void volume. Depending on the age of the concrete, ıt was 3.75% the maximum reduction in sound transmission velocities for different curing times.

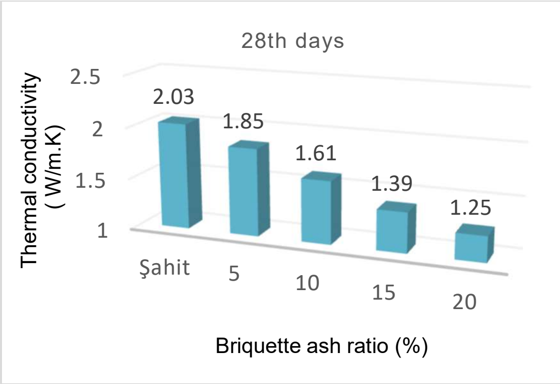

Fig.12 - Variation of thermal conductivity coefficient of hardened concrete samples

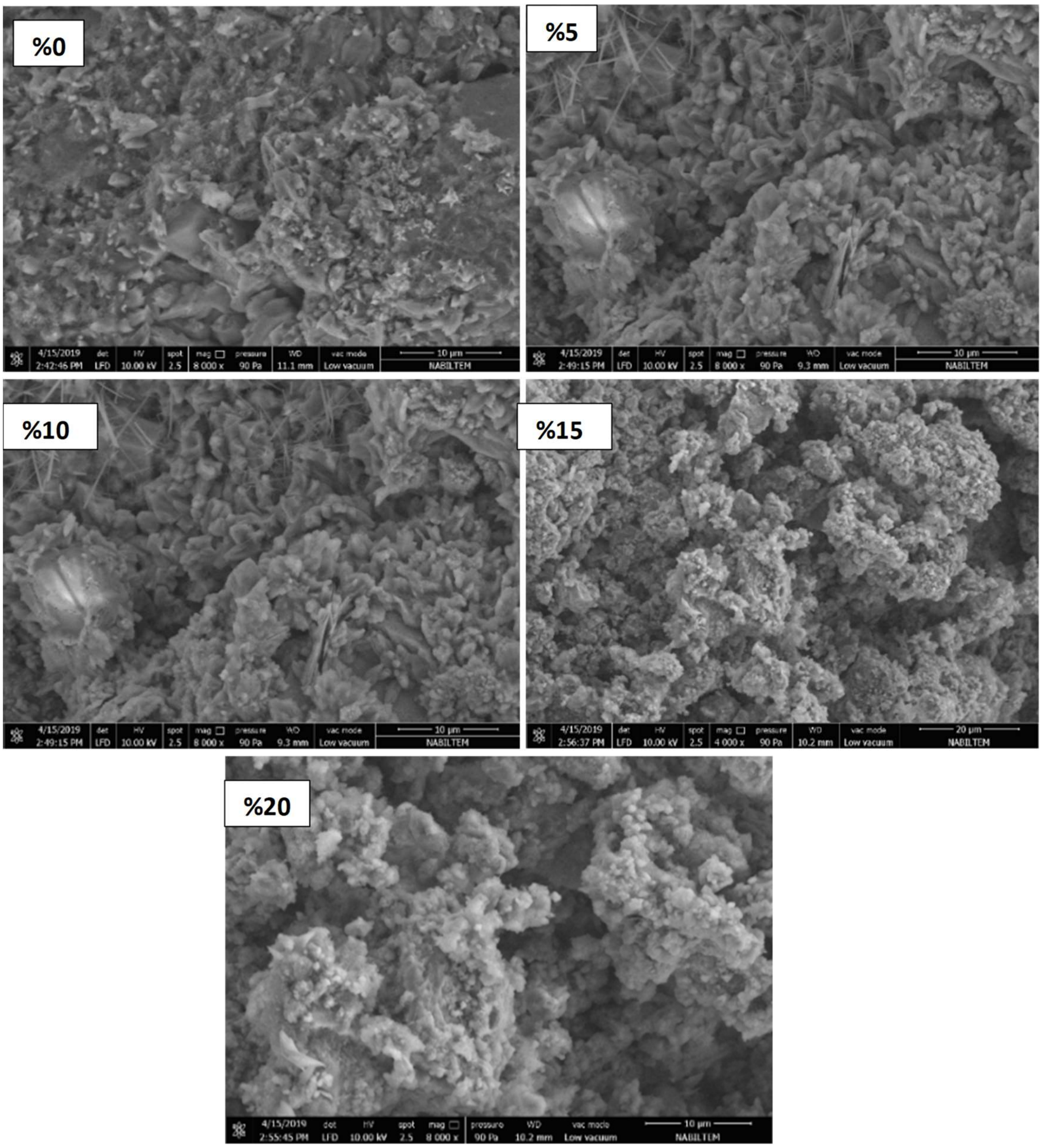

Fig.13. SEM Images of concrete samples

In the study, the sound transmission value is higher than 4.5 km/s in the all curing times and contribution rates.In a different study, concretes with higher than 4.5 km/s a sound transmission velocity were evaluated as excellent quality.[33] In this respect, ıt can be used in materials to be created for sound insulation that briquette ash produced from hazelnut shells

The thermal conductivity coefficient measurements made to determine the thermal insulation properties of the poured concrete samples are given in Figure 12. As the percentage of ash in the mixture increased, the thermal conductivity coefficient decreased from 2.03 W/m.K to 1.25 W/m.K and a significant improvement was achieved in the thermal insulation properties. The improvement in thermal insulation was 38.4% in 20% ash added concrete.

SEM images taken for microstructure analysis of the produced concrete samples are given in Fig. 13. It has been observed that the active silica in the briquette ash, which enters the mixture as pozzolan, reacts with $Ca(OH)_2$ formed as a result of cement hydration and supports the formation of C-S-H gel.

4. Conclusion and Recommendations

In this study, in which the usability of hazelnut shell briquette ashes produced by converting an agricultural waste into a useful product, as a pozzolan in the concrete sector, was examined, it was determined that the physical, mechanical and thermal properties required for the target concrete class in production could be achieved. In the light of the results obtained, it can be recommended to use nutshell briquette ashes in place of up to 5% of cement in terms of strength properties, especially in concretes to be used in carrier elements. It is possible to use briquette ash up to 20% as pozzolan in concretes to be used in building elements that do not have bearing properties and require high insulation properties.

As a result, it is possible to produce cheap and environmentally friendly concrete with high heat and sound insulation, sufficient strength, by using hazelnut shell briquette ashes, which is the waste of a product produced from an agricultural waste, in the production of concrete as pozzolan.

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