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Research Article

Characterization and Thermal Behavior of Modified Perlite with Carbon and Borax

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Abstract: In this article, the effect of surface modifications made with activated carbon and borax on the thermal behavior of perlite obtained from the Van Lake Basin was investigated. The obtained perlite surface was modified with activated carbon and borax. Thus, the thermal and surface properties of pure perlite, activated carbon modified perlite and borax modified perlite particles were investigated. According to the results obtained, the surface of pure perlite did not change significantly with carbon, while the surface of pure perlite clearly changed after borax modification. According to the results of thermogravimetric analysis in the range of 30-1000 ºC, the total mass losses of pure perlite, carbon-coated perlite and borax-coated perlite particles are respectively; It was determined as 3.153%, 3.156% and 1.191%. When these results are evaluated, it shows that the borax modification clearly increases the thermal properties of the pearlite particles.

Karbon ve Boraks ile Modifiye Edilen Perlitin Karakterizasyonu ve Termal Davranışı

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Anahtar Kelimeler
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Karakterizasyon,
Perlit,
Boraks,
Karbon

Öz: Bu makalede, Van Gölü Havzası'ndan elde edilen perlitin aktif karbon ve boraks ile yapılan yüzey modifikasyonlarının perlitin ısıl davranışına etkisi incelenmiştir. Elde edilen perlit yüzeyi aktif karbon ve boraks ile modifiye edilmiştir. Böylece saf perlit, aktif karbon ile modifiye edilmiş perlit ve boraks ile modifiye edilmiş perlit partiküllerinin termal ve yüzey özellikleri araştırılmıştır. Elde edilen sonuçlara göre, saf perlitin yüzeyi karbon ile önemli ölçüde değişmezken, boraks modifikasyonundan sonra saf perlitin yüzeyinin açıkça değiştiği görülmüştür. 30-1000 ºC aralığında ki termogravimetrik analiz sonuçlarına göre saf perlit, karbon kaplı perlit ve boraks kaplı perlit partiküllerinin toplam kütle kayıpları sırasıyla; %3.153, %3.156 ve %1.191 olarak tespit edilmiştir. Bu sonuçlar değerlendirildiğinde, boraks modifikasyonunun perlit partiküllerinin termal özelliklerini açıkça arttırdığını göstermektedir.

1. Introduction

One of the most important agenda items in the world is undoubtedly energy. Conservation of energy, energy-saving, and sustainable energy has been at the center of academic studies in recent years. In the world, the need for energy has increased with each passing time, the search for new energy sources has increased and the need for energy conservation has gradually increased. According to the International Energy Agency, it is predicted that the global energy need will increase by 53% due to the increases in the population of the countries in recent years, the increase in urban activities, and the developments in the industry (Ong et al., 2011). Our country is a foreign-dependent country in the field of energy, and its energy needs are growing every year. Turkey's total energy demand did not show a decrease between the years 2000-2019, except for the years 2001, 2009, and 2019, and continued its increasing trend. In order to meet the increasing energy supply, oil and natural gas explorations increased and nuclear power plants started to be established. This result shows how much electricity demand is related to the country's gross domestic product (GDP) growth rate. While the total electricity demand was 304.2 terawatt-hours (TWh) in 2018, it was 303.7 TWh as of the end of 2019 (Sodeyama et al., 1999).

Moreover, it can contribute to energy savings by using an effective method in terms of thermal insulation in the construction sector (residential, industrial, and commercial buildings), which constitutes a large part of energy consumption. As a result of effective insulation in construction structures, less energy is used for cooling in summer and heating in winter (Uluer et al., 2018). While the energy demand is increasing both in the world and in our country, it is equally important to produce innovative materials that will provide energy saving as well as new resources that can meet this demand. The most important considerations for the innovative materials produced are that the product can be ergonomic, economical, and environmentally friendly. Thermal insulation, which is accepted as a technique with high energy efficiency, is accepted as a technique consisting of materials or composite materials that reduce the thermal flow rate and show high thermal resistance to heat (Al-Homoud & M. S., 2005). Fiberglass, mineral wool, foam, and similar materials are used as thermal insulation materials for building insulation.

Perlite mine is an acidic volcanic rock that erupted from volcanic centers as a result of volcanic activities or that occurs locally as domed uplifts. The color of raw perlite can vary from transparent light gray to bright black. When it expands, the color turns completely white. Perlite mine is extensively used in construction, food, agriculture, industry, medicine, etc. used in sectors (DPT, 2001). When perlite is suddenly heated between 750-1200 ºC, it expands with the effect of the steam coming out of its body and turns into a foam aggregate consisting of glassy grains. It can expand up to 20 times its initial volume, called expanded perlite (DPT, 2001). In terms of being chemically neutral and physically white, expanded perlite can provide an aesthetic appearance to building materials. Since it is chemically neutralized, it is used in many areas such as insulation in the construction industry, bleach in the textile industry, economic irrigation in agriculture, oven insulation applications in industry, and the production of food, medicine, and other chemicals (Lanzón et al., 2008; Levy & Lisensky, 1978; Liu et al., 2014; Majouli et al., 2011; Nasibulin, 2007; Ong et al., 2011; Schubert, 2003; Sengul et al., 2011). Uluer et al. (2018) investigated the usability of perlite directly for thermal insulation in the building sector and/or as a reinforcement material to improve the thermal properties of other building materials. Perlite mineral is used as insulation materials shaped in the roof and floor insulations, perlite plasters, light insulation concrete with perlite aggregate with cement and gypsum binder, lightweight construction elements with perlite aggregate, loose filling material in the inter-floor and wall cavities, and as heat and sound insulator in surface flooring. Among the lightweight concretes produced using lightweight aggregates, the best thermal insulation can be achieved with lightweight concrete with perlite additives. Perlite added concretes provide approximately ten times better thermal insulation than normal concrete. Perlite added lightweight construction materials reduce greenhouse gas emissions by increasing energy efficiency and are therefore known as environmentally friendly materials. In buildings where perlite added concrete is used, it contributes to energy saving and energy efficiency, since heat loss from inside the building to the outside environment will be greatly reduced (Duaij et al., 1997).

Carbon, which is found both naturally and in combination with other elements, makes up about 0.2% of the earth's crust by weight. The purest (pure) forms are diamond and graphite; It is found as a component of coal, coke, and charcoal in lower purity degrees. Carbonate minerals such as carbon dioxide, limestone, and marble, which make up approximately 0.05% of the atmosphere and are dissolved in all natural waters, and hydrocarbons, which are the main building blocks of coal, oil, and natural gas, are the most abundant compounds (Ebbesen, 1997; Kroto et al; 1985). There are carbon-containing polymer structures in the structure of XPS and EPS, which are used as thermal insulation materials in the construction industry.

White powder borax, composed of a mineral and a boric acid salt, and composed of soft and colorless crystals which is water-soluble, is also known as sodium borate, sodium tetraborate, and disodium tetraborate (Levy & Lisensky, 1978). In Turkey, borax is found predominantly in the form of boron. It occurs naturally in evaporite deposits formed by the evaporation of seasonal lakes. Borax is used in the production of many industrial products, for example, in the production of cosmetic detergents, glass fiber production, as a cross-linker in slime, and in many similar areas (Schubert, 2003; Sengul et al., 2011; Shen & O'Connor, 1998). In this study, the effect of carbon and borax modifications on the surface of raw perlite on the thermal behavior of raw perlite was investigated. The produced samples were characterized by Fourier transform infrared spectroscopy (FT-IR), scanning electron microscopy (SEM), X-Ray Diffraction, and thermal gravimetric (TGA) analysis.
In this study, the perlite surface was modified by using activated carbon and borax and characterized by using SEM, FT-IR, XRD, and thermal gravimetric analysis (TGA) to investigate the thermal behavior of the perlite product.

2. Material and Methods

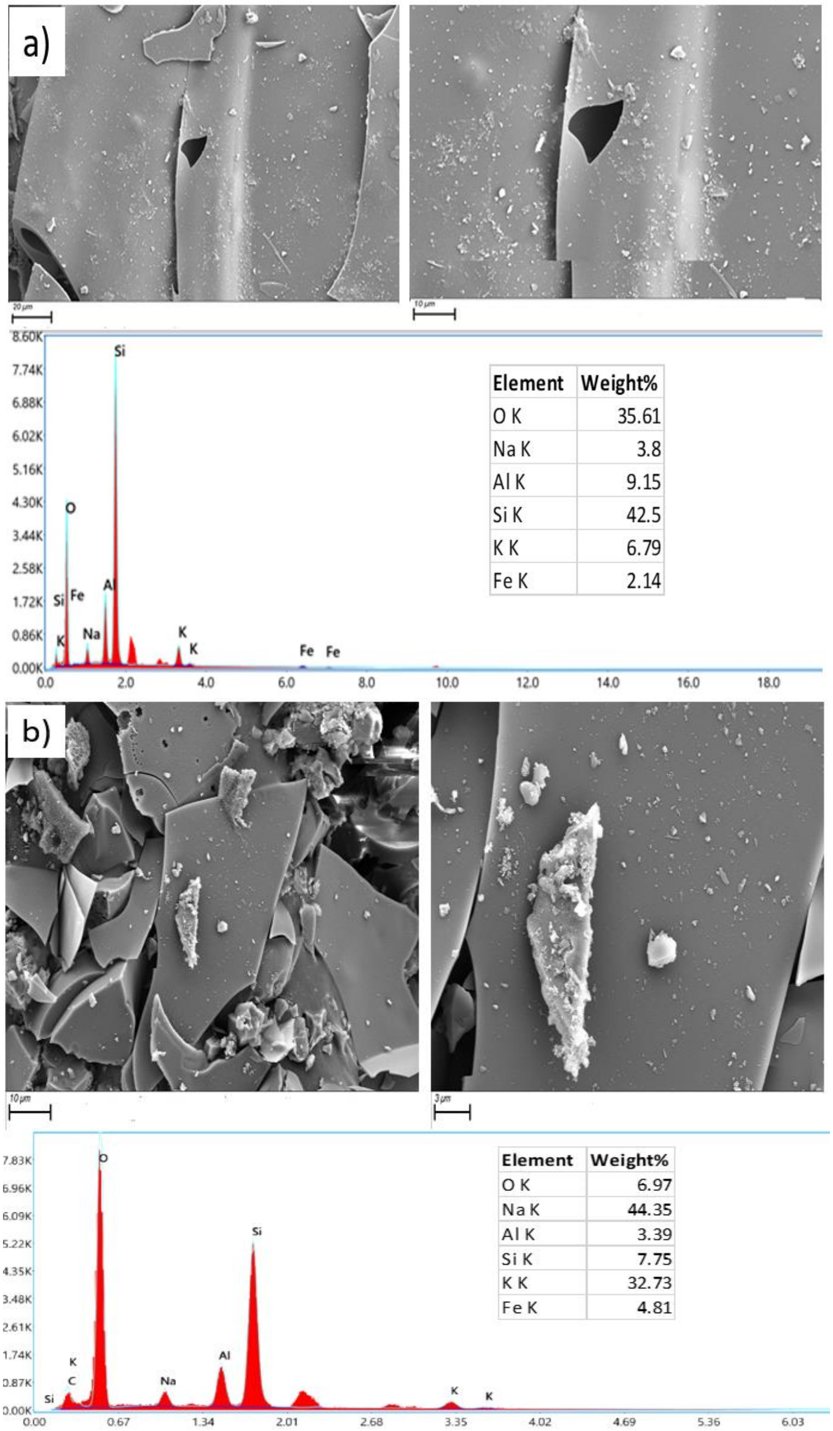
The perlite sample was taken from the lake Van basin. To grind the perlite obtained first in an agate mortar, the jaw crusher was also dimensionally reduced. then the agate was ground in a mortar for 5 hours and subjected to a size reduction process. Sodium boron hydride was purchased commercially from Carlo Erba Reagents. Acetone was purchased from Merck.

Firstly, 10 gr perlite particles mixed with 40 ml of deionized water by a magnetic stirrer in different beakers. Then, active carbon and borax were added to the mixtures separately. The amount of carbon and borax relative to perlite was chosen as 1:20. The chemical reducer ($NaBH_4$) was added about 0.03% by weight of the solution after one hour of mixing. The beakers are sealed with parafilm and the mixture is continued until the chemical reaction is complete. After the chemical reaction is finished, the mixture is washed with distilled water by centrifugation. The mixture is then dispersed with acetone and the washing is completed by filtration with Whatman paper. Finally, the oven is left to dry for 24 hours. The prepared raw perlite carbon-coated perlite and borax coated perlite were denoted as P, PC, and PB, respectively.

3. Result and Discussion

3.1. SEM analysis

The surface SEM image of uncoated perlite and active carbon and borax coated perlite-based particles are given in Figure 1a at different magnifications. As seen in Fig. 1a, many small broken parts were observed on the surface uncoated perlite. The pore structure of the raw perlite sample is seen in Fig. 1a in the SEM images. Figure 1b exhibits the surface of perlite active carbon particles. It is clearly seen that active carbon particles were continuously coated on perlite particles' surfaces. As seen in Figure 1b, partial agglomerated coatings are also seen on the perlite surface. The active carbon particles showed with the red arrow on the perlite surface. Edax taken by SEM (Zeiss Sigma 300) reports supported the existence of active carbon. Similarly, borax particles coated the surface of perlite as seen in Figure 1c. The pore space of perlite particles showed with a red arrow coated with borax as seen in Figure 1c. Edax reports taken by SEM (Zeiss Sigma 300) have supported the existence of borax.


a)
Element Weight%
O K 35.61
Na K 3.8
Al K 9.15
Si K 42.5
K K 6.79
Fe K 2.14
b)
Element Weight%
O K 6.97
Na K 44.35
Al K 3.39
Si K 7.75
K K 32.73
Fe K 4.81

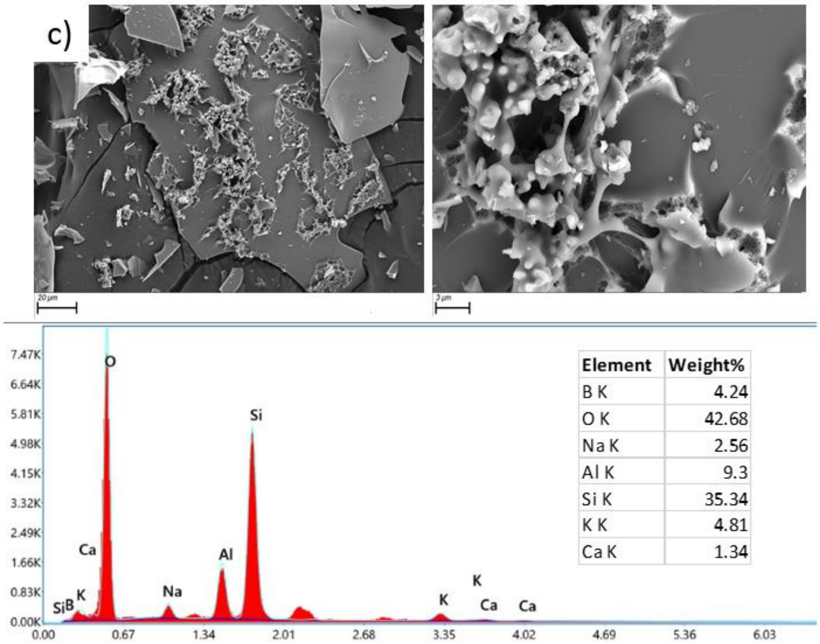


Figure 1. a) Raw perlite b) Active carbon-coated perlite surface c) Borax coated perlite.

3.2. XRD analysis

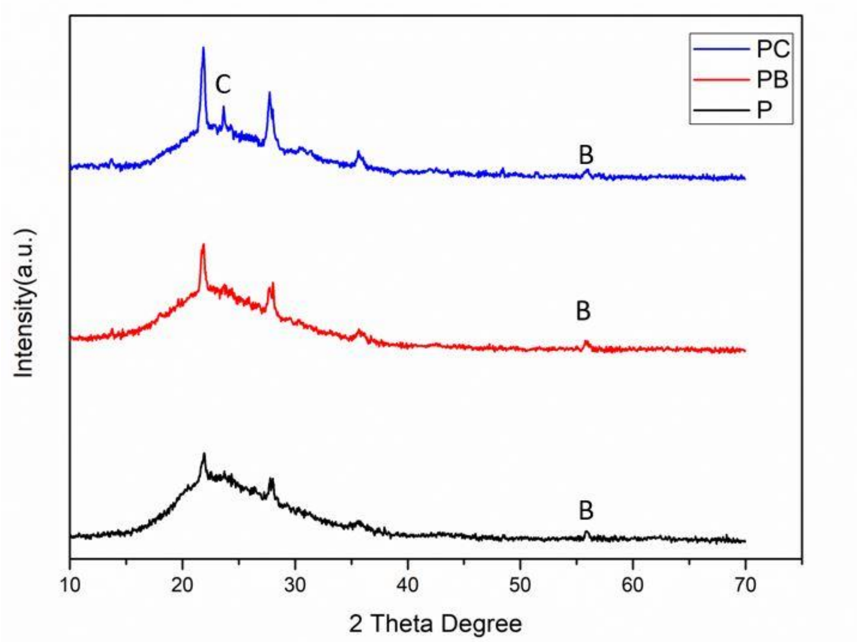


Figure 2. XRD analysis results of raw perlite donated with P, perlite-borax (PB), and perlite-active carbon (PC**).**

Raw perlite 22° 2θ shows a diffuse halo peak. Hemmings and Berry (1987) attribute a broad and diffuse halo peak at approximately 22° 2θ for non-crystalline SiO_2. As seen in Figure 2, there is no noticeable difference in perlite(P), perlite-carbon (PC), and perlite-borax(PB) XRD patterns, which shows that the addition of borax does not affect the structure of raw perlite because borax patterns are observed in the raw perlite structure. In the perlite-carbon sample indicated in blue, the 002 C diffraction peak (2θ =15-30°) can be attributed to amorphous carbon structures.

3.3. FT-IR analysis

Characteristics of Raw Perlite, Perlite Carbon, and Perlite Boraks which are named in Figure P, PC, and PB were researched by using Fourier Transforms İnfrared Spectrometer (FT-IR). The raw perlite infrared spectrum was gained by FT-IR is corresponding to presented by Majouli et al. (2011). According to FT-IR results given in Figure 3, in the spectra curve of raw perlite (P) mainly five absorbers bant were observed around 3400 cm-1, 1630 cm-1, 1000 cm-1, 790 cm-1, and 520 cm-1. The band at 3400 cm-1 is due to OH stretching of H2O which is forming a hydrogen bond. The band at 1630 cm-1 is based on adsorbed binding vibration of water molecules. The bands at around 1000 cm-1 and 790 cm-1 are dedicated to the Si-O stretching vibration of Si-O-Si and Si-O-Al as identified by Sodeyama et al. (1999). The bant at 520 cm-1 is appointed to be O-Si-O ending.

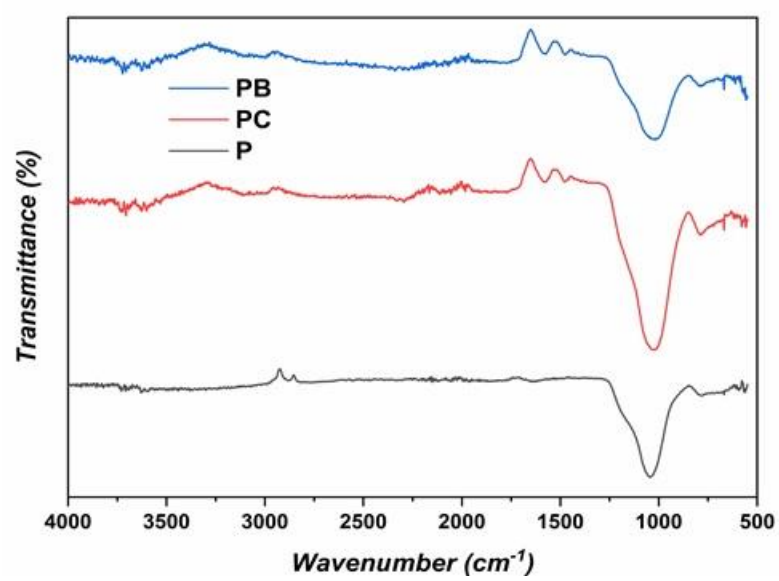


Figure 3. FT-IR analysis of perlite samples.

3.4. TGA analysis

According to the TGA analysis results given in Figure 4, the mass loss of raw perlite due to temperature is 3.153 percent. The mass loss between 200 and 400 ºC in raw perlite is due to the presence of OH groups in the free water molecules in the pores of the perlite. The mass loss of perlite with carbon-doped on its surface, which has a lower mass percent loss than raw perlite, is 3.106 percent. The mass loss of perlite with carbon-doped on its surface, which has a lower mass percent loss than raw perlite, has decreased by 3.106% because the pores of the perlite are covered with carbon. Therefore, the moisture in the perlite could not evaporate anymore. Perlite borax, which shows less mass loss than raw perlite and perlite carbon, has a mass percent loss of 1.191%. This is because the perlite pores are covered with borax and the free water molecules in the pores move away from the structure. Çelik et al. (2013) explained that when the temperature of the raw perlite sample rose above 400 degrees, thermolysis started and the perlite samples began to decompose. At temperatures above 600 degrees, decomposition is complete and the surface area of the perlite structure is reduced. The porosity and compactness ratio decreased depending on the temperature. Similarly, the same mass loss was observed in the carbon-doped perlite on its surface.

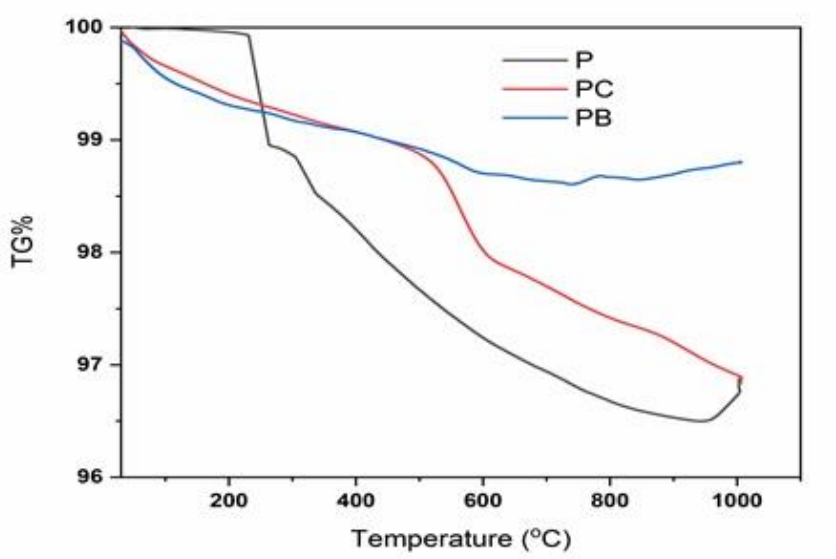


Figure 4. TGA analysis of perlite samples.

4. Conclusion

As a result, perlite modified with borax lost less mass than perlite modified with carbon. The reason for this is that borax closes the pores of the raw perlite, therefore there is not much water loss, and the shrinkage in the perlite borax structure was less than the perlite carbon and raw perlite. When the SEM images of the borax-modified perlite samples were examined, changes in the morphological structure of the raw perlite were observed. Then, in XRD analysis, it was determined that borax did not show a change in the crystal structure of raw perlite. The effect of raw perlite modified with borax on the production of concrete with high thermal resistance may also guide future studies. Perlite coated with borax shows better thermal properties than raw perlite and perlite treated with activated carbon.

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