USABILITY OF AEROGEL AND BORON WASTES IN BUILDING MATERIAL PRODUCTION: A COMPILATION

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ABSTRACT

The indispensable part of the structures built to meet the sheltering needs is the building material. All materials used during the formation of the structure are defined as building materials. While concrete used in building construction is defined as a building material, nails are also defined as building materials. In building production, the main building materials are concrete, cement, plaster and brick. Over time, the current status of these building materials has not been sufficient to meet the needs. For this reason, the structure of the building material has been improved with both new materials and waste. As a result of this improvement, new additive materials with superior properties were obtained. In this study, the use of nanomaterial aerogel and industrial waste boron waste in the production of building materials was investigated. Within the scope of this research, national and international literature has been examined in detail. The academic studies examined have been summarized. Studies in the literature have been classified as the use of aerogel and boron waste in concrete, cement, plaster and mortar, brick and other building materials. As a result of the study, it was observed that both additives reduced the compressive strength and heat transfer coefficient of the building materials. It has been observed that the porosity rate of the material has increased and accordingly the water absorption rates have also increased. It has been determined that aerogel causes impermeable pore formation. It has been understood that it improves thermal comfort conditions and minimizes mold formation. In addition, it has been observed that boron waste and aerogel additive can be used in the production of building materials in appropriate proportions. In case of use, it has been determined that the properties of the building material are improved.

Keywords: Aerogel, boron waste, concrete, brick, cement

AEROJEL VE BOR ATIKLARININ YAPI MALZEMESİ ÜRETİMİNDE KULLANILABİLİRLİĞİ: BİR DERLEME

ÖZET

Barınma ihtiyacının karşılanması için inşa edilen yapıların vazgeçilmezi yapı malzemesidir. Yapı oluşumu sırasında kullanılan tüm malzemeler yapı malzemesi olarak tanımlanmaktadır. Yapı inşasında kullanılan beton yapı malzemesi olarak tanımlanırken, çivi de yapı malzemesi olarak tanımlanmaktadır. Yapı üretiminde ana yapı malzeme olarak beton, çimento, sıva ve tuğla gösterilebilmektedir. Zaman içerisinde bu yapı malzemelerinin mevcut durumları ihtiyaçları karşılamaya yetmemiştir. Bu nedenle yapı malzemesi bünyesi gerek yeni malzemelerle gerekse atıklarla iyileştirilmiştir. Bu iyileştirme sonucunda üstün özellikli yeni katkılı malzemeler elde edilmiştir. Bu çalışmada, nanomalzeme olan aerojel ve endüstriyel atık olan bor atıklarının yapı malzemesi üretiminde kullanılması araştırılmıştır. Bu araştırma kapsamında ulusal ve uluslararası literatür detaylı bir şekilde incelenmiştir. İncelenen akademik çalışmalar özet haline getirilmiştir. Literatürde yapılan çalışmalar, aerojel ve bor atığının beton, çimento, sıva ve harç, tuğla ve diğer yapı malzemelerinde kullanımı şeklinde sınıflandırılmıştır. Çalışma sonucunda, her iki katkının da, yapı malzemelerinin basınç dayanımını ve ısı iletim katsayısını azalttığı görülmüştür. Malzemenin porozite oranını arttırdığını ve bununla bağlı olarak su emme oranlarının da arttıdığı görülmüştür. Aerojelin geçirimsiz gözenek oluşumuna neden olduğu tespit edilmiştir. Termal konfor şartlarını iyileştirdiği ve küf oluşumunu minimize ettiği anlaşılmıştır. Ayrıca, bor atığı ve aerojel katkısının uygun oranlarda yapı malzemesi üretiminde kullanılabileceği görülmüştür. Kullanılması durumunda da, yapı malzemesi özelliklerini iyileştirdiği tespit edilmiştir.

Anahtar Kelimeler: Aerojel, bor atığı, beton, tuğla, çimento

1. INTRODUCTION

It is possible to define building materials as all materials used in the formation of a structure. Materials such as concrete, cement, brick are building materials that lead the formation of the structure. Therefore, the development of these materials is very important. It is possible to improve building materials with different additives. This improvement is sometimes done with industrial wastes (Gaikwad and Sathe, 2025; Mahvash et al., 2025), sometimes with organic wastes (Rihan and Alahmari, 2025; Khankhaje et al., 2025) and sometimes with nanotechnological materials (Xiong et al., 2025; Qu et al., 2025).

In this study, examined one of the additives is boron waste. Türkeye has 955,297 thousand tons of B_2O_3 reserves, which is 72.1% of the world. Colemanite ($Ca_2B_6O_{11}\cdot5H_2O$), ulexite

($NaCaB_5O_9 \cdot 8H_2O$), borax (tincal) ($Na_2B_4O_7 \cdot 10H_2O$) and boric acid are the most important boron minerals used in the production of different types of borates. During these production processes, wastes containing boron are formed. These wastes pollute the environment. In order to minimize the pollution caused by these wastes, boron wastes are evaluated in different types of processes such as cement, concrete and brick production (Aldakshe et al., 2020).

Another material is aerogel. Aerogel, a nanotechnological material, is actively used in the construction field (Alan et al., 2021; Bostancı, 2021). The biggest reason for preference is that it improves thermal properties to an excellent level.

This study aims to investigate the usability of aerogel and boron waste in the production of building materials. In this context, national and international literature was scanned and a detailed examination was made.

2. AEROGEL AND BORON WASTES

2.1. Aerogel

Aerogels are solid materials in which the liquid in the pores has been replaced with air. It is quite light, has a porous structure and contains air instead of liquid in its pores (Bheekhun et al., 2013). Aerogels are highly porous and lightweight materials as they contain 99% air (Figure 1). The pore sizes are billionths of a millimeter. These pores surround the inside of the material like a network and provide them with properties such as low thermal conductivity coefficient and low dielectric constant. Their insulation capabilities are high and they are 40 times superior to fiberglass insulation materials and are very durable materials (Radha, 2008; Öz et al., 2018).

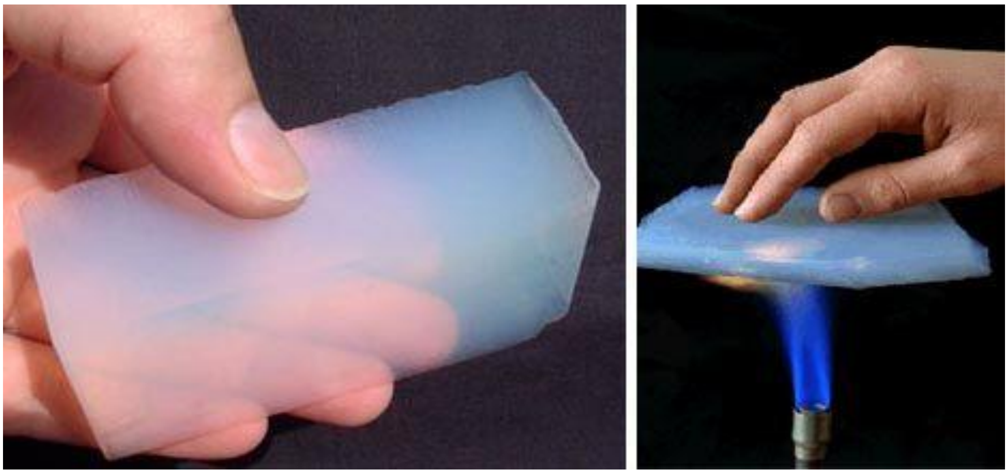

Figure 1. Aerogel (Web message 1)

Due to their properties such as high porous structure, low density and large surface area, aerogels can be used in fields such as chemistry, construction, aviation, electricity, space and biology. However, despite all these advantageous properties, aerogels have not found widespread use today due to problems such as their fragility, difficulty in producing them on a large scale for industry, and high cost (Aegerter et al., 2011).

Aerogels are divided into 5 groups: alumina aerogels, silica aerogels, alumina-silica aerogels, carbon aerogels and other aerogels (Kılınç, 2024).

The aerogels whose properties are given in Table 1 have poor mechanical properties. This makes the aerogel samples brittle, soft and fragile. These shortcomings limit the development and application areas of aerogels. Nowadays, some fibers and hard materials are added to aerogels to improve the mechanical properties of silica aerogels (Huang et al., 2012).

Table 1. Properties of silica aerogels (Doğdu, 2022)

Feature	Value
Density	0.003 g/cm^3
Surface Area	500-1000 m^2/g
Porosity	%80-99.8
Pore Diameter	20-150 mm
Particle Diameter	2-5 nm
Thermal Conductivity	0.017-0.021 W/mK
Coefficient of Thermal Expansion	2.0-4.0*10-6
Speed of Sound	100 m/s
Dielectric Constant	1.1
Refractive Index	1-1.05

2.2. Boron/Boron Waste

Boron is located in Group IIIA in the periodic table and is shown with the symbol B. Boron, with its atomic number of 5 and atomic weight of 10.81 (Altun, 2005), is the only non-metal element (Çağlar, 2016). Boron element is not found free in nature (Güyagüler, 2001). Although there are more than 250 types of boron minerals on earth, only a few of these minerals have commercial importance (Coşar, 2006). The physical properties of boron element are presented in Table 2.

Table 2. Physical properties of Boron (Ata, 2009)

Feature	Value
Atomic Weight	10.801+0.003
Melting Point	2190+20 0C
Boiling point	3660 0C
Thermal Expansion Coefficient (25-105 ^{0}C, for 1 ^{0}C)	5x106-7x106
Knoop Hardness	2100-2580 HK
Mohs hardness (Diamond-15)	11
Vickers Hardness	5000 HV

The economic value of boron minerals is determined by the B_2O_3 ratio in their structure (Dırak, 2011). The boron minerals with economic value are presented in Table 3. The most important minerals with commercial importance are tincal and colemanite (DPT, 2001).

Table 3. Commercially important boron minerals

Structure	Mineral Name	Chemical Formula	%B_2O_3 Ratio	Location
Sodium Borate	Tincal	$Na_2B_4O_7.10H_2O$	36.5	Kırka, Emet, Bigadiç, ABD.
	Kernit	$Na_2B_4O_7.4H_2O$	51.0	Kırka, ABD, Arjantin
Calcium Borate	Colemanite	$Ca_4B_6O_{11}.5H_2O$	50.8	Emet, Bigadiç, ABD
	Pandermite	$Ca_4B_{10}O_{19}.7H_2O$	49.8	Sultançayır, Bigadiç
Sodium-Calcium Borate	Ulexite	$NaCaB_5O_9.\ 8H_2O$	43.0	Bigadiç, Kırka, Emet, Arjantin
	Probertit	$NaCaB_5O_9.\ 5H_2O$	49.6	Kestelek, Emet, ABD
Magnesium-Calcium Borate	Hydroboracite	$CaMgB_6O_{11}.\ 6H_2O$	50.5	Emet

Boron waste is sodium borate-based boron minerals. These wastes, shown in Figure 2, are collected in waste ponds within the facilities in the form of mud (slurry) by adding water. The part called Tinkal Solid Waste is taken from the pond and subjected to ore enrichment processes. These wastes, which contain approximately 25% B_2O_3, contain valuable clay minerals such as illite, montmorillonite and vermicullite (Sarıağaç, 2012).

Figure 2. Boron waste (Web message 2)

Boron waste contains compounds such as quartz (SiO2), iron oxide (Fe2O3) and alumina (Al2O3), which are important for binding. In addition, it is found in potassium oxide (K2O) and calcium oxide (CaO). Table 4 shows the chemical properties of boron waste taken from Eskişehir Kırka Borax Facilities.

Table 4. Chemical properties of boron waste (Akyıldız, 2012)

Component	B_2O_3	CaO	MgO	SiO_2	Na_2O	Al_2O_3	Fe_2O_3	K_2O	LOI
Boron waste, %	25	10.38	13.94	12.98	5.67	0.96	0.20	0.72	29.15

3. ACADEMIC STUDIES ON THE USABILITY OF AEROGEL AND BORON WASTES IN BUILDING MATERIAL PRODUCTION

Aerogel and tincal wastes are actively used in the production of building materials. In this study, academic studies on the use of aerogel and tincal wastes in concrete, cement, plaster and mortar, brick and other building materials are presented.

3.1 Use of Aerogel and Boron Waste in Concrete Production

In their study, ***Li et al., (2024)*** investigated the effect pattern of hydrophobic silica aerogel on aerogel foam concrete (AFC). The study results revealed that the density, compressive strength and thermal conductivity of AFCs were affected by the antifoam effect of SA. At the same time, the thermal conductivity of AFCs decreased to the range of 59.0–83.5 mW/m/K due to both the SA content and the antifoaming effect.

In their study, ***Wang et al., (2019)*** prepared aerogel-infused concrete (AIC) with different aerogel volume additives. The porosity and pore distribution characteristics of AICs were obtained using scanning electron microscopy and microparticle mercury porosimetry. They experimentally investigated the changes in thermal conductivity in the dry state depending on temperature (20-90 °C) and the effect of humidity (35 °C, 0-100% RH) on the thermal conductivity of AICs. Their results show that the thermal conductivity of AIC varies according to a quadratic function depending on the aerogel content. They reported that the highest decrease in thermal conductivity (79.3%) occurred with the increase in aerogel content, and the highest increase was 15.5%.

In his thesis, ***Çimen (2023)*** synthesized silica aerogel (SA) with Bayburt Stone (BT) waste. It has investigated the effects of substituting SA in lightweight concrete at certain rates on properties such as heat and sound insulation, strength and porosity. Physical (unit weight, porosity, water absorption, thermal conductivity and ultrasound transmission speed) and mechanical (compressive strength) tests were applied to the samples. As a result of the study, it was determined that thermal insulation would be optimum with (3%, 350% and 0.40%) levels. It was reported that (3%) SA replacement improved (46%) thermal conductivity value, increased porosity (31.48%) and caused a decrease in compressive strength (9.72 MPa). He found that SA is hydrophobic and has good adsorption properties and that a porous structure is formed around SA in concrete. He reported that the polycrystalline structure in concrete increases with the increase in SA concentration. He detected that this increase causes a decrease in the mechanical strength of the material.

In their studies, ***Aldakshe et al., (2020)*** produced lightweight concrete by using pumice and boron waste as substitution materials at different rates (1%, 3%, 5%, 7% and 9%). As a result, they found that the physical and mechanical properties of the material improved with the increase in boron waste. They achieved the best result with 9% boron waste substitution. They stated that the recycling of environmentally harmful boron waste used in the construction sector will contribute to sustainability.

In their study, ***Öztürk et al., (2020)*** investigated the mechanical properties, electromagnetic (EM) and shielding effectiveness of concrete samples containing boron products and wastes. They also investigated the effects of additives on the strength behavior of concretes. They stated that the addition of minerals would not reduce the strength parameters, in addition to improving the screening behavior. As a result; concretes containing boron products and wastes reported to provide 3.16 to 100 times better screening effectiveness than the control sample, which was a concrete containing only Portland cement. Additionally, they found that additives in concretes increased the shielding effectiveness without adversely affecting the strength parameters.

In their study, ***Yentimur et al., (2022),*** investigated the usability of construction demolition waste (WW) to be generated within the scope of urban transformation by recycling it in concrete. They done experiments using 100% IYA, 100% normal aggregate (NA) and 50% IYA–50% NA. They produced cube samples by adding 2%, 5% boron and 2%, 5% boron waste to the 50% IYA–50% NA sample and measured the compressive strengths of the samples. As a result of the study, the 28-day average compressive strength was;

- ✓ 42.1 MPa for 50% IYA–50% NA sample,
- ✓ 36.2 MPa for 2% boron waste sample,
- ✓ 26.7 MPa for 5% boron waste sample,
- ✓ 35.1 MPa for 2% boron added sample,
- ✓ For the 5% boron added sample, it was determined to be 30.7 MPa.

3.2. Use of Aerogel and Boron Wastes in Cement Production

Kim et al., (2013) investigated the possibility of application of aerogels as insulation building materials and their thermal performance. In the study, aerogels were mixed with cement paste. They reported that the thermal conductivity of aerogel cement was 0.135 W/mK, and the thermal conductivity of cement without aerogel was 0.533 W/mK.

Khamidi et al., (2014) investigated the effect of silica aerogel on the thermal conductivity of cement paste for the construction of concrete buildings in sustainable cities. They prepared samples consisting of ordinary Portland Cement (OPC), free water and different volumes of silica aerogel. They cured for 3, 7 and 28 days. After curing, they applied compressive strength test. At the end of the study, the lowest thermal conductivity of 0.076 W/mK was obtained with the sample mixture containing 20 ml of silica aerogel. They reported that the highest permeable porosity measured for the cement paste containing silica aerogel was 25.6%.

In their study, ***Kunt et al., (2015)*** added calcined and non-calcined borogypsum to clinker and investigated their effects on cement mortar. They used borogypsum at a rate of 1% to 7% to see the effect of borogypsum on cement properties. They applied setting time and consistency analysis to fresh mortar. They performed X-ray diffraction (XRD) analysis for characterization of chemical structure of 28-day mortars. Optimum results were obtained with 3% substitution for both calcined and non-calcined borogypsum.

In their study, ***Korkmaz et al., (2022),*** calculated some radiological parameters of three types of cement at 10–3-105 MeV gamma ray energies. They made the calculations using Phy-X/PSD software. They reported that boron is an ideal material for neutron shielding by simulation, but it is not recommended for gamma ray shielding.

In their study, ***Demirel and Nasıroğlu, (2017)*** investigated the use of boron ore, minerals and wastes in cement in their study. They examined national and international literature in order to reveal the potential use areas of boron cement. Within the scope of the study, they emphasized the effects of boron minerals and wastes such as colemanite, boric acid, borax, tincal, belite on the setting time of cement, the compressive strength of concrete and the insulation industry.

3.3. Use of Aerogel and Boron Wastes in Plaster and Mortar Production

Stahl et al., (2017) conducted a study on the renovation of historical buildings without compromising their cultural and historical heritage. In the study, they produced a highly insulating plaster based on silica aerogel. They applied plaster to a historical structure. As a result of the study, they stated that the thermal conductivity value of the building walls decreased by one third compared to the initial value with the application of 5-6 cm thick plaster.

Moreover, the risk of mould has been significantly reduced and thermal comfort has been significantly increased.

Abbas et al., (2019) conducted research on the production of lightweight, thermally insulating cement-based mortar. In their study, they produced mortar by partially replacing sand with various proportions of silica aerogel. In order to evaluate the effect of silica aerogel on the mechanical and thermal properties of cement-based mortars, they produced cement-based mortar by replacing sand with silica aerogel at 25%, 50%, 75% and 100% by volume. As a result of their study, they reported that the thermal conductivity of the plaster produced with 25% silica aerogel decreased by 35%. They determined that the thermal conductivity of the mortar produced with 100% silica aerogel by volume was 0.33 W/mK.

In their study, ***Can et al., (2024),*** produced silica aerogel from volcanic tuff waste. They produced plaster using silica aerogel powder at different volume ratios (25%, 50% and 75%). They determined the structural and morphological properties of silica aerogel powder with XRD, SEM and BET analyses. At the end of the study, they stated that silica aerogel with the desired properties could be successfully synthesized from volcanic tuff waste. They determined that the BET surface area of the synthesized silica aerogel was 663.0 m^2/g and the total pore volume was 0.91 cm^3/g.

Batar and Köksal (2009) produced plaster material using different proportions of perlite, waste paper, borax and borax waste. They performed heat permeability and pressure tests on the samples. They compared the obtained results with the existing plaster materials actively used in the market. As a result; they revealed that the strength and heat permeability resistance of the substituted products increased compared to the existing plaster material.

In their study, ***Sevim et al., (2019)*** investigated the usability of borogypsum as a mineral additive in mortars. They replaced borogypsum with cement at 0%, 3%, 5%, 10% and 15% by mass. They applied flow table, bending and compressive strength, abrasion, carbonation, absorbency and shrinkage tests to mortar samples containing borogypsum. As a result of the study;

- ✓ The compressive and tensile strengths of mortars increased when borogypsum was replaced with cement at 3% and 5%,
- ✓ Mortars containing 10% borogypsum reached high compressive strength,
- ✓ In later ages, these changes caused a decrease in the depth of abrasion and carbonation of the mortars,
- ✓ Increasing borogypsum reduced the consistency of the mortars,

- ✓ They found that the addition of borogypsum reduced the shrinkage of the mortars examined up to the 28th day.

3.4. Use of Aerogel and Boron Waste in Brick Production

In her study, ***Çağlar (2023),*** examined the effect of silica aerogel produced from boron waste on the compressive strength and thermal performance of the brick. She carried out her work in three stages. In the first stage, silica aerogel was produced using boron waste supplied from the Eskişehir/Kırka region of Türkiye. In the second stage, the silica aerogel produced was substituted into the brick structure at different ratios by volume (0% (REF), 15% (AB1), 25% (AB2), 35% (AB3), 45% (AB4)). They produced mixed brick samples by firing the samples at 900 ºC and 1000 ºC. In the third and final stage, She applied to the produced samples to compressive strength and heat transfer coefficient determination tests. Additionally, SEM images were taken to examine the internal structure of the samples. In conclusion;

- ✓ At both temperatures, with the increase of amount of aerogel resulted to decrease in the compressive strength and heat transfer coefficient value,
- ✓ In SEM images, it is seen that as the amount of silica aerogel increases, the amorphous structure increases and voids and cracks form in some places,
- ✓ It has been reported that the use of silica-containing wastes such as boron waste in aerogel production is a suitable solution for the disposal of wastes.

In their study, ***Aldakshe and Apay (2024)*** investigated academic studies on the use of aerogel in brick production. As a result of the study, they stated that aerogel improves some properties of the brick while negatively affecting others. They reported that aerogel can be used in the re-functionalization of heritage structures. They concluded that sustainable and excellent thermal bricks can be produced with the use of aerogel.

In her study**, *Çağlar, (2024),*** examined the effect of granulated aerogel on the properties of lightweight blend bricks. Granulated aerogel was substituted into blend bricks by volume at the rates of 0%, 2.5%, 5%, 7.5% and 10%. Acidic pumice was used at the rate of 50% for the production of lightweight blend bricks. She fired the samples at 900 ºC and 1000 ºC. He determined the thermal conductivity, unit weight and compressive strength values of blend bricks with granulated aerogel additive. As a result of the study, the thermal insulation properties were improved and blend brick samples with compressive strength in accordance with the standards were produced.

In his study, ***Çelik (2010)*** produced light brick samples with perlite, boron and clay additives. He applied physical, chemical and mechanical tests to the light brick samples, which produced in different sizes. As a result of the study, it was revealed that the produced bricks with additives could be used in the construction sector in terms of their technological properties.

Çimen et al., (2020) aimed to improve the properties of brick building materials by using perlite and boron waste. In the study, they kept the perlite material constant at 5%. They produced bricks by substituting boron waste into clay at rates of 5%, 10%, 15% and 20%. They fired the produced samples at 900 ^{0}C. As a result of the study; they determined that perlite and boron waste additives can be used in brick production at appropriate rates. They reported that the use of perlite and boron waste does not have any problems on the brick properties. They also stated that the use of boron waste in brick production has a positive effect.

3.5. Use of Aerogel and Boron Waste in Other Building Material Production

In their review article, ***Jia et al., (2018)*** discussed the latest technology in aerogel-based cementitious insulation materials. As a result of the study, they reported that the stability of aerogel in cement-based insulation materials, interface transition zone, alkali-silica reaction and property optimization are important parameters. They also stated that some unresolved issues highlighted in previous studies should be addressed and studies should be conducted to further promote industrial applications of aerogels in cement-based insulation materials.

Lu et al., (2020) prepared lightweight aerogel/cement composites (ACCs) by insert a nanosilica reinforced cement paste of a silane coupling agent modified aerogel slurry. They investigated the effect of modification on the pore structure and hardened performance of ACCs. As a result of the study, they reported that nanosilica can strengthen the matrix, surface modification of aerogel will result in better compatibility and facilitate the preparation of ACCs with synergistic mechanical properties and thermal insulation properties. They also stated that when the cement paste was replaced by the modified aerogel slurry at 66% volume, an ACC with a thermal conductivity of 0.067 W/mK, a compressive strength of 1.2 MPa, and a density of 390 kg/m3 could be produced.

Lee et al., (2018) investigated the improvement in thermal insulation properties of protein-based silica aerogel composites produced by a new, cheap and applicable method. They concluded that the resulting material exhibited polymeric foam behavior, including high compressibility, superhydrophobic properties, and excellent recovery in addition to low thermal conductivity.

Christogerou et al. (2009) created ceramic dough by adding 0%, 5% and 15% boron waste to the clay used for ceramic production. They fired this dough at different temperatures such as 800 ^{0}C, 850 ^{0}C, 900 ^{0}C, 950 ^{0}C. According to the results of the tests they applied on the samples, they determined that the most suitable results for ceramics could be obtained by firing 5% boron waste at 900 ^{0}C.

In his study, ***Erdoğan (2016)*** produced insulation material by mixing carpet waste with raw colemanite waste and colemanite pond waste added solution. After determining the necessary mixing ratios for mass production, he investigated the physical properties of the product with experiments. He compared the physical properties of the samples he produced with the products on the market. As a result, they have produced an insulation material with high heat and sound insulation properties that can be used in buildings without any problems.

4. RESULTS

In this study, the usability of aerogel and boron wastes in the production of building materials was investigated. The results obtained from the literature research are presented below.

With the use of aerogel in the production of building materials;

- ✓ By using aerogel in concrete building materials, the thermal properties of the concrete are improved,
- ✓ It was observed that porosity and water absorption rate increased and compressive strength decreased.
- ✓ It has been observed that with the use of cement in construction materials, permeable porosity increases, density decreases, and it has an effect on setting time and consistency.
- ✓ When used as plaster in historical buildings, thermal properties are improved,
- ✓ It has been understood that mold formation is minimized, thermal comfort conditions are improved and compressive strength is increased.
- ✓ When used in brick production, it has been observed that the compressive strength and heat transfer coefficient decrease, and voids and cracks form in the microstructure.
- ✓ It was concluded that it can be used in sustainable brick production.
- ✓ It was concluded that both aerogel and boron waste can be easily used in the production of thermal insulation materials, lightweight building blocks and cement-based composite materials.

With the use of boron waste in the production of building materials;

- ✓ It has been understood that the use of aerogel in concrete building material provides shielding effectiveness, and that with the increase in the amount of boron waste, the compressive strength decreases, and the porosity and water absorption rate increase.

- ✓ It has been determined that cement improves thermal performance and is an ideal material for neutron shielding.
- ✓ By using it in plaster production, It has been observed that plaster strength and heat permeability resistance increase compared to the existing plaster material.
- ✓ In the production of mortar material, when borogypsum is replaced with cement at the rates of 3% and 5%, the compressive and tensile strengths of the mortars increase,
- ✓ Mortars containing 10% borogypsum reached high compressive strength, causing a decrease in the depth of abrasion and carbonation of the mortars,
- ✓ It has been understood that increasing borogypsum reduces the consistency of mortars.
- ✓ It has been observed that boron waste additive can be used in brick production in appropriate proportions and does not have any adverse effects on brick properties.
- ✓ It has been determined that there is no harm in using boron waste in the production of ceramic paste and insulation material.

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