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Granül Aerojelin Hafif Harman Tuğlada Kullanımı: Termal Özellik ve Basınç Dayanımı Üzerine

Use of Granular Aerogel in Lightweight Blend Brick: On Thermal Properties and Compressive Strenght

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ÖZET

Harman tuğla, günümüzde pek tercih edilmese de şimdilerde kullanılan fabrikasyon tuğlaların atası olarak tanımlanabilmektedir. Teknolojinin gelişmesi harman tuğlanın özelliklerini ve formunun değişmesine yol açmıştır. Mimari uygulamalarda sıklıkla karşımıza çıkan harman tuğla kullanımı eskiye nazaran az da olsa devam etmektedir. Günümüzde, restorasyon projeleri başta olmak üzere birçok alanda etkinliğini sürdürmektedir. Bu çalışmada, harman tuğla bünyesine nanomalzeme olan granül aerojel ikame edilerek ısı yalıtımı iyileştirilmiş, birim ağırlığı düşük ve TS standartlarına uygun basınç dayanımına sahip harman tuğla üretimi amaçlanmıştır. Çalışmada, hacimsel olarak, %0, %2,5, %5, %7,5 ve %10 oranında granül aerojel killi toprak ile yer değiştirilmiş ve katkılı tuğla numuneleri üretilmiştir. Hafif tuğla üretimi için kullanılan asidik pomza %50 oranında sabit tutulmuştur. Hafif harman tuğla numuneleri 900 ^{o}C ve 1000 ^{o}C'de pişirilmiştir. Çalışma sonucunda, ısı yalıtım özellikleri iyileştirilmiş ve istenilen standartlara uygun basınç dayanımına sahip harman tuğla numuneleri üretilmiştir.

Anahtar Kelimeler: Aerojel, pomza, harman tuğla, mimarlık

ABSTRACT

Blended bricks can be defined as the ancestor of the fabricated bricks used today, although they are not preferred much today. The development of technology has led to changes in the properties and form of blended bricks. The use of blended bricks, which we frequently encounter in architectural applications, continues, albeit less than in the past. Today, it continues its activities in many areas, especially restoration projects. In this study, it was aimed to produce blended bricks with improved thermal insulation, low unit weight and compressive strength accordance to TS standards by substituting granular aerogel, which is a nanomaterial, into the blended brick body. In the study, granulated aerogel is replaced with clay soil with 0%, 2.5%, 5%, 7.5% and 10% by volume and additived brick samples are produced. Acidic pumice used for lightweight brick production was kept constant at 50%. Lightweight blended brick samples are fired at 900 ^{o}C and 1000 ^{o}C. As a result of the study, blended brick samples with improved thermal insulation properties and compressive strength in accordance to the required standards were produced.

Keywords: Aerogel, pumice, blended brick, architecture

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1. INTRODUCTION

Human beings have been building structures to meet their shelter needs since the day they existed (Gül, 2018; Kale et al., 2021; Aldakshe et al., 2020). They used different materials while building these structures. One of these materials is the blended brick, known as the ancestor of the brick (Al-Hasani et al., 2023b; Rahman et al., 2021). The transformation of blended brick from adobe into building material through heat treatment dates back to the times of protohistoric societies (2500-1750 BC) (Çağlar et al., 2018). Brick, one of the oldest known materials in history, is a building material that has continued to develop over time and has survived to the present day (Al-Hasani et al., 2023a). Generally, It is a large-scale building material used in the construction of exterior and interior walls of buildings (Shakir et al., 2013).

Brick is a building material which is obtained by mixing clay or clay soil with water and firing it in special ovens (Karaman, 2006). The abundance of suitable soil and the cheap and easy production of bricks are the most important reasons for choosing bricks (Çimen vd., 2020; Marotta, 2010).

Features such as durability, high strength and low cost are the most prominent features of bricks. Therefore, bricks are a material widely used in the construction industry for several centuries (Buratti et al., 2022). The modern brick industry is developing more challenging products to meet user demands, especially in terms of thermal insulation (Zhang et al., 2018). One of these products is aerogel (Joo et al., 2021). Aerogels have attracted tremendous interest from scientists since the discovery of silica aerogels in 1931 (Kistler, 1931; Leventis and Koebel, 2011). Cause of this interest is several unique properties, such as ultra-low density, low thermal conductivity and the power-law relationship between compressive modulus and bulk density.

Aerogels are choosen as alternative material for architectural designs (Riffat and Qiu, 2013; Ganobjak et al., 2020), construction industry (Shanmugam et al., 2020; Gu et al., 2024), automotive industries (Kim and Hong, 2024; Fikry et al., 2023), aerospace industry (Bheekhun et al., 2013; Jin et al., 2023), catalyst support (Guilminot et al., 2007; Rotter et al., 2004), thermal insulation (Zhang et al., 2024a; Varamesh et al., Wu et al., 2024), sound insulation (Song et al., 2024; Le et al., 2024), nanoparticle filtration from air (Kim et al., 2016; Zhai et al., 2016), and airborne nanoparticle filtration (Kim et al., 2016). et al., 2017) and drug delivery (García-González et al., 2021; Marin et al., 2014).

Aerogels are actively used in the construction field as well as all areas. Concrete (Han et al., 2024; Shohan et al., 2024), cement-based material production (Koriakovtseva et al., 2024; She et al., 2024), brick (Werney et al., 2017; Ganobjak et al., 2023), plaster (Wakili et al., 2015; Melita et al., 2024) and thermal insulation material production (Li et al., 2024; Zhang et al., 2024b) are the areas where aerogel is frequently used. In the literature research, it was seen that aerogel was never used in the production of blended bricks.

Based on this situation, this study targets to make improvements on blended bricks (Çağlar and Çağlar, 2019), which is the first building material with a history of at least 10,000 years. In line with this target, it was aimed to produce blended bricks with improved thermal insulation, low unit weight and compressive strength accordance to TS standards by substituting granular aerogel, which is a nanomaterial, into the blended brick body.

2. MATERIAL AND METHODS

2.1 Material

2.1.1 Granular aerogel

Granular aerogels used in the study were purchased from Aerogel Türkiye company. Used granular aerogel prevents mechanical vibrations and provides noise insulation. It has more than 90% air permeability. It provides thermal insulation in all weather conditions. It has no harmful effects on human health and the environment. The image of the granular aerogel used is given in Figure 1 and its technical specifications are given in Table 1.

Table 1. Technical properties of granular aerogel (Aerogel Türkiye, 2024)

Features	Value
Working temperature range	Between -200 and +650 ^{o}C
Density	1,115 g/cm^3
Thermal conductivity coefficient	0,012-0,016 W/mK
Porosity	%90-95
Color	Light cream
Vapor permeability	5-5,5μ
Fire class	A1
Compressive strength	40kPa

Table 1 continued…	
Ecological Impact	4,32 kg CO_2 for kg
Specific heat	1000 j/kg/K
Surface contact angle	>165 degrees
Waterproofness	superhydrophobic
Dielectric constant	K<2
Sound Absorption	-20 db (1/100) (500 Hz)

Figure 1. Granular aerogel

2.1.2 Pumice

Pumice is a frequently preferred material in the production of lightweight bricks (Tezel et al., 2020). 1 mm sieve acidic pumice material was used in the production of brick samples. The pumice used was taken from within the borders of Nevşehir province. The chemical analysis of acidic pumice is given in Table 2. It is seen in the table that the SiO2 ratio is 75.37%.

Table 2. Chemical analysis of acidic pumice

Component	Ratio (%)
SiO_2	73,37
Fe_2O_3	1,85
Al_2O_3	10,76
MgO	0,04
Na_2O	3,31
CaO	0,99
K_2O	4,86
TiO_2	0,02
MnO	0,03
SO_3	0,04
L.O.I	4,73

2.1.3 Clay soil

The clay soil that used for the production of granulated aerogel-added brick samples was taken in the borders of Ankara province. The chemical analysis of the clay soil is given in Table 3 and its image is given in Figure 2. According to the table, there is 40.18% Silicium in clay soil. Apart from Silicium, the elements Fe, Al, Mg and O are found.

Figure 2. Clay soil

Table 3. Chemical analysis of clay soil

Element	Value (%)
Si	40,18
Fe	5,46
Al	10,03
Mg	1,98
Nb	6,26
O	20,01
Ca	14,65
K	1,53

2.1.4 Mixing Water

Ankara province drinking water was used as mixing water in the production of granulated aerogel added brick samples. The mixed water is clear, clean and drinkable quality.

2.2 Material

2.2.1 Production of samples

In the experimental study, the clay soil used as the main material was taken from the clay soil pile located within the borders of Çankaya district of Ankara province. Pumice was provided from the borders of Nevşehir province.

Clay soil taken by quartering method was ground in laboratory type roller crusher. Then, 1 mm sieve material was obtained. The recipe prepared for the mixture is given in Table 4. Mixing water was added to the prepared samples at a rate of 20% of the total material weight for each mixture.

Tablo 4. Mixture recipe

Samples	Granular Aerogel (%)	Pumice (%)	Clay Soil (%)	Mixed Water (%)
REF	0	50	50	20
AT1	2,5	50	47,5	20
AT2	5	50	45	20
AT3	7,5	50	42,5	20
AT4	10	50	40	20

Then, they were weighed a precision balance and taken in the determined proportions. Taken the materials were put into the mixer and mixed in dry form. After the dry mixture was made, water was added. After mixing again, the dough was left to rest. The prepared dough is rested for 24 hours so that it does not lose its moisture. Then, it is mixed with a mixer until it reaches a plastic consistency. This mixing process continued until there were no air bubbles left (5 minutes). After the kneading process was completed, the mixture prepared in plastic consistency was poured into steel molds of 4x4x16 cm dimensions.

The test samples were removed from the molds after being kept under normal weather conditions for 24 hours. The extracted samples were left to dry in a semi-open area for 7 days. After 7 days, the blended bricks were fired in a timed electric curing oven at 900 °C and 1000 °C for 8 hours. After the samples cooled, they were brought to room temperature (+ 21°C) as seen in Figure 3. Thermal conductivity coefficient determination and compressive strength tests were applied to the fired samples.

Figure 3. Granular aerogel added brick samples

2.2.2 Production of samples

Thermal conductivity coefficient determination test;

The most important criterion of thermal insulation properties is the thermal conductivity coefficient. In the experiment, each sample was tested under three different heat and humidity conditions. Each test consisted of at least 10 thermal measurements. The heat conduction coefficient was calculated by taking the arithmetic average of the measurement results (Sütçü et al., 2015; Çağlar, 2018).

Compressive strength test;

Compressive strength test was carried out according to TS EN 772-1, 2012 "Masonry Units - Test Methods - Part 1: Determination of Compressive Strength" standard. The compressive strengths of the granular aerogel added samples were determined by a computer-controlled compressive press. The samples were dried in the oven at +105 ^{0}C until they reached constant weight. The compressive strength value of the dried samples was calculated by dividing to the surface area (4x4 cm) of the breaking load.

3. RESEARCH RESULTS AND EVALUATION

3.1 Thermal conductivity coefficient determination test results

The graph showing the heat conduction coefficient of all produced samples is given in Figure 4. In the graph, at 900 ^{o}C, while the highest heat transfer coefficient belongs to the REF sample with 1.076 w/mK, the lowest heat transfer coefficient was obtained from the AT4 sample with 0.87 w/mK. At 1000 ^{o}C, while the highest heat transfer coefficient was obtained from the REF sample with 1.062 W/mK, the lowest heat transfer coefficient was obtained from the AT4 sample with 0.71 W/mK. At all temperatures, the lowest thermal conductivity coefficient was obtained from the AT4 sample. When the change curve was examined, it was seen that the heat conduction coefficient decreased with the increase in the firing temperature. This situation can be understood from the fact that all samples at 1000 ^{o}C are located under the change curve. In short, it was observed that the heat conduction coefficient of the brick samples decreased with the increase in the amount of aerogel. The significant amount of air spaces in the aerogel pores insulates the heat. This situation is resulted with lower thermal conductivity of the samples. Gao et al., (2014), Westgate et al., (2018), Rostami et al., (2021) and Çağlar, (2023) reported in their studies that aerogel reduces the heat transfer coefficient of the brick. They obtained similar results to the article in their studies.

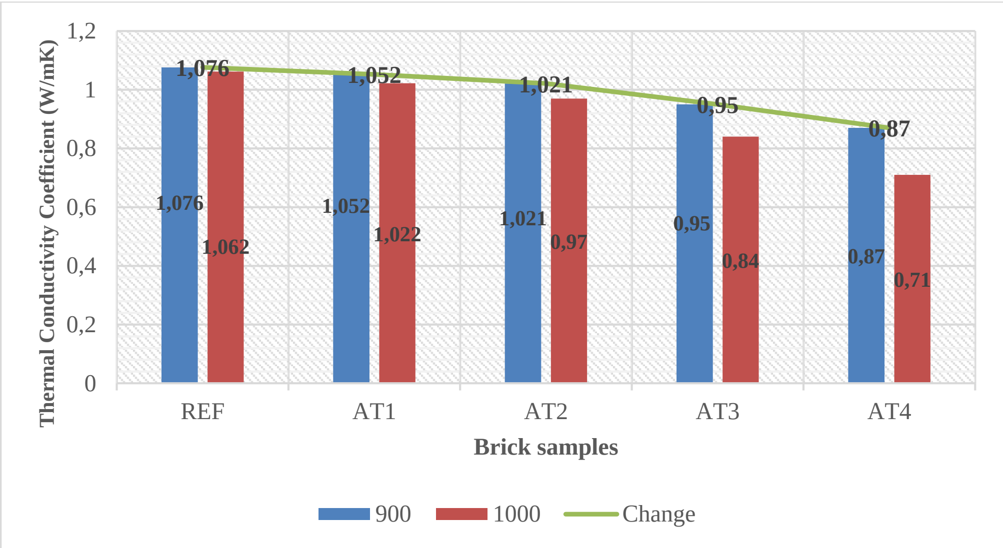

Figure 4. Heat transfer coefficient determination graph

In Figure 5, the decrease rates in the thermal conductivity coefficient of the samples with granular aerogel additives are given. At 900 ^{o}C, the lowest reduction rate was obtained from the AT1 sample and the highest reduction rate was obtained from the AT4 sample. The reduction rates are 2.23%, 5.11%, 11.71% and 19.14%, respectively. At 1000 ^{o}C, the lowest reduction rate of 3.76% was obtained from the AT1 sample, and the highest reduction rate of 33.14% was obtained from the AT4 sample. The reduction rates are 8.66% and 22.22%, respectively. In short, at both temperatures, the highest reduction rate was obtained from the AT4 sample.

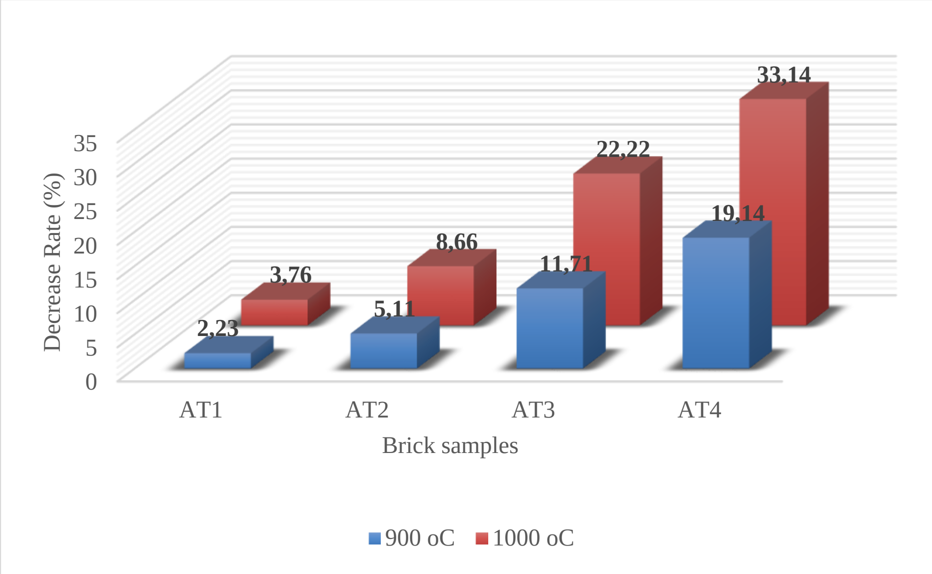

Figure 5. Thermal conductivity coefficient reduction rates

3.2 Compressive strength test results

The compressive strength graph of the samples produced within the scope of the study is given in Figure 6. According to the graph, at 900 °C, the highest compressive strength was obtained from the REF sample with 5.4 MPa, while the lowest compressive strength was obtained from the AT4 sample with 3.1 MPa. At 1000 °C, the highest compressive strength was obtained from the REF sample with 5.9 MPa, while the lowest compressive strength was obtained from the AT4 sample with 3.8 MPa. At both temperatures, the highest compressive strength belongs to the reference sample. At both temperatures, a decrease in compressive strength occurred with the increase in the aerogel amount. The reason for this decrease is that aerogel has a highly porous and brittle structure, and it turns the brick body into a brittle structure.

When granulated aerogel blended bricks are classified according to their compressive strength;

- At 900 °C, AT1 and AT2 samples are in the medium strength brick class (min. 4 MPa), while AT3 and AT4 samples are in the low strength brick class (min. 2.5 MPa).
- At 1000 °C, AT1, AT2 and AT3 samples are in the medium strength brick class, and AT4 sample is in the low strength brick class.

Westgete et al., (2018), Adhikary et al., (2020) and Çağlar (2023) reported in their studies that aerogel negatively affects the compressive strength of the brick. These studies support the article.

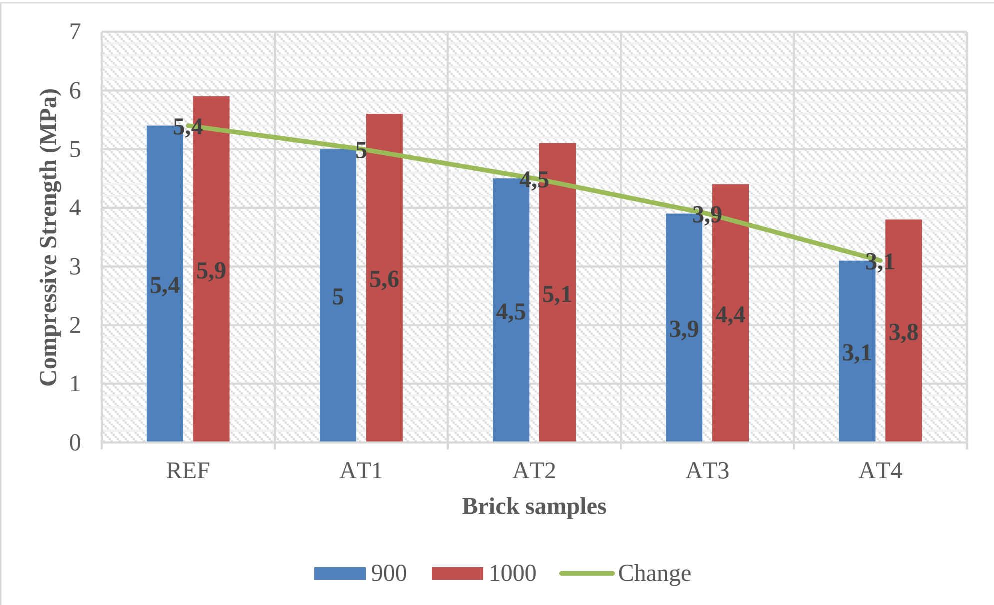

Figure 6. Compressive strength graph

In Figure 7, the compressive strength reduction rates of the samples with granular aerogel additives are given. At 900 °C, the lowest reduction rate was obtained from the AT1 sample, and the highest reduction rate was obtained from the AT4 sample. The reduction rates are; 7.4%, 16.66%, 27.77% and 42.59%, respectively. At 1000 °C, the lowest reduction rate of 5.08% was obtained from the AT1 sample, and the highest reduction rate of 35.59% was obtained from the AT4 sample. The reduction rates are; 13.55% and 25.42%, respectively. In short, at both temperatures, the highest reduction rate was obtained from the AT4 sample which is the highest granular aerogel additive ratio. At both temperatures, although the compressive strengths decrease AT1 and AT2 samples are in the medium strength brick class.

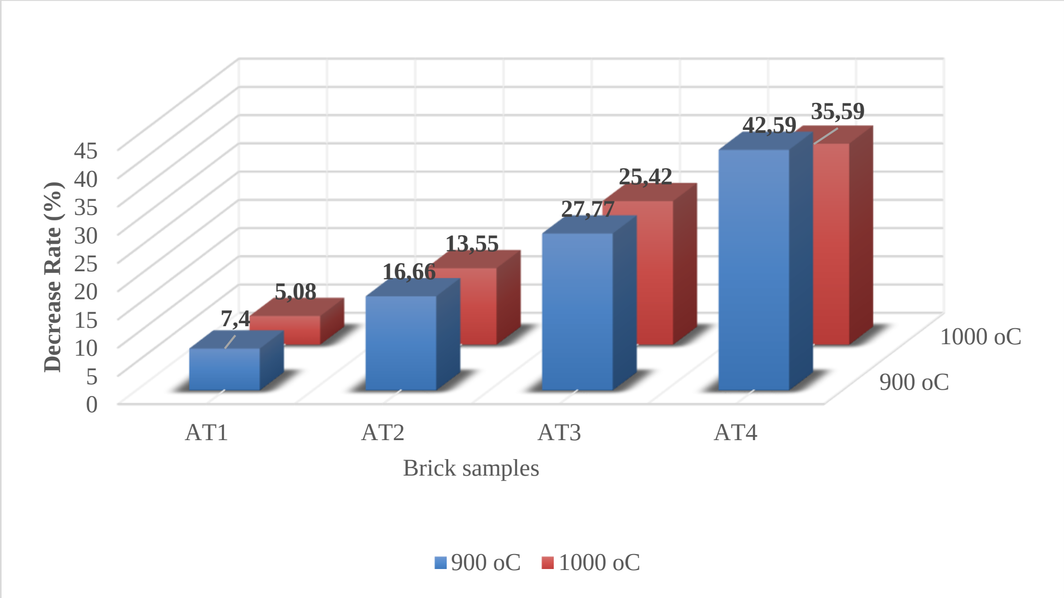

Figure 7. Compressive strength reduction rate

4. CONCLUSION AND RECOMMENDATIONS

In this study, the usability of granulated aerogel in the production of lightweight blended bricks was investigated and obtained results and made recommendations are given below.

- A decrease in the heat conduction coefficient is occurred with the increase of the amount of granular aerogel.
- At both temperatures, the lowest thermal conductivity coefficient is obtained from AT4 samples.
- Among all samples, the lowest heat conduction coefficient belongs to the AT4 sample fired at 1000 oC.
- Temperature increase was an important factor in the decrease of the heat transfer coefficient.
- As the amount of granular aerogel increased, the compressive strength decreased.
- Among the additive samples, the sample with the highest compressive strength is AT1, and the sample with the lowest compressive strength is AT4.
- At both temperatures, compressive strength decreased as the amount of granular aerogel increased.
- At both temperatures, AT1 and AT2 samples are in the medium strength brick class.
- AT3 and AT4 samples, which are in the low strength class, can be easily used in decoration and landscaping applications.
- In future studies, the effects of aerogel on different properties of blended bricks should also be investigated.
- Different additives can be substituted to increase the compressive strength of the blended brick.
- In the construction sector, opportunities should be provided for the more frequent use of nanotechnological materials.

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