POLİTEKNİK DERGİSİ

JOURNAL of POLYTECHNIC

ISSN: 1302-0900 (PRINT), ISSN: 2147-9429 (ONLINE)
URL: http://dergipark.org.tr/politeknik

Determination of physical and mechanical properties of porous blocks (bricks) produced with brick clay

Tuğla kili ile üretilen gözenekli blokların (tuğlaların) fiziksel ve mekanik özelliklerinin belirlenmesi

Yazar(lar) (Author(s)): *Ahmet BİLGİL[1], Tuba ARI POLAT[2], Osman ŞİMŞEK[3], Ergün YEŞİLYURT[4]*

ORCID[1]:0000-0002-4196-0484

ORCID[2]: 0000-0001-9125-3449

ORCID[3]: 0000-0003-3842-5541

ORCID[4]: 0000-0003-2164-9063

To cite to this article: Bilgil A., Polat A. T., Şimşek O ve Yeşilyurt E., "Determination of Physical and Mechanical Properties of Porous Blocks (Bricks) Produced with Brick Clay", ***Journal of Polytechnic***, 27(3): 985-994, (2024).

Bu makaleye şu şekilde atıfta bulunabilirsiniz: Bilgil A., Polat A. T., Şimşek O ve Yeşilyurt E., "Determination of Physical and Mechanical Properties of Porous Blocks (Bricks) Produced with Brick Clay", ***Politeknik Dergisi***, 27(3): 985-994, (2024).

Erişim linki (To link to this article): http://dergipark.org.tr/politeknik/archive

DOI: 10.2339/politeknik.1246745

Determination of Physical and Mechanical Properties of Porous Blocks (Bricks) Produced with Brick Clay

Highlights

- *The technical properties of the porous clay brick produced at different rates of expansion additive and different firing temperatures were investigated.*
- *The most suitable expander additive ratio was determined as 15% and the most suitable firing temperature was determined as 1150 °C.*
- *It was determined that the production of porous clay bricks with low unit weight but higher compressive strength compared to normal bricks was determined.*

Graphical Abstract

Expander additive ratio in different ratios and the effect on the physical and mechanical properties of porous clay brick produced at 1150°C firing temperature are given

Table. Technical properties of 1150 °C fired porous clay brick

Expander Additive Ratio(%)	Ref-0	3	6	9	12	15	18	21
Compressive Strength (MPa)	26.58	7.12	7.00	7.00	6.94	6.90	6.88	6.93
Unit Weight (kg/m3)	1720	878	866	804	734	712	716	719
Specific Strength (Strength/UW)	15.453	8.109	8.089	8.705	9.455	9.691	9.609	9.638
Freeze-Thaw Compressive Strength / Unit Weight	9.093	6.264	6.247	6.716	7.289	7.514	7.316	7.288
Water Absorption Ratio(%)	16.7	31.1	31.3	31.4	31.5	31.6	31.6	31.3
Porosity Ratio(%)	17.8	34.7	35.6	35.9	35.9	36.1	36.3	27.4
Thermal conductivity coefficient (λ=W/mK)	0.75	-	-	-	-	0.16	-	-

Aim

Determination of optimal properties of brick clay and porous block (brick) with the help of different ratios of expanding agent

Design & Methodology

The unit weight, compressive strength, water absorption rate, freeze-thaw loss and heat transmission coefficient of the produced porous brick were determined experimentally.

Originality

The technical properties of the porous brick produced by the gas-forming admixture and the brick mud forming air bubbles independently from each other were investigated.

Findings

The compressive strength/unit volume weight ratio of the porous brick was obtained at a temperature of 1150C with the highest expansion contribution of 15%.

Conclusion

It has been determined that expander additive and firing temperature are effective in the production of porous bricks. The most suitable physical and mechanical properties of the porous brick produced with an expander additive ratio of 15% and fired at 1150 oC were provided.

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Determination of Physical and Mechanical Properties of Porous Blocks (Bricks) Produced with Brick Clay

Research Article

Ahmet BİLGİL[1], Tuba ARI POLAT[2], Osman ŞİMŞEK[3]*, Ergün YEŞİLYURT[4]

[1]Nigde Omar Halisdemir University, Engineering Faculty, Civil Engineering Depertment, 51200 Niğde, Turkey
[2]Polat Engineering Office, 51100 Niğde, Turkey
[3]Gazi University Faculty of Technology, Department of Civil Engineering, 06500, Ankara-Turkey
[4]Kayseri University, Vocational School, Department of Construction-Technology, 38030 Kayseri, Turkey

(Geliş/Received : 03.02.2023 ; Kabul/Accepted : 14.02.2023; Erken Görünüm/Early View : 06.03.2023)

ABSTRACT

Clay brick has recently become a very inevitable product for the construction industry due to the being a sustainable and relatively cheaper material especially with the parallel of developments on foam-forming agents. These bricks have two main problems. These are high unit volume weight and thermal conductivity. In this study, an expansion agent was added to the brick raw material to reduce the unit weight of the brick and to increase the thermal insulation. Samples were produced by adding a mixture of expanding at certain rates. The produced samples were fired at 850, 900, 950, 1000, 1050 and 1100 ºC to obtain 100×100×100 mm bricks. The unit volume weight, water absorption, void ratio, compressive strength, compressive strength after freezing-thawing and thermal conductivity properties of the produced bricks were investigated. According to the data obtained in the research, the optimum expansion chemical ratio is 15%. The most suitable firing temperature was determined as 1100 ºC. The samples produced with 15% expander at 1100 °C, unit volume weight 744 kg/m^3, water absorption 31.83%, void ratio 36.88 %, compressive strength 6.93 MPa, compressive strength after freezing-thawing 5.10 MPa and thermal conductivity λ=0.16 W/mK.

Keywords: Porous clay brick, expanding agent, lightweight clay bricks,

Tuğla Kili ile Üretilen Gözenekli Blokların (Tuğlaların) Fiziksel ve Mekanik Özelliklerinin Belirlenmesi

ÖZ

Kil tuğla, özellikle köpük oluşturucu maddelerdeki gelişmelere paralel olarak, sürdürülebilir ve nispeten daha ucuz bir malzeme olması nedeniyle son zamanlarda inşaat endüstrisi için çok vazgeçilmez bir ürün haline gelmiştir. Bu tuğlaların iki ana sorunu vardır. Bunlar, yüksek birim hacim ağırlığı ve termal iletkenliktir. Bu çalışmada, tuğlanın birim ağırlığını azaltmak ve ısı yalıtımını arttırmak için tuğla hammaddesine genleşme maddesi ilave edilmiştir. Numuneler belirli oranlarda genleşen karışıma eklenerek üretilmiştir. Üretilen numuneler 850, 900, 950, 1000, 1050 ve 1100 oC'de pişirilerek 100×100×100 mm tuğla elde edilmiştir. Üretilen tuğlaların birim hacim ağırlığı, su emme, boşluk oranı, basınç dayanımı, donma-çözülme sonrası basınç dayanımı ve ısıl iletkenlik özellikleri incelenmiştir. Araştırmada elde edilen verilere göre optimum genleşme kimyasal oranı %15'tir. En uygun pişirim sıcaklığı 1100 oC olarak belirlenmiştir. 1100 °C'de %15 genleştiricili, birim hacim ağırlığı 744 kg/m3, su emmesi %31,83, boşluk oranı %36,88, basınç dayanımı 6,93 MPa, donma-çözülme sonrası basınç dayanımı 5,10 MPa ve ısı iletkenliği λ=0,16 W olarak üretilen numuneler /mK.

Anahtar Kelimeler: **Gözenekli kil tuğla, genleşen ajan, hafif kil tuğlalar,**

1. INTRODUCTION

Bricks are one of the first man-made building components on the globe. The first industrial production of brick corresponds to the construction of the Tower of Babel in the 4th century BC. The estimated number of bricks used in this construction was figured out to be 85 million pieces. The production methods were improved by the time and the Romans started its trade and specified the first standards for brick production leading to a new dimension in the industry. With the developing technology following industrial revolution, fabrication of bricks started as a new process. Bricks, as an irreplaceable element of construction, did have a permanent place in the architecture of world in 19th and 20centuries [1].

**Sorumlu Yazar (Corresponding Author)*
e-posta : simsek@gazi.edu.tr

Clay bricks are a still traditional component which allows the construction of buildings. Clay bricks generally do have physical and mechanical strength requirements to construct. However, they still have two basic issues being high unit weight and thermal conductivity. Therefore, they need to be developed to be competitive in the industry. With the increasing

environmental sensitivity during the last three decades, clay bricks have been tried to be modified adding waste or renewable materials or mineral resources to the paste. Additives that forms pores in the body of bricks are generally used to decrease unit

weights but they also contribute to alter the features of porosity, density, mechanical strength and even thermal conductivity. In this context, it is a significant matter to produce new components with high mechanical strength and low thermal conductivity [2].

Clay bricks have high UWs since they have low porosity and are widely used as wall components. High UW leads self-weights of buildings to increase and this is one of the greatest issues in construction industry. The increase in its own self-weight causes some structural problems. This also causes the benefit/cost ratio to change negatively. The risk of getting damaged or knocked down by earthquakes increase directly proportional to self-weights of buildings. Therefore, lighter materials are preferred to get used in constructions. However, lightweight building materials that have desired features are of minute amount and of high cost [3, 4].

Generally, bricks must have some physical properties as well as insulation, compressive strength properties. In addition to carrying their own weight in the clay brick wall, it is aimed to provide heat insulation on the outer walls.

It has been determined as a result of researches that approximately 40% of the heat loss in buildings occurs through the walls [5,6]. This represents 36% of global CO_2 emissions, and previous studies estimate that 50% of this energy is lost through walls [6,7].

Due to environmental effects, sustainable building material research is gaining great importance. They examined the use of industrial waste materials in brick production to produce independent high porosity bricks in order to reduce the dead load on the walls and increase the thermal insulation. These industrial waste materials are a wide variety of waste materials such as fly ash, slags, sawdust, cotton waste, limestone dust, paper production waste, kraft pulp production waste, waste tea. As these waste materials are used alone, hollow bricks are produced by adding them to the brick clay mud with different methods [8, 9].

A number of researchers used various waste materials to increase porosity of fired-clay bricks. Some of these waste is paper production residue [10], vegetable matter [11 rice husk [12], sugarcane pulp ash waste [13], corn cob [14], organic and inorganic wastes [15,16], granite dust [17], domestic solid waste incinerator slag [18], fine kaolin furnace residue, granulated blast furnace slag, granite-basalt fine furnace residue [19], industrial nano-crystalline aluminum sludge [20, 21], Fe Cr Slag and Natural Zeolite [22], sand, chamotte and waste brick [23]. In this study, it is to produce porous bricks with high porosity and compressive strength, low unit volume weight and heat conduction by adding expansion additives at different rates to the brick clay mud (dough).

2. MATERIAL AND METHOD

2.1. Material

Material used in the study is the clay mineral available in Kolsuz region, Niğde, Turkey. This mineral has been used before in brick production and is currently being used in the production of cement by ÇİMSA Niğde Cement plant. Mineral bulk to be used in the study was composed by mixing the minerals obtained in equal amounts from four different locations within the Kızılbayır formation in Kolsuz region. The chemical analysis of the clay used in the experiment is given in Table 1, the sieve analysis in Fig. 1 and the XRD analysis in Fig 2.

Clay obtained from the reserves in Kolsuz region was ground and sifted through the sieve of 0.5 mm square mesh openings. The pressed oven-dry unit weight and density were measured as $\gamma h=1.67$ g/cm^3 and $\gamma k= 2.57$ g/cm^3 respectively

Table 1. Chemical composition of clay used in the study

Component	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MgO**	**Na_2O**	**K_2O**	**SO_3**	**Loss of Ignition**
Amount (%)	50.97	11.58	6.77	8.40	3.90	1.83	2.31	0.13	13.63

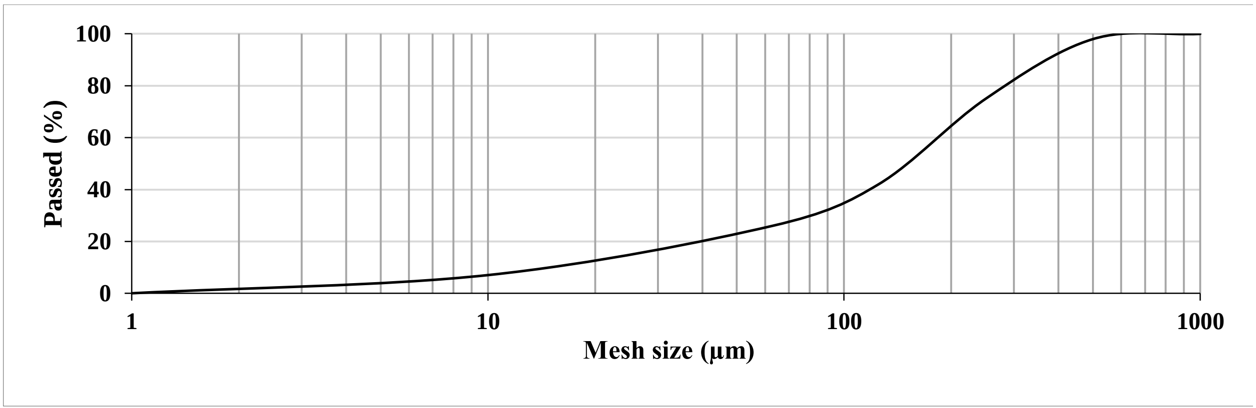

Fig 1. Sieve analysis of the clay sample used in the study.

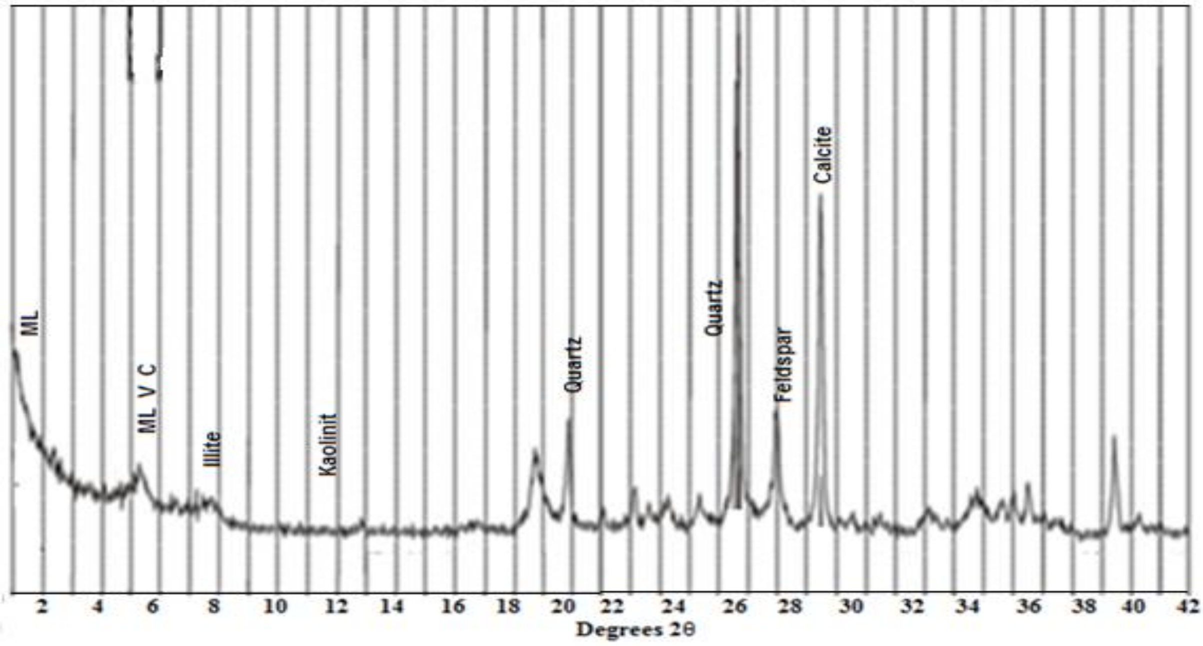

Fig 2. XRD Measurements of clay of kolsuz region

Expanding agent (EA) consisting of three different chemicals was added to the clay mud in order to create a pore (independent space) in the brick samples. The ingredients and mixing ratios of this expander are sodium bicarbonate ($NaHCO_3$) 50%, acetic acid ($C_2H_4O_2$) 45% and natural liquid soap (potassium hydroxyl) 5%. Here, while providing the gas bubbles formed by the reaction of sodium bicarbonate ($NaHCO_3$) and acetic acid ($C_2H_4O_2$), natural liquid soap (Potassium hydroxyl) ensures that the bubbles maintain their shape. Tap water was used in the mixtures. The chemical specifications of the additives used in the mixtures were given in Table 2.

Table 2. Chemical specifications of the additives.

Specification	**$NaHCO_3$**	**$C_2H_4O_2$**
$NaHCO_3$(%)	99,1 <	-
Na_2CO_3 (%)	0,7 >	-
Cl (mg/kg)	700 >	-
SO_4 (mg/kg)	300 >	-
Water Insoluble(mg/kg)	500 >	-
Fe Total (ppm)	10 >	-
Bulk Density (g/cm3)	1,02	1,02
Molecular Weight	84	60
Dilution (%)	-	10
Dilution (%10) was prepared by Emir Kimya Ltd.		

2.2. Method

Brick dough was produced by mixing 0 (Ref), 3, 6, 9, 12, 15, 18 and 21 % of the weight of clay used in this EA mixture. Samples were shaped in moulds of 100×100×100 mm size with these produced doughs. Samples in the mould were removed from the mould after waiting for at least 24 hours in the laboratory environment. The samples removed from the mould were kept in a ventilated oven at 23±2 ^{0}C for 72 hours and brought to the oven dry.

The mixture parameters in Table 3 were pre-determined experimentally to fulfil the moulds 1000 cm^3 in volume, considering the expansion capability of the pastes.

Table 3. Mixture parameters

Mixture	Clay (g)	Water (g)	$NaHCO_3$ (%)	$NaHCO_3$ (g)	$NaHCO_3$ (mol)	$C_2H_4O_2$ 10 %	Liquid soap (g)
M_0(Ref)	1500	258,0	--	--	---	--	---
M_3	750	250,0	3	22,50	0,27	22,50	10
M_6	750	227,5	6	45,00	0,54	45,00	12
M_9	750	205,0	9	67,50	0,81	67,50	14
M_{12}	750	182,5	12	90,00	1,08	90,00	16
M_{15}	750	160,0	15	112,5	1,34	112,5	18
M_{18}	750	137,5	18	135,00	1,61	135,00	20
M_{21}	750	115,0	21	157,50	1,88	157,50	22

3. EXPERIMENTAL FINDINGS

Having moulded all the proposed samples, the dimensions and weights of them were measured and firing process was started. After the fired samples were cooled down to the ambient temperature, the dimensions and weights of the samples re-measured. These measurements were made for calculating the shrinkage and ignition loss of the samples. The samples fired at 1100 ^{o}C have had formal deformations. All the samples were trimmed down to 100×100×100 mm bythe current production technology was followed.

10 samples from each mixture group were weighed, measured for dimensions and then placed into the oven to be fired at the temperatures 850, 900, 950, 1000, 1050 and 1100 ^{o}C as given in Fig 3. Thus, samples were fired for each temperature and each group was given a code which represents the temperature and mixing group writing $M_{850-1100}$ in Table 3. For instance, M_{850} represents the group of 10 samples with % 0-21 expander additive and fired at 850 ^{o} C. Homogeneity in medium and experiment conditions was aimed by forming such groups.

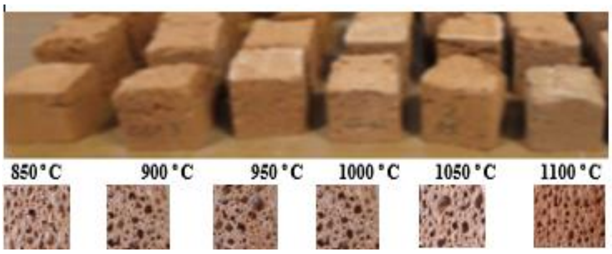

Fig 3. Image of clay brick according to firing degrees

3.2. Unit Weight

Unit weights of the samples were determined according to EN 772-13 [24]. Therefore, oven-dry weights of the samples were determined first, taking the arithmetic saw-cutting to obtain homogeneous dimensions and even surfaces. Then, physical and mechanical properties of the samples were determined. In brick samples produced with 15% EA additive are shown.

3.1. Firing of the Samples

In general, firing process in the production of bricks consists of placing, heating, firing, cooling and unloading phases. In this study, this general order in The temperature in the oven was set to increase 5 ^{o} C per minute. After arriving the targeted temperature, the samples were kept in the oven for one hour, and then the internal temperature of the oven was decreased to the mediums. The samples were unloaded from the oven and weight and dimension measurements were repeated for each sample. The samples were fired at each temperature setting. After firing they were controlled visually and between 850 ^{o}C and 1100 ^{o}C not any deformation, cracks or colour change was observed.

means of 10 samples' values as the unit weight of a group. As seen in Fig 4, it was fired between 850 and 1100 ^{o} C. The unit weights of the samples at 1100 ^{o} C decreased from 1740 to 744 kg/m^3 depending on the additive ratio. However, when the additive ratio was 21%, the unit weight increased significantly. The reason for this is that after the amount of additive is 15%, the trapped spaces (descend) collapse. In other words, it has decreased due to the scratching of the chemicals forming the voids from the clay dough. The high amount of additive deformed the paste, causing the paste to release higher amount of gas. Meanwhile, the gas that could have been locked inside the body was released also, the pores were opened to the air thus allowed the water inside and the paste collapsed in.

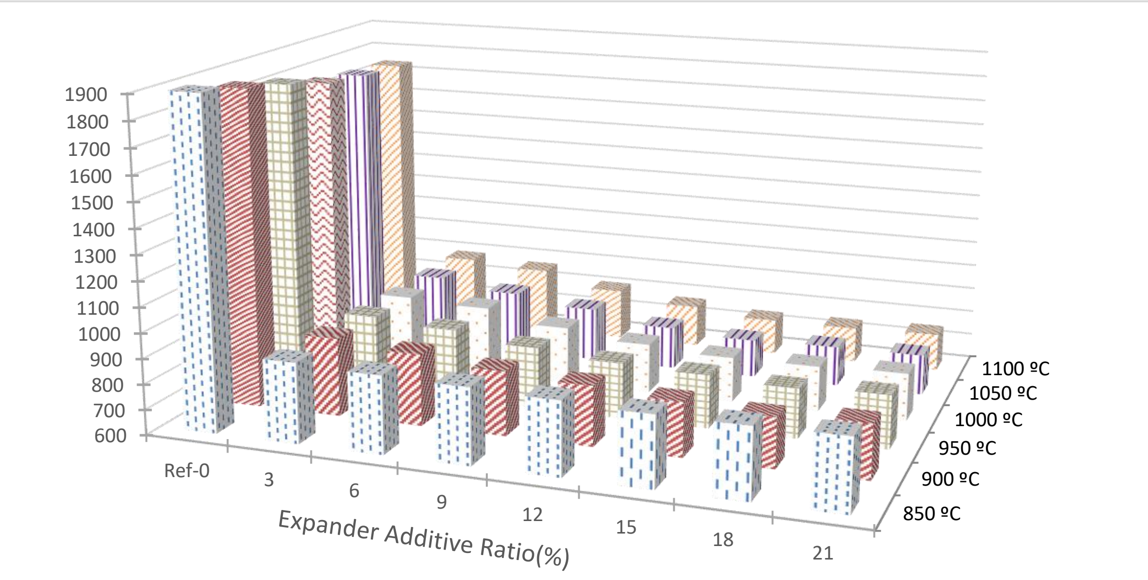

Fig 4. Expander additive ratio unit weight relationship depending on firing temperature

Unit weight differentiation actualized nearly at zero level in the sample groups with 3 and 6% additives. In other groups it decreased with the increasing additive ratio. With additive ratios higher than 15%, unit weights of samples considerably decreased but firing temperatures did not have a considerable effect on unit weights. As it would be seen in Fig. 4, unit weights of the bricks that were produced have nearly decreased down to 60% compared to the control (reference) samples.

3.3. Water Absorption Rate

The water absorption rates of the samples were determined according to the EN 771-1 [25] standard. As seen in Fig 5, it shows that the expanded samples have higher water absorption rates than the Control samples. This increase is around 60%. A similar behaviour occurred in the samples at all firing temperatures. The water absorption rates of the samples fired at 850 and 1100 ºC showed little increase depending on the chemical additive ratio in the mixtures. While this increase continued until the chemical additive ratio was 15%, a slight decrease in 21% was observed in all samples.

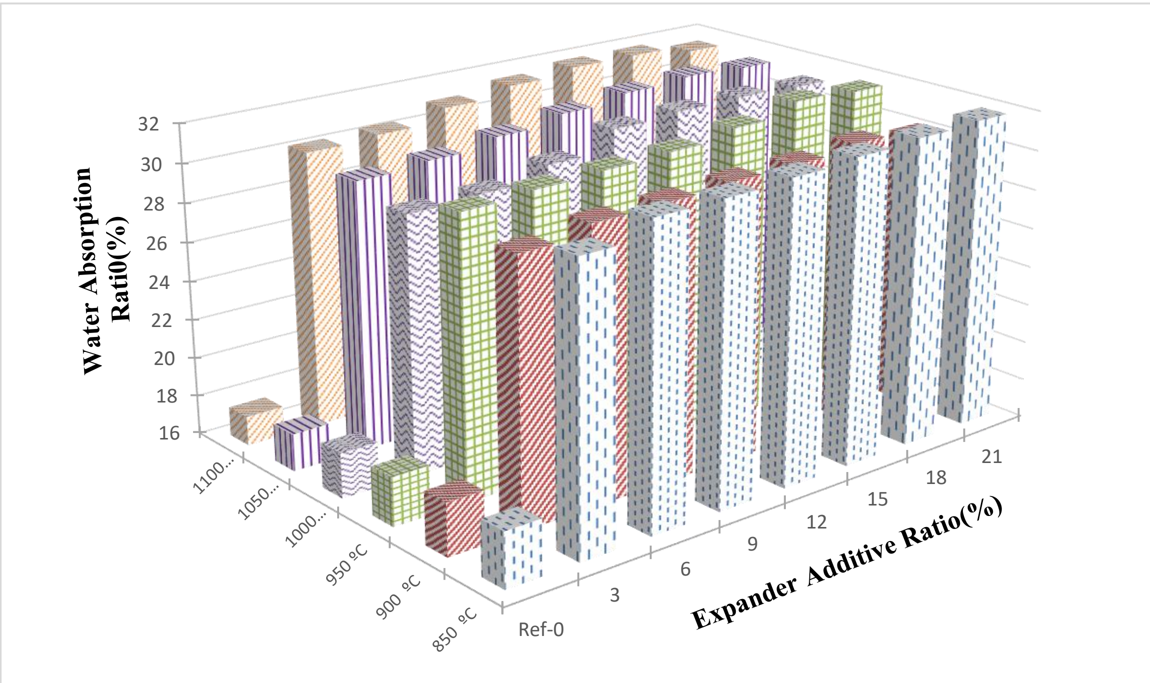

Fig. 5. Expander additive ratio water absorption relationship depending on firing temperature

3.4. Porosity

Porosity is the ratio of pores in the material mass. The void ratio of the control samples is approximately 75% less than the samples produced with the expansion agent. In Fig. 6, it is seen that the void ratio of the control samples is around 18%, while the void ratio of the expanded brick samples is above 33%. It is seen that the expanded samples increase depending on the EA ratio.

Depending on the different firing degrees of the samples, the void ratio changed slightly. The average porosity rate of the samples fired at 1100 °C and produced with 15% additive ratio is 36.88%.

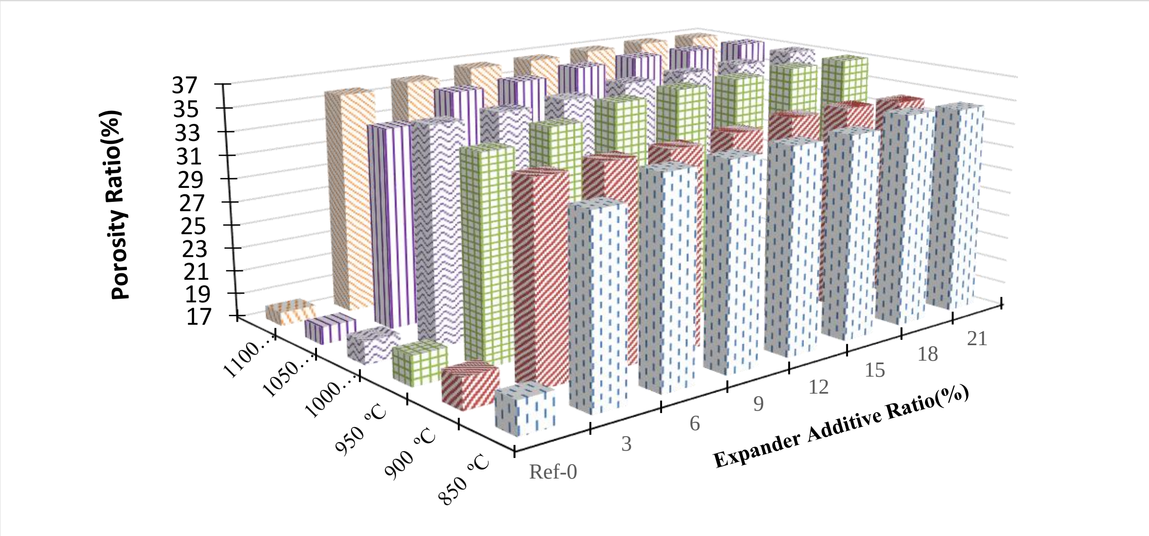

Fig. 6. Expander additive ratio porosity relationship depending on firing temperature

3.5. Compressive Strength

The process suggested by the standard EN 772-1[26] was implemented to determine compressive strengths of the samples. The arithmetic means of each group were assigned the strength value of the related group. The results were summarized in Table 4.

As can be seen from Fig 7, the compressive strength of the reference samples is approximately 4 times higher than the samples produced with 15% additive. As can be seen in Fig. 6, the compressive strength of the reference samples is approximately 3 times higher than the samples produced with 15% additive.

Expander additive ratio, specific power (compressive strength/unit weight) relationship depending on fired temperature. When the relationship was examined, the highest rate was obtained from the samples produced with 15% chemical additives and fired at 1100 °C. In other words, the compressive strength of the samples produced with 15% additive is 68% lower than the Ref. sample. Samples produced with 18% and 21% additives had collapsed (volume loss) before firing. The collapse (volume reduction) occurring within the samples is seen in the production of foam concrete [27]. However, it was observed that the compressive strength of the expanded samples increased with increasing firing temperature. The reason for this can be explained as the silica in the raw material is sintered into a ceramic structure

Table 4. Compressive strength values (MPa)

Fired Temperature	**Expander Additive Ratio(%)**							
(°C)	**Ref-0**	**3**	**6**	**9**	**12**	**15**	**18**	**21**
850	10.87	5.69	5.61	5.59	5.53	5.50	5.56	5.66
900	13.37	5.72	5.67	5.62	5.58	5.53	5.43	5.38
950	14.42	5.87	5.84	5.70	5.60	5.56	5.58	5.70
1000	15.99	6.01	5.98	5.97	5.79	5.64	5.64	5.73
1050	18.37	6.14	6.09	5.93	5.86	5.83	5.79	5.93
1100	21.59	7.30	7.00	6.90	6.90	6.93	6.89	6.91

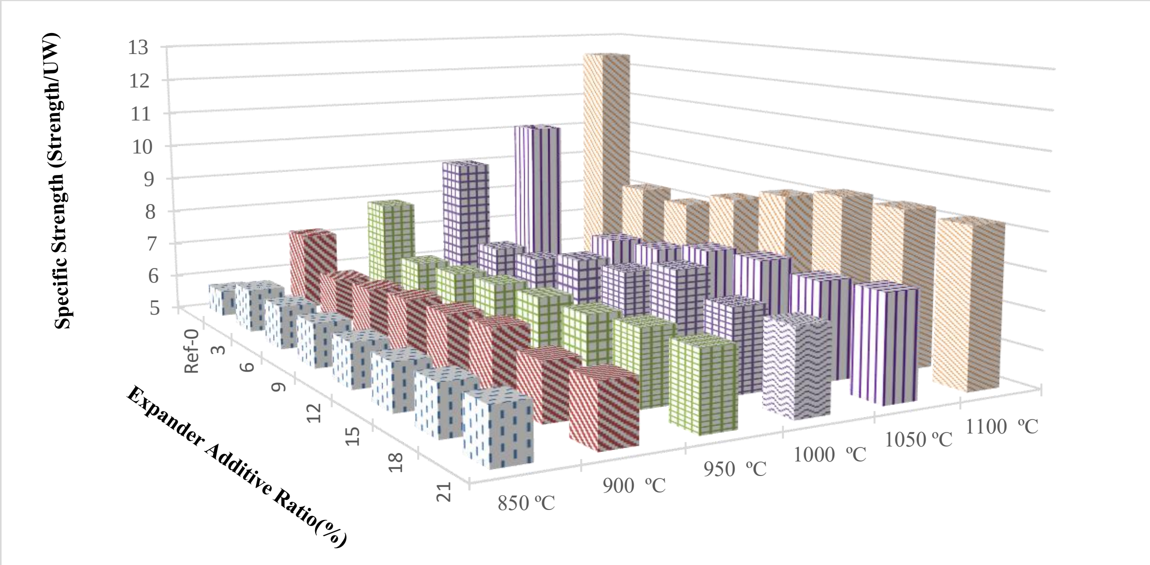

Fig. 7. Expander additive-rate specific strength relationship depending on firing temperature

Firing temperature directly affects the normal strength. The clay particles are sintered as bonded with each other by the firing process. During this firing process, a series of conversions are existed by some minerals such as quartz, feldspar, calcite, dolomite and hematite. This is owing to the completion of the crystallization process known as vitrification as silicate particles fuse together to form a dense brick structure [28]. Aluminum silicate (Al_2O_3 $2SiO_2$) were formed by combining Al_2O_3 and SiO_2 at temperature of 550-900 º C with firing clay minerals. After this time, these types of products cannot return again to their original form with absorbing water. A compound called as Mulita is formed at the specific temperatures greater than 900 º C. As a result of this, free SiO_2 composes glass phase and then mechanical properties of the products start to increase. In this study, it was observed that the mechanical properties of brick products increased by about 1 MPa at temperatures above 1050 ºC. To use brick products in masonry building according to Eurocode 6, the compressive strength of this product must be greater than 12 MPa [29]. The brick product that was produced for this study could not reach to required strength according to Eurocode 6. However, this product has some important properties to be used for constructing carcass building as a construction material.

3.6. Resistance to Freeze-Thaw Process

After the samples were conditioned by getting saturated by water, were frozen at -15 °C for a duration of 2 hours, then thawed in the water at 20±5 °C for one hour, and then were frozen again. This cycle was applied for 30 times [30]. After testing, samples were visually inspected and slight flaking was observed. Since the structure of the samples is independent from each other, no capillary cracks were detected in the freeze-thaw tests. In Fig. 7, axial compressive strength values for the samples subjected to freeze-thaw process and for those non-subjected were given. Compressive strength values after freeze-thaw are given in Table 5. While the highest compressive strength was seen in the 1100 º C reference samples, the lowest compressive strength was seen in the samples produced with 21% expansion additive fired at 900 º C.

Table 5. After Compressive strength values (MPa)

Fired Temperature (ºC)	**Expander Additive Ratio(%)**							
	Ref-0	**3**	**6**	**9**	**12**	**15**	**18**	**21**
850	8,81	4,47	4,47	4,44	4,38	4,32	4,28	4,25
900	10,72	4,45	4,44	4,41	4,39	4,33	4,26	4,20
950	13,72	4,71	4,71	4,60	4,56	4,53	4,49	4,32
1000	14,82	5,02	4,98	4,97	4,86	4,78	4,45	4,42
1050	15,14	4,90	4,87	4,65	4,65	4,62	4,55	4,30
1100	17,38	5,80	5,65	5,60	5,20	5,10	5,10	5,05

In order to determine the optimum expander additive ratio and firing temperature depending on the highest post-freezing compressive strength of the porous clay brick, the ratios are given in Fig. 8 as a result of dividing the post-freezing compressive strength by the unit weight. When Fig. 8 is examined and analyzed, it can be said that the highest rate was the porous clay brick fired at 1100 ºC and produced with 15% expansion additive ratio.

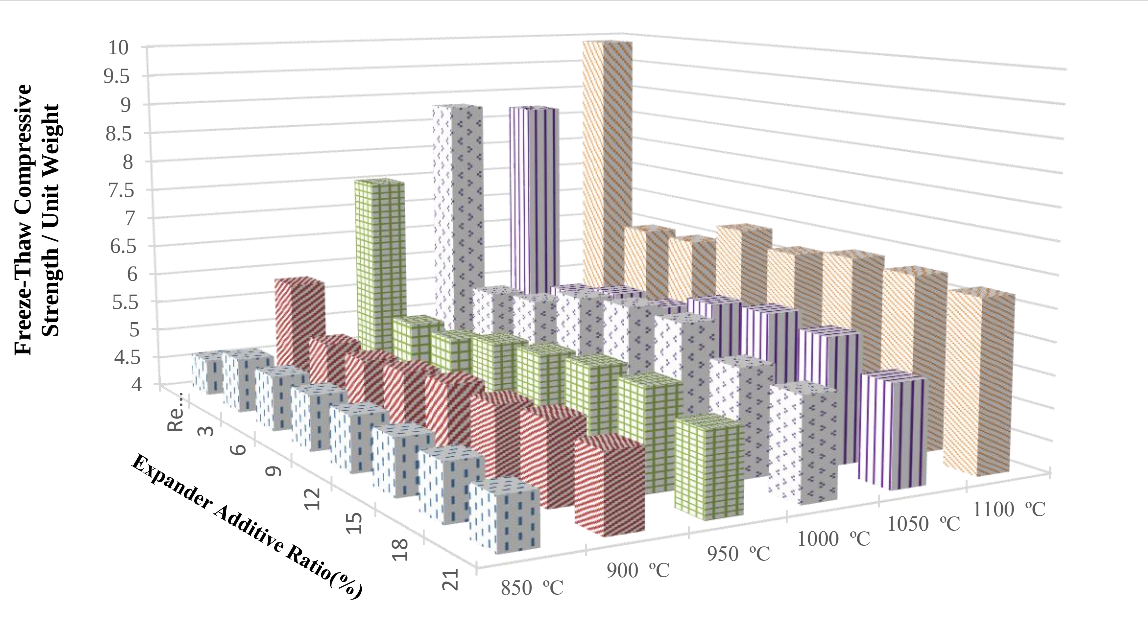

Fig. 8. Expander additive ratio after freeze-thaw compressive strength/ Unit weight relationship depending on firing temperature

3.7. Thermal Conductivity Coefficient

Thermal conductivity coefficient was determined for the sample group which had the lowest unit weight (the group with the mixture in which 15% gas-releasing chemical additive was added and which was fired at 1100°C). For this, 3 samples of 30 mm diameter and 30 mm thickness were prepared from the material fired at 1100°C. The increase in the dimensions did not cause any formal deformation. The unit weights of the new samples were determined and the one with the lowest unit weight was chosen for conductivity test. Thermal conductivity coefficient for this sample was determined to be λ=0.16 W/mK. The λ=0.75 W/mK value of the control sample was found to be λ=0.16 W/mK of the sample produced with 15% additive ratio. It is known in the literature that a normal brick with a unit volume weight of 1.20 kg/dm^3 has this value, λ=0.50 W/mK [31, 32]. This can be considered quite good enough relative to the literature and control samples.

Thermal conductivity values showed a trend of 68% decrease from 0.50 W/mK (this value is recommended for thermal conductivity in buildings) to 0.16 W/mK. It is clearly seen that the thermal conductivity of bricks is directly related to the porosity. It is widely known that as the porosity of the samples increases, the unit weight and thermal conductivity decrease. If the walls are made of bricks with low thermal conductivity, thermal comfort and efficiency will increase.

4. CONCLUSION AND DISCUSSION

Brick used in construction technology is produced by pressing. In this study, it was produced by forming gaps with the gas-releasing chemical additives without being pressed. Mechanical and physical properties of the samples were investigated and the following results were obtained;

The unit volume weights of the samples decrease as the amount of gas-releasing chemical additives increases. The excessive amount of as-releasing chemical additives increased the pore ratio. The lowest unit volume weight value was 0.744 kg/dm^3 for the specimen containing 15% gassing chemical at 1100 ºC of firing temperature. Compared to the control sample, the unit weight of the samples produced with gaseous chemical additives was reduced by 60%. In parallel, porosity values increased. There is a natural relationship between porosity and water absorption by mass. The water absorption (by mass) was in the range of 30-32%. At 850 to 1100 °C of fired temperature, the compressive strength values of the samples were linearly increased in the range of 5-8 MPa. The highest value was obtained as 6.93 MPa in the samples produced with 15% expansion additive and fired at 1100 º C. However, when compared to the control samples, chemical additives that release gas cause approximately 4 times the strength loss due to the voids created by the chemical. After the samples were subjected to freezing-thawing, the light flaking was observed on the surface and no other significant deformation was observed. However, it is observed that there is an average loss 20% for the compressive strength. There was a linear relationship between porosity, bulk density and thermal conductivity. The thermal conductivity measured on the sample produced at 15% the gas-releasing chemical additives and firing at 1100 º C was found to be λ = 0.16 W/mK. Compared to the bricks used in the sector, 50% improvement was observed. Samples produced by expanding have engineering properties that can be used as constructive construction material.

DECLARATION OF ETHICAL STANDARDS

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Ahmet Bilgil : He analyzed the results of the experiments

Tuba Arı Polat: He conducted the experiments and analyzed the results

Osman Şimşek: The writing of the article and the interpretation of the results

Ergün Yeşilyurt: He completed the writing process of the article

CONFLICT OF INTEREST

There is no conflict of interest in this study

REFERENCE

[1] Polat Arı T. "Investigation of characteristics of lightweight building components produced by getting clay paste expanded with a chemical". **Master Thesis**. Niğde Ömer Halisdemir University Institute of Science, 2011 Niğde- Turkey.

[2] Bories C, Borredon ME, Vedrenne E, Vilarem G. "Development of eco-friendly porous fired clay bricks using pore-forming agents: A review". ***Journal of Environmental Management***; 143: 186-196. (2014).

[3] Aouba L, Coutand M, Perrin B, Lemercier H. "Predicting thermal performance of fired clay bricks lightened by adding organic matter: Improvement of brick geometry". ***Journal of Building Physics,*** Vol. 38(6) 531–547, (2015).

[4] Simsek O, Gökçe M . "Investigation of the expanded ability of Kalecik Ankara clay feature". ***Journal of Polytechnic***; 20 (3) : 639-645, (2017).

[5] Metz B. Intergovernmental panel on climate change. climate change 2001: mitigation. Cambridge (UK): **Cambridge University Press**, (2001).

[6] Muñoz P, Morales MP, Mendívil MA, Juárez MC, Muñoz L. "Using of waste pomace from winery industry to improve thermal insulation of fired clay bricks. Eco-friendly way of building construction". ***Construction and Building Materials***, 71:181–187, (2014).

[7] Wouter P. Energy performance of building: assessment of innovative technologies. **ENPER-TEBUC**, Final Report, (2004).

[8] European Environment Agency. Energy efficiency and energy consumption in the household sector (ENER 022) Assessment published. April, (2012).

[9] Zhang L. "Production of bricks from waste materials–A review". ***Construction and Building Materials,***47: 643–655, (2013).

[10] Sütcü M, Akkurt S. "The use of recycled paper processing residue in making porous brick with reduced thermal conductivity". ***Ceram. Int.;*** 35: 2625–31, (2009).

[11] Saiah R, Perrin B, Rigal L. "Improvement of thermal properties of fired clays by introduction of vegetable matter". ***Journal of Building Physics***, 34 (2): 124–142, (2010).

[12] Gürhan G, Simsek O. "Porous clay bricks manufactured with rice husks***". Construction and Building Materials;*** 40: 390–396, (2013).

[13] Faria KCP, Gurgel RF, Holanda JNF. "Recycling of sugarcane bagasse ash waste in the production of clay bricks". ***J. Environ. Manage.,*** 101:7–12, (2012).

[14] Njeumen Nkayem DE, Mbey JA, BKenne Diffo B, Njopwouo D. "Preliminary study on the use of corn cob as pore forming agent in lightweight clay bricks: Physical and mechanical features". ***Journal of Building Engineering,*** 5: 254–259, (2016).

[15] Mohammed MS, Ahmed AE.-SI Osman RM, Khattab I. "Combinations of organic and inorganic wastes for brick production". ***Polym. Compos***., 35: 174-179, (2014).

[16] Sütcü M, Oztürk S, Yalamac E, Gencel O . "Effect of olive mill waste addition on the properties of porous fired clay bricks using Taguchi method". ***Journal of Environmental Management;*** 181: 185-92, (2016).

[17] Menezes RR, Ferreira HS, Neves GA, Lira HL, Ferreira HC. "Use of granite sawing wastes in the production of ceramic bricks and tiles". ***J. Eur. Ceram. Soc.,*** 25(7): 1149–1158, (2005).

[18] Lin KL. "Feasibility study of using brick made from municipal solid waste incinerator fly ash slag". ***J. Hazard. Mater,*** 137, (3): 1810–1816, (2006).

[19] El-Mahllawy MS. "Characteristics of acid resisting bricks made from quarry residues and waste steel slag". ***Construction and Building Materials,***22: 1887–1896, (2008).

[20] Santos P, Martins C, Júlio E. "Enhancement of the thermal performance of perforated clay brick walls through the addition of industrial nano-crystalline aluminium sludge". ***Construction and Building Materials,*** 101: 227–238, (2015).

[21] Cavaco E, Grilo I, Gouveia JP, Júlio E, Neves L. "Mechanical performance of eco-efficient hollow clay bricks incorporating industrial nano-crystalline aluminium sludge". ***European Journal of Envıronmental and Cıvıl Engıneerıng,*** 24:12, 1921-1938, (2018).

[22] Cay VV, Sütcü M, Gencel O, Korkut T. "Neutron radiation tests about FeCr slag and natural zeolite loaded brick samples". ***Science and Technology of Nuclear Installations***, 5, (2014).

[23] Zouaoui H, Bouaziz J. "Performance enhancement of the ceramic products by adding the sand, chamotte and waste brick to a porous clay from Bir Mcherga (Tunisia)". ***Applied Clay Science,*** 143: 430-6, (2017).

[24] EN 772-13. Methods of test for masonry units- part 13: determination of net and gross dry density of masonry units (except for natural stone) , (2002).

[25] EN 771-1. Specification for masonry units – Part 1: Clay masonry units (2015).

[26] EN 772-1. Methods of test for masonry units- Part 1: Determination of compressive strength (2015).

[27] Gökçe M. and Toklu K., "Ultra-Low Density Foam Concrete Production Using Electrolyzed Water". ***Journal of Testing and Evaluation 50. Published ahead of prin***t, 01 September (2021).

[28] Zhao Y., Ren B., O'brıen A., O'toole S., "Using alum sludge for clay brick: an Irish investigation". ***International Journal of Environmental Studies***, Vol.73, 5: 719–730, (2016).

[29] The eurocode 6 online. Available online at: http://www.eurocode6.org/ (accessed September (2019).

[30] EN 772-18. Methods of test for masonry units - Part 18: Determination of freeze-thaw resistance of calcium silicate masonry units, (2012).

[31] TS 825. Thermal insulation requirements for buildings, (2013).

[32] Simsek O, Building Material-I (materials science) 6th edition. **Seçkin publishing house**, ISBN: 9789750269028 Ankara(2021).