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Investigation of the Effect of Fly Ash and Boron Waste Additive on Brick Structure Material

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Keywords
Boron waste,
Fly ash,
Brick,
Clay,
Baking temperature

Abstract: The aim of this study was to produce bricks using boron waste of Eskişehir Kırka region and fly ash waste of Seyitömer thermal power plant. At the end of the study, it was aimed to produce bricks that are more durable than normal bricks, resistant to freeze-thaw and having thermal insulation properties in terms of physical and mechanical. 10% boron waste was kept constant and 10%, 20% and 30% fly ash were used in the bricks produced within the scope of the study. The study was carried out in three phases. In the first phase, bricks were produced using 100% clay soil and named as reference samples. In the second phase, doped brick production was carried out. The samples produced were baked at 800, 900 and 1000 ^oC. In the third and final phase, physical and mechanical experiments were applied to the brick samples produced. As a result, it was determined that fly ash and boron waste were not harmful to brick production and the optimum temperature was 900 ^oC.

Uçucu Kül ve Bor Atığı Katkısının Tuğla Yapı Malzemesi Üzerine Etkisinin Araştırılması

Anahtar Kelimeler
Bor atığı,
Uçucu kül,
Tuğla,
Kil,
Pişirme sıcaklığı

Öz: Bu çalışmada, Eskişehir Kırka bölgesi bor atığı ve Seyitömer termik santrali atığı uçucu kül kullanılarak tuğla üretimi hedeflenmiştir. Çalışma sonunda fiziksel ve mekanik açıdan normal tuğlaya göre daha dayanımlı, donma çözülmeye dayanıklı ve ısı yalıtım özelliğine sahip tuğla üretimi amaçlanmıştır. Çalışma kapsamında üretilen tuğlalarda %10 oranında bor atığı sabit tutulmuş, %10, %20 ve %30 oranlarında uçucu kül kullanılmıştır. Çalışma üç aşamada gerçekleştirilmiştir. Birinci aşamada, %100 oranında killi toprak kullanılarak tuğla üretilmiş ve referans numune olarak adlandırılmıştır. İkinci aşamada katkılı tuğla üretimi gerçekleştirilmiştir. Üretilen numuneler 800, 900 ve 1000 ^oC'de pişirilmiştir. Üçüncü ve son aşamada ise üretilen tuğla numunelerine fiziksel ve mekanik deneyler uygulanmıştır. Sonuç olarak; uçucu kül ve bor atığının tuğla üretiminde herhangi bir sakınca olmadığı ve optimum sıcaklık 900 ^oC olduğu tespit edilmiştir.

1. INTRODUCTION

Brick are one of the oldest industries continuing since 8000 BC [1,2]. Brick is a block obtained by firing clay at certain temperatures [3]. It is exposed to 500-900 oC during the manufacture process, which could make the transformation of silicate crystal structureinto amorphous compounds [4]. Because of the availability of raw materials, environmental compatibility and their advantageous acoustic, thermal and mechanical properties, they are used as construction material worldwide [5]. It is a building material with a wide range due to its use in building walls [6].

One of the major disadvantages of traditional brick production is the rapid consumption of fertile soils in brick manufacturing [7-10]. For this reason, some countries such as China limit the use of clay in brick production to solve this problem [11].

Some researchers have studied brick production using different waste materials. Waste such as glass and boron waste can be used as an additive in brick production. Bricks with high compressive strength and low water absorption rate were produced by using glass waste [12]. Agricultural wastes such as sugarcane, scrub ash and rice husk ash can also be used in clay bricks [13,14]. In addition to agricultural waste, Industrial wastes such as fly ash, blast furnace slag, silica fume and boron waste are used as additives and substitutes in brick production [15].

Fly ash, which is an industrial waste used in the scope of the study and formed during the burning of coal, causes environmental pollution. Therefore, recycling of fly ash as a raw material for the construction industry has been a very beneficial solution in terms of economy and environment [16]. The properties of fly ash vary depending on the type of burnt coal, the type of combustion equipment used and the fly ash collection mechanism used [17]. Worldwide, approximately 600 million tons of fly ash is released annually [18]. It has been observed that substituting certain amounts of fly ash with clay improves the brick properties [19-27,1].

A large literature study has been conducted on the use of fly ash as a substitute in brick production [30, 25]. Bricks which is substitution fly ash have 10% lower unit weight compared to standard bricks [8]. Fly ash has the ability to increase compressive strength and reduce water absorption [6]. Leiva et al. [31] stated that the bricks showed a decrease in compressive strength with increased fly ash content below 1000 °C at baking temperature. Çiçek and Çinçin [30] revealed that the thermal properties of fly ash bricks were better than standard bricks. The edges of fly ash substituted bricks are smoother than standard bricks [8]. Fly ash can be used in brick production that is 10% lighter compared to clay bricks [31]. Fly ash also increases strength and decreases water absorption [32]. Many countries prefer fly ash instead of cement in concrete [33]. Also, standard brick production cost is 2% higher than fly ash substituted brick production cost [34]. Therefore, the use of fly ash in clay brick production is important in terms of cost effectiveness, strength and durability of bricks. In all of the studies, it has been observed that fly ash added bricks have higher water adsorption and lower wear resistance than standard bricks. It has also been reported that reinforced bricks have lower fire resistance and high porosity [35].

Another industrial waste used in the study is boron waste. Used boron waste was obtained from Kırka region of Eskişehir. It is understood that boron and boron wastes have a positive effect on the brick when substituted into the brick structure [36-40]. Boron wastes allow the use of cement, concrete, brick, tile etc. in the construction industry etc. [41, 42]. This enables both the assessment of boron wastes and the production of cheaper and quality building materials [42].

It was to produce bricks using boron waste of Eskişehir Kırka region and fly ash waste of Seyitömer thermal power plant. At the end of the study, it was aimed to produce bricks that are more durable than normal bricks, resistant to freeze-thaw and having thermal insulation properties in terms of physical and mechanical.

2. MATERIAL AND METHOD

2.1. Material

Fly Ash; The fly ash used in the study was obtained from Seyitömer thermal power plant. The chemical analysis of fly ash is presented in Table 1. The specific gravity of fly ash is 1.58 g/cm^3, the specific surface area is 0.115 m^2/g and the pH is 8.3. The fly ash used is also the type F fly ash, which has a lighter structure compared to other fly ashes.

Tablo 1. Chemical Analysis of Seyitömer fly ash [13]

Component	(%)
SiO_2	52,34
CaO	7,47
MgO	5,75
Fe_2O_3	9,30
Al_2O_3	18,91
Na_2O	0,88
K_2O	2,17
SO_3	2,25
Na_2O (equ)	2,31
Free CaO	0,20

Boron Waste; Boron waste used in the scope of the study and obtained from Eskişehir Kırka region, contain compounds such as SiO_2, iron oxide (Fe_2O_3) and magnesium oxide MgO, which has binding properties at the rate of 12.8% (Table 2).

Table 2. Chemical properties of boron waste [39]

Component	Boron waste (%)
B_2O_3	25
CaO	10,38
MgO	13,94
SiO_2	12,98
Na_2O	5,67
Al_2O_3	0,96
Fe_2O_3	0,20
K_2O	0,72
Loss of Ignition	29,15

Clay; Clay soil used as the main material in the study and whose clay mineralogy was given in Table 3 was obtained from Taşköprü district of Kastamonu province.

Table 3. Clay Mineralogy

Element	Weight (%)
O	21.83
Mg	1.87
Al	8.67
Si	38.49
Nb	5.21
K	2.06
Ca	14.95
Fe	6.93

Mixing Water; For the mixing water used in the production of samples, drinking water of the mains water of Boyabat district of Sinop province was used.

2.2. Method

Production of Brick Samples; The soils obtained from Taşköprü district of Kastamonu province was brought to the factory site. The clay soil was rested for a month at the factory site for the disposal of the salt and carbonated content contained in it. Soil samples were taken while taking care not to mix plant roots into the soil. The clay soil sample has been brought to the desired sizes after the resting process has been completed. Prior to brick production, all materials were dried at 105±5 ^{o}C in drying oven until they became oven dry. Then the mixtures were prepared according to the recipe given in Table 4.

Table 4. Mixture recipe

	Clay Soil (%)	Fly Ash (%)	Boron waste (%)
REF	100	0	0
10% FA	90	10	10
20% FA	80	20	10
30% FA	70	30	10

First, dry materials were mixed. Then water was added with the sprinkler method at the rate of 15%. In order for the mixture to be homogeneous and not to be lumped, the dough formed by spraying water on the sample in 3 stages was constantly mixed [45].

The obtained mixture was poured into special moulds of 4x4x16 cm with the help of a manual pressure press (Figure 1a). The samples removed from the moulds were dried for 24 hours in semi-open space and then for 24 hours in the drying oven at 100 ^{o}C in order to avoid cracking during baking (Figure 1b).


a


b


c

Figure 1. a) Pouring the samples into the moulds, b) Keeping the samples in a semi-open space, c) Bringing the samples to room temperature

After drying, the samples were baked at 3 different temperatures: 800, 900 and 1000 ^{o}C. After the baking process is completed, the samples are provided to reach room temperature (Figure 1c).

Experiments Applied to Samples; Dry unit volume weight, water absorption, porosity, freeze-thaw effect, determination of thermal conductivity in solid bodies were conducted for determination of physical properties of brick samples with fly ash and boron waste additive. In order to determine the mechanical properties of brick samples, compressive strength and flexural strength tests were applied.

3. RESEARCH RESULTS AND ASSESSMENT

3.1. Dry Unit Volume Weight

In Figure 2, dry unit volume weights of reference, 10% boron waste and fly ash doped samples were compared. When the figure is examined, it is seen that the dry unit volume weights of the samples vary between 1.71-1.88 g/cm3. It was observed that dry unit volume weights decreased as the amount of fly ash increased in brick samples. The reason for this is thought to be that the density of fly ash being less than clay. There is no limitation for the unit volume weight of the bricks at TS 705 [46]. However, in order to reduce the total weight of the building, the use of bricks with less unit volume weight will decrease the dead load of the building.

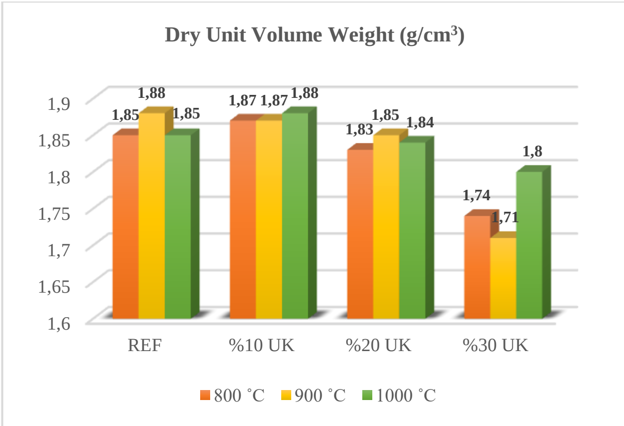

Figure 2. Dry unit volume weight values of samples

3.2. Water Absorption (Weight)

Water absorption is linked to the volume of open pores (cavities) that are associated with the surface of the samples. As the sintering process continues, the cavities on the brick surface turn into a round form and become smaller compared to the solid form. After the sintering process, the cavities become disconnected with the outer surface and closed. At temperatures above 900 °C, sintering occurs in a fast and glassy phase. The obtained glassy phase closes the pores and disconnects them from other pores. This situation can be explained as the increase in temperature causes the decrease in the amount of water absorption [47].

When the water absorption values of brick samples is examined, it is seen that the water absorption rate decreases with increasing temperature in general. With the increase in fly ash added rates, it is observed that there is also an increase in water absorption rates. It is observed that the amount of water absorption is high at low temperature (800 ^{o}C) and the amount of water absortion increases as the fly ash contribution rate increases. More water absorption at 800 ^{o}C is thought to be due to insufficient sintering (Figure 3). According to TS 705 standard, the water absorption rate of brick material should be 18% maximum. It is observed that the samples produced within the scope of the study are below this value.

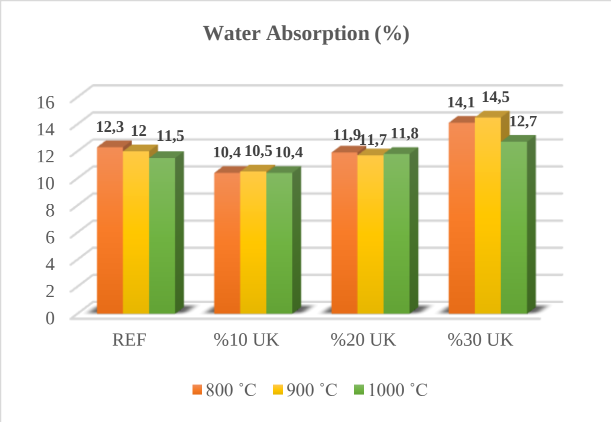

Figure 3. Water absorption values of samples

3.3. Porosity

When the porosity values of the brick samples are examined in Figure 4, it is seen that the reference sample is 35% at 800 ^{o}C, 28,6% at 900 ^{o}C and 27,2% at 1000 ^{o}C. It is observed that a decrease in porosity amounts occurred with an increase in the baking temperature of the samples. The reason for this is thought to be that sintering at low temperature does not occur adequately, and as the temperature increases, the glassy phase ratio within the brick increases, causing it to decrease the porosity value. Also it was found that the use of fly ash at the rate of 10% and boron waste at a rate of 10% reduced porosity values, fly ash at a rate of 20%, boron waste at the rate of 10%. Fly ash at a rate of 30%, boron waste at a rate of 10% have been determineted to increase porosity value. The reference sample baked at 800 ^{o}C with a ratio of 35% has the highest porosity, while the sample with 10% fly ash baked at 1000 ^{o}C with a ratio of 23,5% is observed to have the lowest porosity.

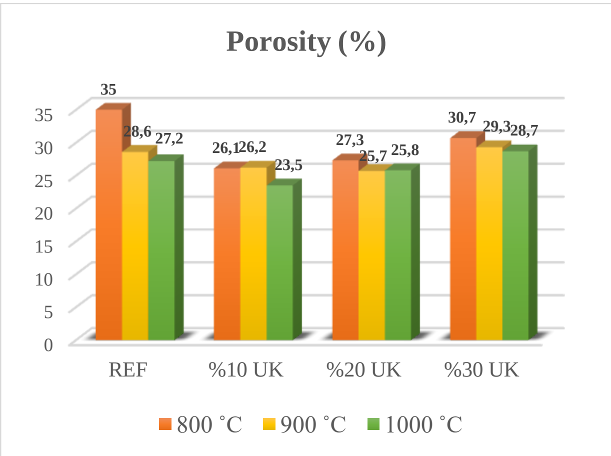

Figure 4. Porosity values of samples

3.4. Effect of Freeze-Thaw on Compressive Strength

Boron waste and fly ash doped brick samples were subjected to freeze-thaw test and compressive strength test was also applied on the samples. The effect of freeze-thaw on compressive strength of doped samples was determined according to the data obtained.

No dispersal event occurred in any sample after the experiment. When the samples given in Figure 5 are examined, it is seen that the highest value was obtained from the reference sample baked at 1000 ^{o}C. When all samples were examined, it was determined that the best results were obtained from samples baked at 1000 ^{o}C. In addition, the effect of freeze-thaw on pressure decreased as the amount of fly ash increased. The lowest results were obtained from samples baked at 800 ^{o}C.

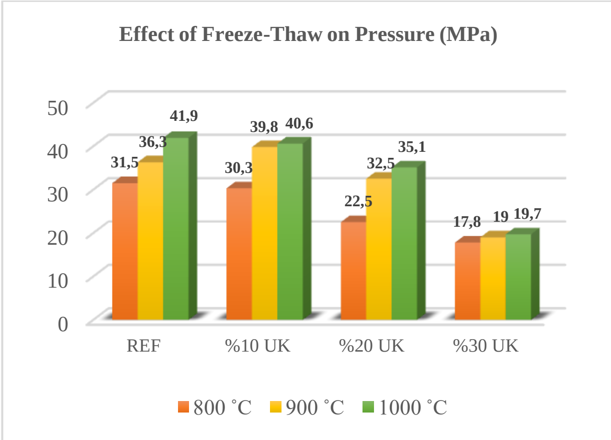

Figure 5. The values about the effect of freeze-thaw on pressure of samples

3.5. Determination of Thermal Conductivity in Solid Bodies

The thermal conductivity values of the brick samples are presented in Figure 6. On the graphic, the highest thermal conductivity was found to belong to the reference sample baked at 0.94 W/mK and 800 ^{o}C. When the samples were examined one by one, it was determined that the increase in temperature lowered the thermal conductivity. The increase in the amount of fly ash used in the samples resulted in a decrease in the thermal conductivity of the samples. The best result was obtained from 30% fly ash+10% boron waste substituted samples baked at 1000 ^{o}C. This is due to the fact that fly ash and boron waste are more hollow, light and low density than clay.

It has been reported that the thermal conductivity of brick building materials varies between 0.50-0.96 W/mK in TS 825 standard. It was observed that the data obtained as a result of the experiment conducted within the scope of the study was even lower among these values.

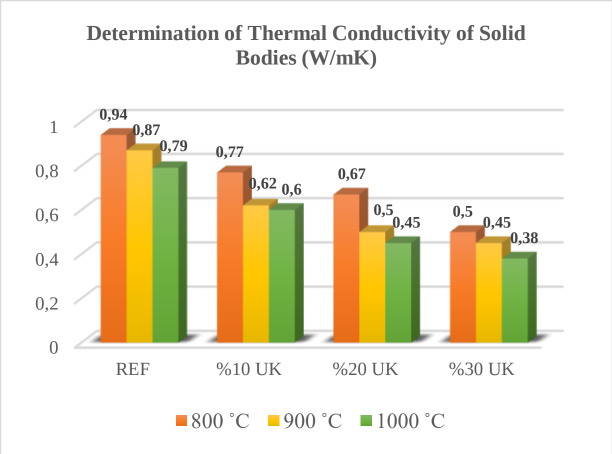

Figure 6. Thermal conductivity values of solid bodies

3.6. Compressive Strength

The compressive strength, which is the most important feature of the brick, is an important parameter used in order to meet the engineering quality of the building materials. Therefore, it is important to determine the compressive strength of the brick [48].

The compressive strength values of the produced brick material are presented in Figure 7. On the graphic, it is seen that the best results belong to the reference sample. The highest value was obtained from brick samples baked at 1000 ^{o}C in the reference sample. When the doped samples are examined, the best result is obtained with 10% fly ash and 10% boron waste. With the increase in the amount of fly ash, a decrease in compressive strength occurs. When the baking temperature is considered, the compressive strength of the samples is increased by increasing of the temperature. The lowest compressive strength value was obtained at 800 oC with 19.7 MPa and with the addition of 10% boron waste 30% fly ash.

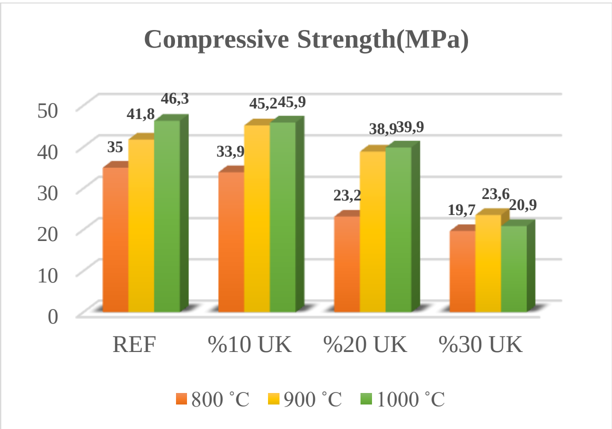

Figure 7. Compressive strength values of samples

3.7. Flexural Strength

When the flexural strength values of the brick sample given in Figure 8 were examined, it was observed that there is an inverse ratio between the amount of fly ash and the flexural strength values. In other words, the increase in the amount of fly ash has resulted in a decrease in flexural strength. The highest value was obtained from reference sample baked at 6.67 MPa and 1000 ^{o}C, while the lowest value was obtained from sample doped with 30% fly ash, 10% boron waste baked at 800 ^{o}C with 2.83 MPa.

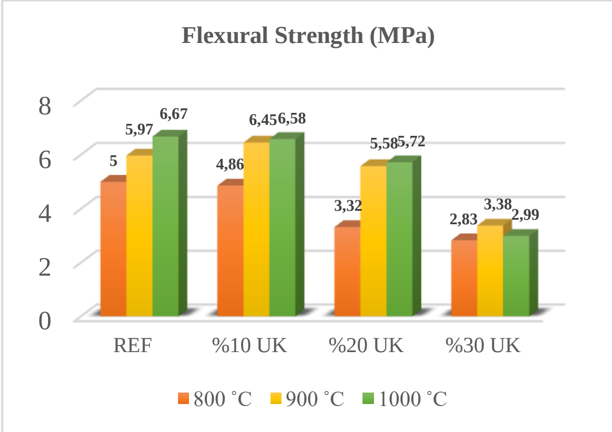

Figure 8. Flexural strength values of samples

4. CONCLUSION AND RECOMMENDATIONS

In the study, boron waste, which is industrial waste, was kept constant at a rate of 10% and bricks were produced by adding fly ash into the clay soil at certain ratios. The prepared semi-finished product was baked at 800, 900 and 1000 ^{o}C. Physical and mechanical experiments were performed on the brick samples and the results were presented in items.

When the results obtained from all physical and mechanical tests are evaluated; It was determined that by firing the samples at high temperatures, porosity and water absorption values decreased, dry weight per unit of volume values increased, compressive strengths increased and thermal conductivity values decreased as a result of freeze-thaw. According to these results, considering the tests performed at 3 different temperatures and the cost, it was concluded that the optimum cooking temperature was 900 degrees.

When the effect of FA and boron wastes is evaluated; It was determined that as the amount of FA increased, the dry weight per unit of volume values decreased and the water absorption and porosity values increased. For these reasons, it has been determined that as the amount of FA increases, not only the compressive strength due to freeze-thaw, but also normal compressive strengths and flexural strengths decrease. However, the increase in the amount of FA created a tendency to decrease the thermal conductivity due to the increase of porosity and increased the thermal insulation property of the material. According to all these results, even if the physical properties deteriorate as the amount of FA increases and the mechanical properties decrease accordingly, the results obtained meet the minimum requirements that should be in the standard. Therefore, using 30% FA, 10% boron waste additive ratio, waste evaluation and reduction of disposal costs, reduction of environmental pollution, etc. it has been concluded that it will provide various advantages.

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