



Effect of Boron Wastes on the Engineering Properties of Perlite Based Brick

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Abstract: The industrial development brings about the formation of wastes. These wastes can be reused in other sectors as byproducts to mitigate the harmful effects they have on the environment. One of the areas where these wastes are evaluated is in brick manufacturing for the construction sector. This study focuses on the use of industrial boron waste to improve physical and mechanical properties of bricks locally produced adding perlite. In this study brick samples were produced by using boron wastes at ratios of 5%, 10%, 15% and 20% while keeping perlite materials constant at 5%. The samples were heated at 900°C. Physical and mechanical tests were performed on brick samples obtained after heating in the oven. Specific gravity, water-saturated unit volume, porosity and freezing-dissolution tests were performed to determine physical properties. In order to determine the mechanical properties, compressive strength and bending tensile strength tests were conducted to the brick samples. As a result of the mechanical tests, the best result was obtained from 20%BT+5%P doped brick samples. It is concluded that the usage of perlite and boron wastes as additives in the production of bricks has desirable effects on improving physical and mechanical properties of bricks.

Bor Atıklarının Perlit Esaslı Tuğlanın Mühendislik Özelliklerine Etkisi

Anahtar Kelimeler

Bor atığı,
Tuğla
üretimi,
Perlit,
Fiziksel
özellikler,
Mekanik
özellikler

Öz: Endüstrinin gelişmesi atıkların oluşumunu beraberinde getirmektedir. Bu atıkların uygun sektörlerde kullanılması atıkların çevreye vereceği zararı minimize etmektedir. Bu atıkların değerlendirildiği alanlardan biri de inşaat sektörünün tuğla koludur. Bu çalışmada yerel malzemelerimizden olan perlit ve kıymetli endüstri atığı olan bor atığının tuğla yapı malzemesi özelliklerinin iyileştirilmesi üzerinde durulmuştur. Çalışmada tuğla bünyesine %5 perlit malzemesi sabit tutularak, %5, %10, %15 ve %20 oranlarında bor atığı ikame ederek tuğla numuneleri üretilmiştir. Üretilen numuneler 900 OC'de pişirilmiştir. Pişirilme sonucunda elde edilen tuğla numunelerine fiziksel ve mekanik deneyler uygulanmıştır. Fiziksel farklılıklarının tespiti için özgül ağırlık, suya doygun birim hacim ağırlık, porozite ve donma-çözünme deneyleri yapılmıştır. Mekanik özelliklerinin tespiti için ise tuğla numunelerine basınç dayanımı ve eğilmede çekme dayanımı deneyleri uygulanmıştır. Sonuç olarak; perlit ve bor atığı katkısının uygun oranlarda tuğla üretiminde kullanılabileceği, kullanılması durumunda tuğla özelliklerine herhangi bir sakıncası olmadığı ve olumlu yönde etki sağladığı görülmüştür.

1. INTRODUCTION

Brick is a construction material obtained by heating in special kilns a mixture of clay or clay soils with water, sometimes sand is also added [1]. The fact that the proper soil for brick production is abundant and the production is cheap and easy causes bricks to be used intensively in the construction industry [2]. A through rapid industrial and technology development, new products are added to the construction sector. The process of improving the properties of brick materials by partially replacing local raw materials with industrial wastes of these additives is also gaining momentum. When studies in the literature are considered on the improvement of brick materials It has been determined that boron clay wastes can be used in brick construction as replacement of raw materials [3].

Recent studies have reported on the manufacturing of bricks by using different industrial wastes such as boron wastes, thermal power plant ash, colemanite and coal dust [4, 5]. Yamık et al. examined the usability of industrial byproducts such as fly ash, colemanite waste and brick clay obtained from the Seyitömer thermal power plant as partial replacement of raw materials into brick making. As a result, they stated that bricks meeting Turkish Standards were successfully produced by using 15%, 15% and 70% of fly ash, colemanite and clay respectively [6]. Uslu and Arol found that boron waste causes environmental pollution. They investigated the use of borax wastes in brick production to reduce waste problems. They produced bricks by adding up to 30% boron waste by weight. They made physical and mechanical tests on the samples they produced. As a result, they determined that boron is suitable for brick production [7].

It was found by Kavas that mechanical properties of bricks were greatly improved by substituting 15% of clay by boron waste, furthermore boron waste can be used as a fluidizing material [8]. It was reported by Abali that industrial waste bricks have positive effects on shortening of drying time, water absorption and weight loss properties [9]. Christogerou et al. in their studies, substituted 0.5% and 15% of the clay material used in the production of ceramics [10]. In his study Rashad investigated the effect of expanded perlite, which is generally used as building material, on the fresh and hardened properties of conventional cementitious materials and other binders [11]. Topçu et al. used perlite to provide thermal insulation in buildings. In the traditional brick manufacturing, they have produced high temperature resistant bricks by adding perlite to clay. Clay and perlite were used in the study. It worked to form a material resistant to high thermal conductivity, and as a result, the best mixture was determined to be a mixture containing 30% perlite [12]. Velasco et al. has used various environmentally friendly wastes in brick production. Reuse of waste in brick production is a different way of managing waste. In addition to increasing brick properties, it can have several advantages for brick manufacturers [13]. Çiçek et al. to evaluate boron wastes, wall and floor tile production.

The place has been found to meet the requirements of TS EN ISO 10545 standard [14].

In this study, it is aimed to investigate the usability of our local materials such as perlite (main raw material) and clay-boron waste (natural binder) into the production sustainable bricks. By using perlite and boron wastes it is intended to produce bricks having low weight and high strength. There is a large amount of perlite aggregate in our country. In addition, boron waste is generated during the processing of boron.

2. MATERIAL AND METHOD

2.1. Materials

2.1.1. Boron waste

Boron, indicated with the symbol B in the periodic table. Ca, Mg and Na elements exist as hydrate compounds. These are boron minerals of economic value. Tincal ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$), which have commercial value among boron minerals, were used in our study [15, 16]. Boron is a valuable underground richness that is widely used in industry (glass-ceramic industry, cleaning-whitening industry, health, cement, metallurgy, energy, etc.). In the study, the boron waste used as additive material was obtained from Eti Mine Enterprises, Directorate General of Kırka Boron (Kırka/Eskisehir, Turkey). The physical and chemical properties of boron waste are given in Table 1 and The component rates of boron waste are given in Table 3.

Table 1. Chemical analysis of boron waste

%	Chemical Properties										
	B ₂ O ₃	CaO	SiO ₂	MgO	SrO	Al ₂ O ₃	Fe ₂ O ₃	Na ₂ O	K ₂ O	SO ₃	A.Za.
Boron Waste	22.9	11.8	9.06	12.63	0.59	0.47	0.10	4.48	0.20	0.11	40.59

2.1.2. Clay soil

Clay mineral is a soft and very fine-grained raw material which can be found easily and abundantly in nature. Clay is an aluminum silica compound with high water holding power. In experimental studies, the content of 38.49% Si, 21.83% O, 14.95% Ca, 8.67% Mg, 6.93% Fe, 5.21% Nb, with 2.06% K and 1.87% Mg, Taşköprü from the region (Kastamonu, Turkey) subtracted, red clay was used (Table 2).

Table 2. Chemical analysis of clay soil

%	Chemical Properties							
	O	Mg	Al	Si	Nb	K	Ca	Fe
Clay Soil	21.83	1.87	8.67	38.49	5.21	2.06	14.95	6.93

2.1.3. Perlite

The perlite material was obtained from Persan Inc. in Erzincan. The properties of perlite aggregate are given in Table 3.

Table 3 Perlite constituents of perlite aggregate

%	Chemical Properties								
	SiO ₂	K ₂ O	CaO	Fe ₂ O ₃	MnO	Al ₂ O ₃	Na ₂ O	MgO	TiO ₂
Perlite	71-75	4-5	0.40-0.82	0.3-0.5	0.071	12.5-16	3.2	0.02-0.03	0.01

2.2. Method

A total of 192 samples were produced for the determination of physical and mechanical properties. To determine the physical properties, specific gravity, water saturated unit volume weight, porosity, capillary water absorption, freeze-thaw effect test, compressive strength and flexural tensile strength tests were applied on the prepared samples.

Specific gravity test and water saturated unit volume weight test was performed according to [17]. Similarly, porosity test, capillary water absorption and freeze-thaw test were performed according to TS EN 772-4, TS EN 772-11 and TS CEN / TS 12390-9 respectively [18–20]. In order to specify the mechanical properties of brick samples produced with boron waste and perlite added The compressive strength [21], tensile strength tests for bending was carried out according to TS EN 772-6 [22].

2.2.1. Preparation of test samples

The production of doped boron waste samples was made in the Emek Brick Factory R & D laboratory located in Boyabat district of Sinop province. The sample taken from the clay soil masses by the method of quartz was grinded in the laboratory type roller hammer and then 1 mm. sieve material was obtained. Boron waste and expanded perlite to be used as additive in the test were also applied to the same processes. The recipe prepared for brick stuff is given in Table 4. When preparing the samples, 20% of the total weight of the material was added to each mixture. The samples were produced in 4x4x16 cm sizes using the moulding procedure.

The samples were first become oven dry in the oven and then weighed on the sensitive scale and taken in the prescribed proportions. The collected dry materials were mixed for 15 minutes to obtain a homogeneous dry mixture. Water was added to the dry mixture and mixed with a mixer and the resulting paste was rested. The prepared dough was allowed to stand for 24 hours in such a way that it did not lose its moisture and was stirred (5 minutes) in the mixer until no air bubbles were left in it. After the kneading process was finished, the mixture prepared in plastic consistency was poured into steel molds.

Table 4. The prescription of mixture ratio

	Clay Soil (%)	Boron Waste (%)	Perlite Additive (%)	Water (%)
Ref. Sample	100	-	-	20
%5BW+%5P	90	5	5	20
%10BW+%5P	85	10	5	20
%15BW+%5P	80	15	5	20
%20BW+%5P	75	20	5	20

BW: Bor Waste; P: Perlite Additive

The test samples were removed from the molds after standing for 24 hours under normal weather conditions. Samples of semi-finished bricks was left to dry in a semi-open area for 7 days. After 7 days, it was baked in an electric ash oven with timed temperature at 900°C,

which was suitable for brick material [7]. After the cooking process was finished, the samples were allowed to cool and removed from the oven. Extracted bricks samples were brought to room temperature (+2°C) as shown in Figure 1. Laboratory type electric furnace with a volume of 500 lt and a cooking capacity of 1200 oC was used in the firing process of the brick samples. As a firing regime, 2.5 oC / minute was applied and the oven was turned off after the samples were kept for one hour at the final temperatures. Six samples were produced for each experiment. The required tests were performed to determine the mechanical and physical properties of the samples.



Figure 1. View of brick samples

2.2.2. Samples tests

Physical (specific gravity, water-saturated unit volume weight, porosity, effect of freezing-dissolution on compressive strength) and mechanical (compressive strength, tensile strength in bending) experiments were applied to brick samples.

3. RESULTS AND DISCUSSION

Given in the graphs, REF; refers to reference sample, 5%BT; 5% boron waste added samples, 10%BT; 10% boron waste added samples, 15%BT; 15% boron waste added samples, 20%BT; 20% boron waste added samples, 5%P; 5% of perlite added samples.

3.1. Specific Gravity

When compared between doped samples, it is seen that the highest specific gravity is obtained from the 5%BT+5%P doped brick sample and the lowest specific gravity is 20%BT+5%P brick Figure 2. As a result, with the increase of the amount of boron waste, it was determined that the specific gravity of the brick samples decreased.

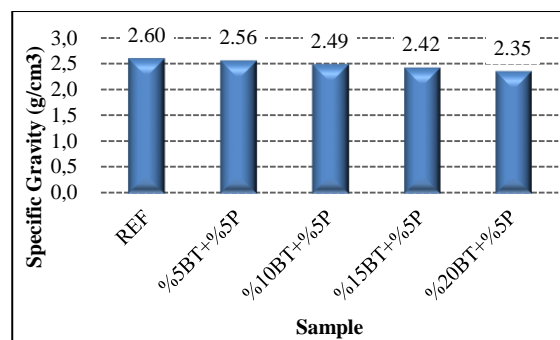


Figure 2. Comparison of specific gravity of samples

3.2. Water-Saturated Unit Volume Weight

The doped sample brick of 20%BT+5%P is the highest sample with a weight value of 1.98 gr/cm³ water-saturated unit volume Figure 3. This brick sample is followed by 1.92 gr/cm³ with 15%BT+5%P doped sample brick. Sample with the water-saturated unit weight is %5BT+%5P doped brick sample. Due to the fact that water-saturated unit volume of the %5BT+%5P doped brick sample is low, it is seen that the samples of the brick which will be exposed to atmospheric conditions and the building envelope will be more durable against rain and snow waters compared to other samples.

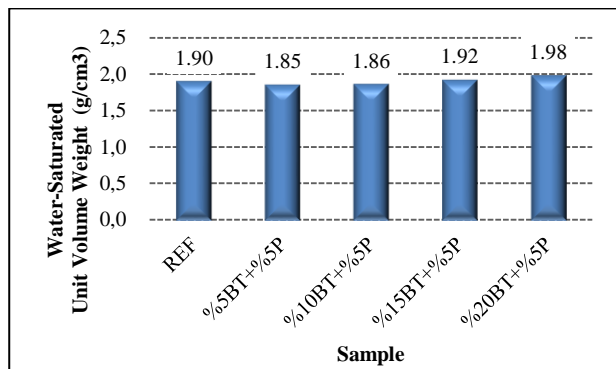


Figure 3. Comparison of water-saturated unit volume weights of the samples

3.3. Porosity

It is seen in the graph that the void ratio of the reference sample is higher than boron waste and doped samples Figure 4. The highest porosity value of boron waste and perlite doped brick samples with a ratio of 26.8% belongs to the sample of 5%BT+5%P brickdoped sample. The lowest porosity value is 20%BT+5%P doped brick sample with 24.8%. Although perlite admixture creates cavities within the brick sample, it passes through the glass to the vitreous phase during cooking and fills the cavities. For this reason, the decrease in porosity value occurs with the increase in the amount of boron waste in the brick sample.

3.4. The Effect of Freezing-Dissolution on Compressive Strength

When the graph is examined, the reference sample was the most resistant brick sample with 25.27% compared to other samples Figure 5. The reference sample was followed by 24.94% with 5%BT+5%P added brick sample, 24.32% with 10%BT+5%P doped brick sample, 20.46% with 15%BT+5%P doped brick sample and 11.71% with 20%BT+5%P doped brick sample. Even though 20%BT+5%P doped brick sample with 11.71% value is seen the lowest, this low value indicates that the strength loss of 20%BT+5%P doped brick sample is low. That is, the low compressive strength value of the 20%BT+5%P doped brick sample after freezing dissolution means that this sample is less affected by the freeze dissolution test than other samples.

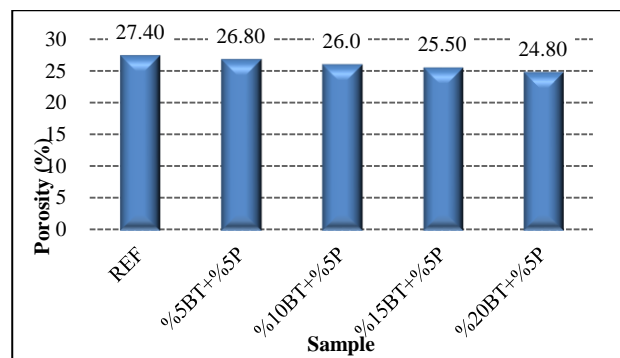


Figure 4. Comparison of porosity values of samples

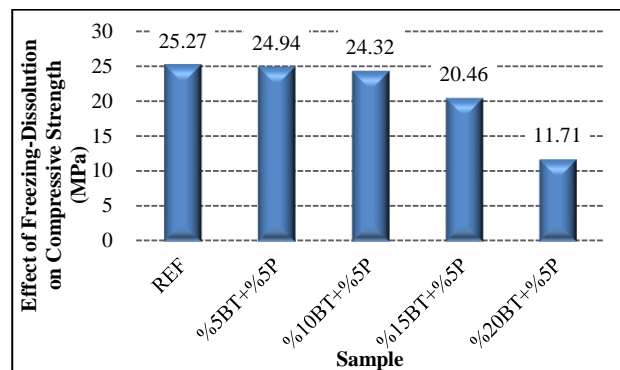


Figure 5. Comparison of the effects of freezing-dissolution on compressive strength of samples.

In the literature; Demirboğa found that silica fume and fly ash improve the freezing-dissolution properties in lightweight concretes produced by various mixtures of expanded perlite and pumice aggregates. This study supports freezing-dissolution test results within the scope of made under the thesis study [23].

3.5. Compressive Strength

Uslu found the compressive strength of the reference sample as 20.7 MPa, and found the highest compressive strength as 22.5 MPa in the sample with 30% waste clay [7]. In his study, Elbeyli found values in the range of 16.64-28.0 MPa for the average compressive strength in the 10% boron doped sample[24]. In this study, reference sample has the lowest compressive strength. It was observed that the compressive strength of the brick samples increased as the boron waste was added to the samples. While the highest compressive strength is 20%BT+5%P doped brick sample with 30.42 MPa, this brick sample is followed by 15BT+5%P doped brick sample with 28.82 MPa, 10%BT+5%P doped brick sample with 25.48 MPa and 10%BT+5%P doped brick sample with 21.12 MPa. The compressive strength values of the samples are given in Figure 6. Although the addition of the perlite contribution to the brick sample has a compressive strength decreasing effect [25], addition of the 5%, 10%, 15% and 20% boron waste to the brick structure increases the compressive strength of the produced brick samples. The increase of the compressive strength generally means the external effects of the brick to be used in the building shell and the strength of the structure under moving and dead loads. This will extend the life of the building, reducing

maintenance costs and transferring the building to future generations.

When examined the studies in the literature; [7, 24] reported in their studies that the brick sample produced by adding 10% boron waste has a higher compressive strength than the reference sample. It was found that bricks produced with boron waste additive have high strength properties compared to standard bricks. The results of the compressive strength test conducted within the scope of the thesis study are consistent with the studies in the literature. Compressive strength and after the effect of freezing-dissolution compressive strength values comparative was given Table 5.

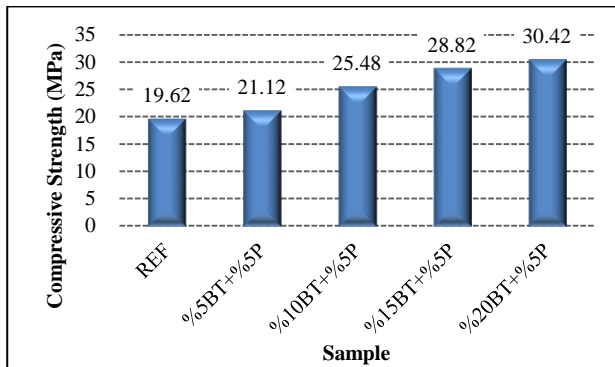


Figure 6. Comparison of compressive strength values of samples

Table 5. Comparison of compressive strength values before and after freeze-thaw testing

Boron waste and Perlite added sample values (MPa)							
Sample	N1	N2	N3	N4	N5	N6	
Comp. Strength	REF	19.6	19.61	19.6	19.63	19.64	19.64
	%5BT+%5P	21.09	21.09	21.12	21.15	21.12	21.15
	%10BT+%5P	25.48	25.52	25.48	25.44	25.44	25.52
	%15BT+%5P	28.72	28.85	28.92	28.82	28.78	28.83
	%20BT+%5P	30.4	30.4	30.42	30.42	30.46	30.42
TEF-DCS	REF	14.65	14.65	14.66	14.66	14.67	14.67
	%5BT+%5P	15.83	15.92	15.85	15.8	15.85	15.85
	%10BT+%5P	19.24	19.26	19.27	19.23	19.21	19.24
	%15BT+%5P	22.9	22.91	22.93	22.92	22.94	22.92
	%20BT+%5P	26.84	26.87	26.85	26.86	26.88	26.86

TEF-DCS: The Effect of Freezing-Dissolution Compressive Strength

3.5. Tensile Strength in Bending

When examined the tensile strength values of bending of brick samples given Figure 7, it is seen that the reference sample has the lowest bending tensile strength. The results of the brick samples produced by increasing the perlite rate by 5% and increasing the amount of boron waste indicate that the tensile strength of the bending increases with the rising in the amount of boron waste. While the highest bending tensile strength is obtained from 20%BT+5%P doped brick sample with 2.85 MPa, this brick sample is followed by 15%BT+5%P doped brick sample with 2.78 MPa, 10BT+5%P doped brick sample with 2.63 MPa 5BT+5%P doped brick sample with 2.52 MPa and reference sample with 2.40 MPa.

Increasing tensile strength in bending means that perlite and boron waste add plastic properties to the brick sample. Due to this feature, the use of the produced samples in the structure will help to stretch the brick walls at the time of the earthquake, thus reducing the damage rate.

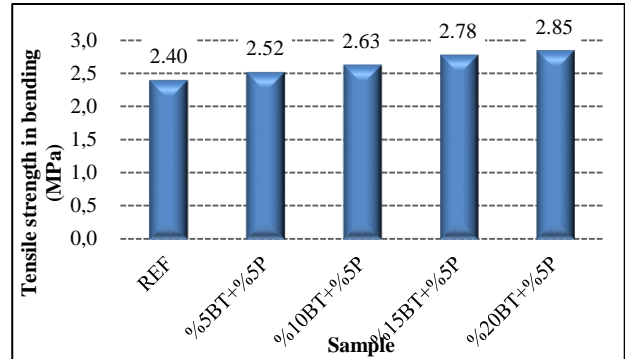


Figure 7. Comparison of bending tensile strength values of samples

4. CONCLUSIONS

The use of boron waste as an additive in brick production means eliminating a waste that causes environmental pollution and joining it into the industry. Thus, the use of boron wastes, which is an industrial waste, in the brick production sector is an important step in preventing the pollution of air, water and soil wastes left to the nature. The results of the experimental study carried out to determine the physical and mechanical characteristics of brick produced by adding boron waste and perlite is given below.

- In the specific gravity test, the highest specific gravity was found to belong to the reference sample. As a result of keeping 5% perlite ratio constant and the increasing addition of boron waste by 5%, 10%, 15%, 20% to the brick sample, it was occurred that the specific gravity values decreased.
- With the increase of boron waste contribution of in brick samples, the values of water-saturated unit volume weight have increased, the best result was obtained with 5% boron waste and 5% perlite admixture. The perlite admixture resulted in an increase in the water-saturated unit volume weight.
- It was determined that the samples with 20% boron waste and 5% doped perlite had the lowest porosity value. It has been found that the boron waste which is substituted into the brick samples can form enough liquid phase for sintering at 900 OC. This result has a positive effect on the cost of heating.
- Keeping constant the amount of perlite and increasing the amount of boron waste had positive effects on the compressive strength after freezing-dissolution. As a result of the increase in the amount of boron waste, an increase in the compressive strength after freezing-dissolution occurred.

- The addition of boron waste amount also increased the compressive strength. The best result was obtained from 20% boron waste and 5% doped perlite brick samples.
- By increasing the amount of boron waste, the tensile strength of bending has increased. While the best results were obtained from 20% boron waste and 5% perlite brick samples, it has detected that all brick samples were above the standards.

According to the results of the tests, it was concluded that perlite and boron waste would improve mechanical properties of bricks if they were replaced in appropriate proportions to the brick sample. The high strength and elastic properties of the bricks manufactured by using perlite and boron waste will increase the resistance of these bricks to the earthquakes in the buildings built through the earthquake zone. The number of studies to evaluate boron waste in larger areas and different sectors should be increased. Studies in this area should not only be included in the literature, but also be effectual in the industry. Because it has been determined from this study that natural resources such as perlite and industrial wastes such as boron waste can be used in brick production.

The results obtained with boron waste and perlite additive used in the production of bricks should be investigated in more detail and considered seriously in order to gain the industry. Furthermore, the scope of this study focused on the investigation of mechanical properties, there is a need for further studies on the effect of boron waste utilization on physical properties of bricks.

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