POLİTEKNİK DERGİSİ

JOURNAL of POLYTECHNIC

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

Use of industrial wastes in clay based brick

Endüstriyel atıkların kil tabanlı tuğlalarda kullanımı

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To cite to this article: Murathan, Ö.F., "Use of industrial wastes in clay based brick", ***Journal of Polytecnic***, 26(2): 871-875, (2023).

Bu makaleye şu şekilde atıfta bulunabilirsiniz: Murathan, Ö.F., "Use of industrial wastes in clay based brick", ***Politeknik Dergisi***, 26(2): 871-875, (2023).

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

DOI: 10.2339/politeknik.1080435

Use of Industrial Wastes in Clay Based Brick

Highlights

- *Industrial waste*
- *Clay based composite brick*

Graphical Abstract

It is well known that industrial wastes are considerably hazardous to the environment therefore recycling such wastes by combining them into building materials is an appropriate solution. This research reviews the use of waste casting sand (WCS) and waste boron (WB) in clay based bricks.

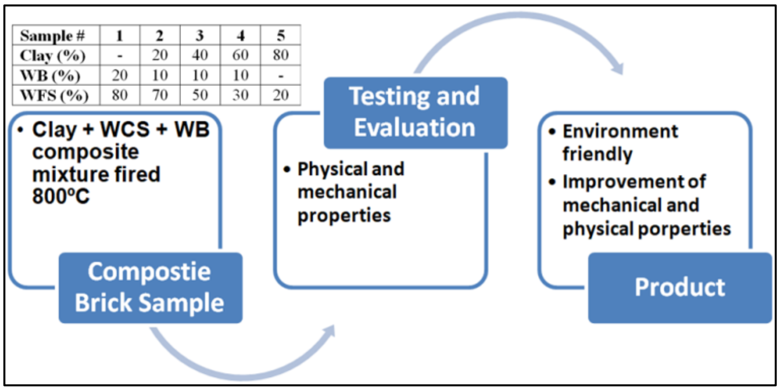

Figure Composite brick production sequence

Aim

Use of industrial wastes in clay based brick were investigated.

Design & Methodology

Composite bricks produced by adding appropriate mixtures of wastes and various chemical additives in cement free clay, firing temperature of the composite bricks was 800ºC.

Originality

Investigation of produced low cost bricks highlights in existing literature.

Findings

Sample 3 showed the highest bulk density (1900 kg/m^3) and compressive strength (65 MPa) in addition sample 1 showed the lowest drying shrinkage (6%) and water absorption (5.2%) values.

Conclusion

In addition to the mentioned improvement on mechanical and physical properties, other brick properties such as plasticity, drying time and crack formation were also enhanced. All the bricks produced with various proportions of WCS and WB wastes were found to satisfy the norms of drying shrinkage and bulk density properties of good quality bricks. This study indicates that the replacement of clay with these wastes has positive effects on the environment.

Declaration of Ethical Standards

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

Use of Industrial Wastes in Clay Based Brick

Araştırma Makalesi / Research Article

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(Geliş/Received : 28.02.2022 ; Kabul/Accepted : 21.03.2022 ; Erken Görünüm/Early View : 24.05.2022)

ABSTRACT

It is well known that industrial wastes are considerably hazardous to the environment therefore recycling wastes by merging them into the building materials is an appropriate solution. This research reviews usability of waste casting sand (WCS) and waste boron (WB) in clay based bricks. For this purpose, composite bricks produced by adding appropriate mixtures of wastes and various chemical additives in cement free clay. Firing temperature of the composite bricks was 800ºC. When compared with standard specifications, experimental results showed that with the addition of WCS into the bricks, strength and bulk density improved. Moreover, drying shrinkage and water absorption values decreased. The presence of WCS and WB in clay bricks enhanced the compression strength which is higher than standard bricks.

Keywords: Bulk density, composite brick, foundry wastes, compressive strength.

Endüstriyel Atıkların Kil Tabanlı Tuğlalarda Kullanımı

ÖZ

Endüstriyel atıkların çevreye belirgin bir şekilde zararlı olduğu çok iyi bilinmektedir, bu sebeple atıkların geri dönüşümü yapı malzemeleri ile birleştirilerek kullanılması uygun bir çözümdür. Bu araştırma atık döküm kumu ve atık borun, kil tabanlı tuğla üretiminde kullanılabilirliğini incelemiştir. Bu amaçla, uygun miktarda atık ve çeşitli kimyasal ilaveler çimento içermeyen kile eklenerek kompozit tuğlalar üretilmiştir. Tuğlaların pişirme sıcaklığı 800ºC'dir. Standart veriler deneysel çalışma sonuçları ile kıyaslandığında; atık fabrika kumu ilave edilen tuğlaların dayanım ve yığın yoğunluk değerleri yükselmiştir. Ek olarak, kompozit tuğlaların hacim küçülmesi ve su emme değerlerinde düşüş görülmüştür. Atık fabrika kumu ve atık borun kil tuğlalarında kullanılması basınç dayanımını iyileştirmiş ve bu değer standart tuğlalar ile kıyasla daha yüksek çıkmıştır.

Anahtar Kelimeler: Yığın yoğunluk, kompozit tuğla, fabrika atıkları, basınç dayanımı.

1. INTRODUCTION

Industrial wastes that can be found in various areas cause considerable levels of environmental problems. Therefore, evaluation of industrial wastes is important for sustainable development. The key objective of waste management is to maximize economic benefits as well as to protect the environment. Recycling such wastes by combining them into a building material is a practical solution to decrease the waste issue. Foundry industry is considered as one of the most important indicators of a country economic level and its industrial development. However, casting industry is an example for hazardous wastes which is dangerous for human health and also for the environment (Table 1).

There are unique methods in casting processes. For instance, non ferrous alloys with low melting point mostly require mass production with complex shapes. In order to meet these specifications, die casting method is used and dies are made of steel molds that can be used many times. Sand casting for example is the most used method due to the low costs when compared with other casting methods. In sand casting, molds are made of high quality silica sand with some chemical additions in order to produce desired molds having appropriate properties to enhance the casting surface. Similar to the metal molds, in sand casting silica molds can be re-used until its limit. When the limit is reached, it is removed from the casting process and named as waste casting sand [1].

Many researchers [2-9] experimentally manufactured a composite brick by using foundry wastes and effects on the mechanical properties were reported. Algin and Turgut [2] used powder wastes from cotton and limestone as a brick material. According to their findings, compressive and flexural strength, ultrasonic pulse velocity (UPV), unit weight and water absorption values of samples were fulfilled the relevant standards. Kadir and Mohajerani [3] reviewed that most of the manufactured bricks that contain different wastes have enhanced the properties of fired clay bricks. Mohammed et al. [4] reported that different types of clay including rice straw (RS), microcrystalline cellulose (MCC), with / without adding cement kiln dust (CKD) were also produced.

In another research, tensile properties of fiber-based composites and flexural strength of natural fiber-reinforced polymer sheets were investigated by externally gluing on masonry bricks. Two types of matrices have been used (polymer and mortar-based) and composite materials were produced [5]. Freeda Christy et. al. [6] combined bricks and fly ash as a binding

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material in order to form a brick. Short prisms have been tested under axial compressive load by using clay and fly ash bricks. Ibrahim et al. [7] produced an eco-efficient composite bricks that contains zeolite-poor rock and Hen's eggshell as a waste. According to their findings; in addition to minimized bulk density that led a light weight brick which lowers the transportation expenses, conservation of energy, water absorption, porosity, mechanical strength of the composite bricks enhanced. Başar and Aksoy [8] suggested that waste casting sand (WCS) can be effectively utilized in the production of ready mixed concrete (RMC) by a maximum of 20% replacement instead of fine aggregates with no adverse physical, mechanical, environmental and micro-structural impacts. Aggarwal and Siddique [9] studied the effect of waste casting sand and bottom ash in equal quantities as partial replacement of fine aggregates between 0–60%, on concrete properties (mechanical and durability characteristics). Pérez et al. [10] produced Galvanic sludge wastes by the physico-chemical treatment of waste-water generated by electroplating plants. Results indicated a successful inertization of the pollutants.

Table 1. Wastes from sand casting process and impact on the environment [1]

Casting Process	Environmental Impact and Waste
Core making and molding	Use of natural resources, gas and dust emissions, waste sand
Melting and casting	Use of natural resources, gas and dust emissions, metal wastes
Melting and transportation	Use of natural resources, vehicle emissions, packaging wastes

In this study, usability of waste casting sand and waste boron in composite bricks has been discussed and change on the physical and mechanical properties were investigated.

2. MATERIALS AND METHOD

Clay bricks obtained from Gümüşhane region, waste boron obtained from Eti Mine Kırka Boron Works and waste casting sand obtained from Erkunt Foundry Industry. In order to obtain uniform particle size, raw materials were crushed and grinded until obtaining an appropriate powder particle size of 150 µm. Raw materials were dried at 110ºC for 24h in order to remove moisture and obtain representative samples. Chemical analysis of clay and the wastes were given in Table 2.

Clay, WCS and WB were formerly dried then cooled under natural conditions. Subsequent cooling, the wastes were well mixed with clay in order to obtain homogeneous mixtures. Table 3 shows the mixture ratios of wastes and clay. Samples were produced under the optimum moisture content. Solid bricks with 50x50x50 (mm) in adjustable cubic-shaped wooden molds were compressed in a hydraulic press under 40 MPa pressure. In order to prevent crack formation and structure defects in final product, molding process was completed under constant pressure. Control brick having 100% clay was also prepared in order to compare with composite bricks. Drying conducted in an open atmosphere for 24 hours and then bricks were fired in an oven at 800ºC for 24 hours. Finally, samples were cooled up to the room temperature inside of an oven by natural convection.

Table 3. Mixing ratios of bricks (wt. %)

Sample #	1	2	3	4	5	6 (control)
Clay	-	20	40	60	80	100
WB	20	10	10	10	-	-
WCS	80	70	50	30	20	-

Three different composite brick samples were tested to obtain bulk density, drying shrinkage, water absorption, compressive strength and resistance to frost. Tests conducted according to EN 771-1 standard [11].

Ratio of dry mass and standard volume was used for the calculation of bulk density. By using a caliper (± 0.01 mm) before and after drying, length of the samples were obtained and used calculate the drying shrinkage. Water absorption value was calculated by using standard procedure. At 110ºC, cubic shaped samples were dried up to constant weight. At first, samples measured at dry state, held in water for one week then again dried and measured. Compressive strength tests conducted on dried samples with respect to standard procedure EN 771-1 in a 5 kN Shimadzu AG-I device. On the upper face of samples, load applied on center until fracture (20 MPa/s).

3. RESULTS AND DISCUSSION

Bulk density values of the specimens (composite brick samples and control sample) given in Figure 1. According to EN 771-1 [11], bricks with clay should have a bulk density of 1600-2000 kg/m3. Sample 3 showed the highest bulk density (1860 kg/m3), containing 40% of clay, 50% of WCS and 10% of WB mixture. Rest of the composite samples bulk density is between 1700 - 1825 kg/m3. This showed that, similar portions of clay and wastes enhanced the bulk density. Obviously, bulk density values were affected by the amount of WCS and clay. In addition to WCS, WB was also in the composite brick which was interacted with WCS at drying.

In composites, by addition of equal portions of clay and wastes, high density values were obtained. Increase in the

Table 2. Chemical analysis of composite brick components

Materials	B_2O_3	SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3	SO_3	K_2O	Na_2O	LOI
Clay (C)	-	53.0	3.5	1.0	22.2	7.8	-	2.3	1.5	5.2
Waste Casting Sand (WCS)	-	85.5	-	0.3	3.3	1.1	-	0.3	0.6	0.4
Waste Boron (WB)	33.1	19.0	11.0	21.0	0.3	0.3	-	-	3.4	17.0

amount of WCS and WB, density of the composites were decreased due to interaction between the two wastes at drying. In the other composites, high quality bricks were obtained according to EN 771-1 [11], also it was obtained environment-friendly and energy-saving composite materials without using any chemicals. This result is closely related the other specifications as demonstrated in between Figure 1 - Figure 5. According to researchers, larger pore size which lowers the density is directly affected by the amount of water in mixture [3, 9 and 12].

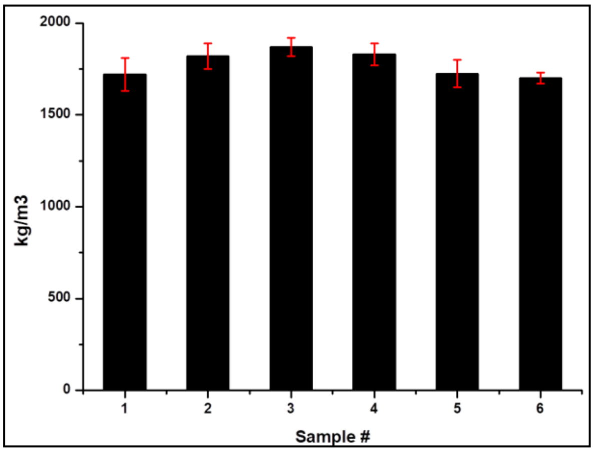

Figure 1. Bulk density of the samples

Drying shrinkage of the samples was improved with increasing the clay amount (Figure 2). This can be explained by evaporation of bound water in the clay. For the control specimen (100 % clay) the shrinkage value is 9%. The lowest shrinkage was determined as 6% in Sample 1 composite which is clay free. Due to higher clay and lower waste content [12-15], sample 1 showed higher drying shrinkage value when compared with rest of the composites and control sample. When considered the good combination of wastes, shrinkage values were acceptable. Moreover, no deformation was observed in all composites.

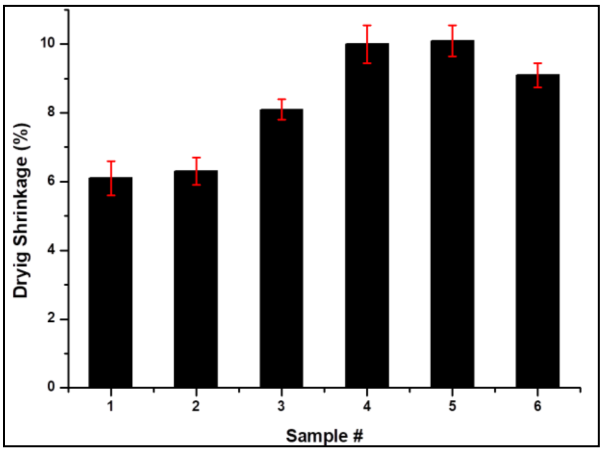

Figure 2. Drying shrinkage of the composite samples

The compressive strength graph is given in Figure 3. Waste free brick (100% clay) has a compressive strength of 24 MPa [11]. When compared with standard brick specifications and other findings (Table 4), Sample 3 showed 65 MPa having 40% of clay, 50% of WCS and 10% of WB (without curing) and in different researches similar results were obtained [15-19]. In addition to the compressive strength, Sample 3 was also showed best drying shrinkage result. This is because of increase in WCS. In addition, pore volume of Sample 3 is higher than rest of the composite bricks and WB which is known for bonding the water [13].

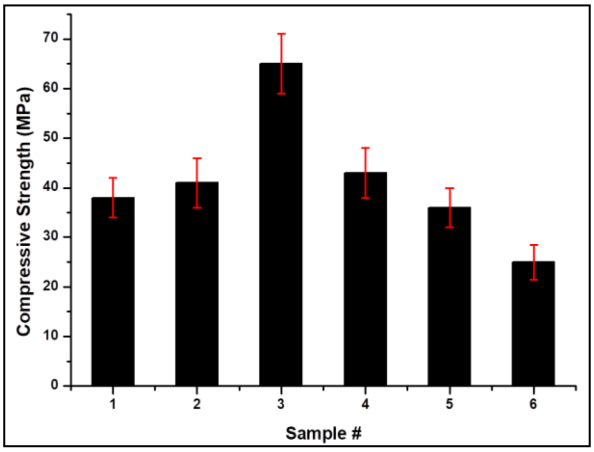

Figure 3. Compressive strength of the composite samples

Durability of a brick is directly depends on water absorption. For a standard brick, long durability and environment resistance is expected. Therefore the internal structure of the brick must be dense enough to avoid the intrusion of water. The brick water absorption in the control sample was higher than the others. In addition, this value was lowest (5.2 %) for the composite brick that contains only WCS and WB (Figure 4).

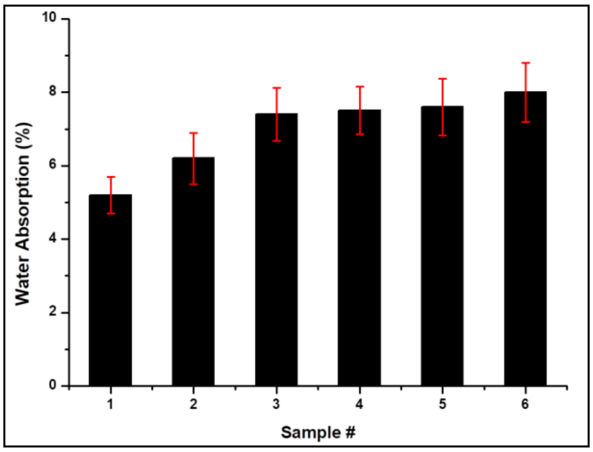

Figure 4. Water absorption of the composite samples

Table 4. Effect of the wastes on the compressive strength and water absorption values in clay based composites

Composite Additives	Compressive Strength (MPa)	Water Absorption (%)	Reference
Clay, fine wastes, red mud	60	8.38-9.59	13
Clay, fly ash, basaltic pumice	11-28.5	16.79-27.48	14
Clay, paper mill sludge, carbonation sludge	2.4-36.6	8.1-37.8	20
Clay, waste marble powder	7.5-35	13-26	21

Composites showed lower water absorption values when compared with the control sample and this result better than standard clay. Composite samples were held in water for one week and for both room temperature and -20ºC, no deformation was observed. In addition to frost resistance, composites showed good water absorption values which are good agreement in existing literature [3, 12-18].

Porosity is an important parameter that must be considered when choosing a brick. For a brick, generally water absorption values are directly proportional with porosity where the compressive strength values are indirectly proportional. Porosity results of the composites were given in Figure 5. Sample 1 showed lowest pore percentage when compared with rest of the samples. This result was expected due to the water absorption results. For this work, raw material amount in composites directly affect the physical and mechanical properties in which the difference between Sample 1 and Sample 6 obvious.

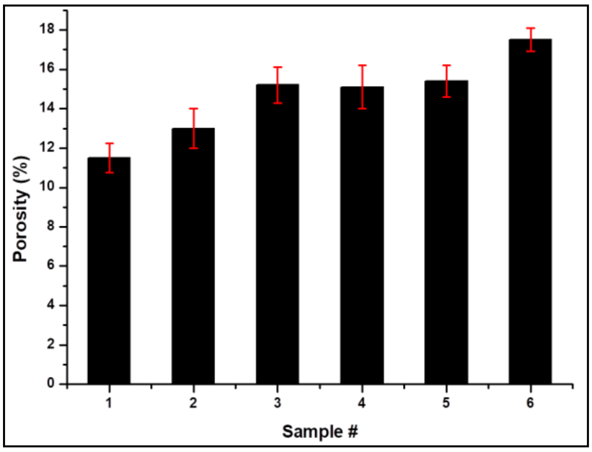

Figure 5. Porosity of the composite samples

4. CONCLUSION

- This study revealed that high amount of environmental wastes such as WCS and WB can be used as an additive material in clay for production of bricks.
- The strength of bricks is higher than the standard specifications (65 MPa). In addition, produced composite bricks showed low water absorption, low drying shrinkage and high resistance to frost.
- Other brick properties such as plasticity, drying time and crack formation were also enhanced. In addition, it was observed that the obvious improvement in compressive strength was achieved by adding 40% of WCS and 10% WB into a clay brick. The possibility of substituting these wastes offers technical and environmental advantages.
- All the bricks produced with various proportions of WCS and WB wastes were found to meet the norms of drying shrinkage and bulk density properties of good quality bricks.
- All the composite bricks that contain WCS and WB wastes satisfy the drying shrinkage and bulk density properties with respect to standard specifications of good quality bricks. This proves that not only physical properties but also by combining wastes into a various materials, it also has a positive effect for the environment by recycling wastes that lowers the issues associated with discarding. Moreover, composites can be obtained by environmental friendly products due to low firing temperature and no necessity for chemical additives.

DECLARATION OF ETHICAL STANDARDS

The author 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

Ömer Faruk MURATHAN: Produced specimens, conducted experiments, analysed results, wrote the manuscript.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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