Utilization of Borax Waste, Fly Ash and Silica Fume in Manufacturing of Building Brick

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ÖZET: Endüstriyel kaü atıklar günümüzün en önemli problemlerinden birisidir. Bu atıklann inşaat endüstrisinde katkı olarak kullanılması çevre koruma için bir alternetiftir.Türkiyenin çeşitli bölgelerinde 25.000 ton/yıl boraks atığı, 15 milyon ton/yıl uçucu kül ve 1000 ton/yıl silis dumanı üretim sonrasında meydana gelmektedir. Bu çalışmanın amacı uçucu kül, silis dumanı ve boraks atıklannm inşaat tuğlası üretiminde kullanılabilirliğinin araştırmaktır. Tuğla kompozisyonlan; %20 boraks atığı, %20 boraks aüğı+ % 20 uçucu kül ve %20 boraks atığı + % 10 silis dumanı olarak seçilmiştir. Seçilen kompozisyonlardan oluşan kanşımlar 10 bar basınçla preslenip 970,1000 ve 1030 °C ler de pişirilmiştir. Pişirme sıcaklığının ve atık katkı oranının tuğlanın soğukta basınç mukavemeti, porozite, su absorpsiyonu, hacim yoğunluğu, kızdırma kaybı gibi özellikleri üzerindeki etkisi belirlenmiş ve bu özelliklerin Türk Standartlanna (TS705) uygunluğu araştınlmıştır.Test sonuçlan incelendiğinde tuğla kalitesi üzerinde atık katkı oranının ve pişme sıcaklığının etkili faktörler olduğu görülmüştür.Düşük B_20_3 içeriğine sahip boraks atığı katkılı tuğlalannlOOO °C de pişirilmesiyle tuğla kalitesi üzerinde zararlı etki gözlenmemiştir.Boraks atığının standartlara uygun tuğla üretiminde kullanılabileceği belirlenmiştir.Ancak boraks atığı ve kil karışımına silis dumanı veya uçucu kül katkılanmn katılmasıyla elde edilen tuğlaların yüksek porozite ve su absorpsiyonu değerlerinin yanısıra düşük soğukta basınç mukavemeti değerine sahip olduğu bulunmuştur. Yapılan kalite testleri sonucunda 1000 °C de pişirilen tuğla örneklerinden en iyi değerler elde edilmiştir.

ABSTRACT: Industrial solid wastes have become one of the most serious problem today, and the use of these wastes in building industry as admixtures offers a potential alternative for protection of environment. In various regions of Turkey, 25.000 tons/year of borax waste, 15 million tones/year of fly ash and 1000 tons/year of silica fume were generated from the productions. This study is aimed borax waste, fly ash and silica fume in clay bodies used in brickmaking were investigated. Composition of the bricks was adjusted to contain 20% borax waste, 20% borax waste+20%fly ash, 20% borax waste+10%silica fume and these mixtures were molded in 10 bar squeezing pressure and fired at 970, 1000 and 1030°C. At the end of this process, the effects of firing temperatures and the percentage of the added wastes on the compressive strength, porosity, water absorption, bulk density and loss on ignition of building bricks were determined under the criteria of Turkish standards (TS705) Results of the tests indicated that the waste proportion and firing temperatures were affecting factors the brick quality. It was determined that the addition of borax waste which has low boron content at a firing temperature as 1000°C has no significant harmful effects on the brick quality. Although it was found that the borax waste could be used to produce bricks conforming to the standard quality, there were some problems in addition of the silica fume and fly ash together with borax waste to brick clay such as higher porosity, higher water absorption and low compressive strength. At the end of the quality tests, best values for brick samples obtained at 1000°C firing temperature.

1. INTRODUCTION

Utilization of various industrial wastes produced, such as fly ash, silica fume and borax wastes as useful building materials, is an important process because it is not only convert the wastes into useful materials but also prevents the environmental pollution. In the past, a range of different types of waste materials has been used as raw materials for brick production, for example fly ashes, steel dust, papermaking sludge, coal fly-ash, and slug (Hammer et.al., 2002). Building bricks are usually produced mixing of clay and sand or together with other materials, which are mixed and molded in various ways, after they are dried and fired.

Borax waste is formed during the production of borax from tincal ore in Bandırma Etibank Borax Plant. The amount of this waste is approximately 25.000 tons/year. The borax waste contains some insoluble and soluble boron minerals with clay. Boron compounds in this waste discharged to land dissolved by rain water and mix with soil where they have some complexes with heavy metals. These metals cause some environmental pollution and serious health problems (Boncukçuoğlu et.al., 2003). In order to decreasing the pollution problem at borax plants, several works have been carried out to use this waste in construction applications. There are only a few detailed works on the utilization of borax waste in building materials such as cement and concrete (Boncukçuoğlu et.al., 2002, Elbeyli et.al., 2003). These studies showed that borax waste can be used in red bricks up to 30 % addition and may be used as cement additive 5-10% by weight (Uslu et.al., 2003, Özdemir et.al., 2003).

Fly ash formed during the combustion of coal for energy production and that is one of the industrial by-products and it also causes environmental pollution. Properties of fly ash depended on primarily the type of coal burned, the type of combustion equipment used and the type of fly ash collection mechanism employed (Tütünlü et. al., 2003). Fly ash is recognized as an excellent source of pozzolanic material. Pozzolans are siliceous or siliceous/aluminous materials and when mixed with lime and water, form cementitious compounds. Physically, fly ash is very fine, powder material, predominantly silica, with particles almost spherical in shape and excellent source of pozzolanic material. The properties of fly ash allow making a good binding agent. Therefore, it is an accepted beneficial ingredient in the construction industry and widely used in blended cements (Özdemir et.al., 2003). The use of fly ash as additive in the production of bricks has been subject of investigation in recent years (Weng et.al., 2003). These studies showed that fly ash bricks have higher water adsorption, low resistance to abrasion, low fire resistance, and high porosity. In contrast to this, the utilization of fly ash in brick production is very important due to cost effectiveness and strength and durability of bricks (Kumar, 2002).

Silica fume, a by-product in the manufacture of ferrosilicon and also of silicon metal, is a very efficient pozzolanic material. Electric arc furnace is used in the manufacture of ferrosilicon or silicon metal release silica fume. The fume consists of very high content of fine spherical particles of silicon dioxide, is collected by filtering the gases escaping from the furnace. The fumes generally contain more than 90% SİO2, mostly amorphous. It consists of very fine vitreous particles with a specific surface area in order of 20.000 m^2/kg. Silica fume is generally more efficient in cement and concrete applications. The main problems in using this material are associated with its extreme fineness and high water requirement when mixed (Malhotra et.al., 1982).

In this study, the effects of firing temperatures and addition of the borax waste, fly ash and silica fume materials on the compressive strength, porosity, water absorption, bulk density and loss on ignition of bricks were investigated.

2. MATERIALS AND METHODS

2.1. Materials

The brick clay sample was obtained from Işıklar Holding in Istanbul, Turkey. Borax waste that is used in study was provided from Eti Holding Borax Plant in Bandırma and it was supplied from the outlet of the thickener unit. Fly ash was taken from the Seyitömer Thermal Power Plant and silica fume was taken from the Electrometallurgical Plants in Antalya, Turkey. The main constituents of these materials and clay sample are given in Table 1.

Table 1 indicated that both clay and the wastes have similar chemical composition but high B2O3 content of the borax waste can be observed in the table.

Table 1. The chemical composition of cement and borax waste by weight percent (%).

Constituent (%)	Brick Clay	Borax Waste	Fly Ash	Silica Fume
SiO_2	60.22	16.67	46.67	90.80
Al2O3	15.13	0.940	16.10	1.020
Fe_2O_3	11.83	0.350	8.410	1.930
MgO	1.040	11.80	4.790	0.940
CaO	1.150	13.53	12.37	2.550
Na_2O	1.200	6.870	2.580	-
B2O3	-	14.09	-	-
Heating lost	9.430	35.75	3.01	1.57

2.3 Preparation and testing of the brick samples

The borax waste was dried in oven at 105°C for 2 h, crushed, ground and sieved under in a 200um. Leaching process was applied to borax waste before being added to the mixtures for recovery of B_2O_3 from the waste. Experiments were carried out at 98°C with solid/liquid ratio of 1/5 and dissolving for 40 minutes by Na_2CO_3 solution (2.5 %). At the end of the reaction, solid and liquid parts of waste were extracted with vacuum filtration system. B_2O_3 component and water-soluble materials are passed to filtrate with this application. Thus, boron is recovered by decreasing of its content in waste. The amount of boron remaining in cake and filtrate forms were determined by titration method (Kumar, 2002). To produce the brick, borax waste treated with soda solution was added to brick clay in ratio of20%(wt/wt)(Fig.1).

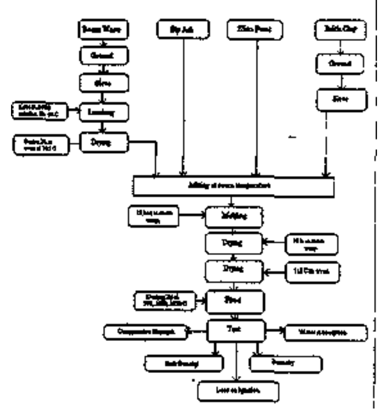

Figure 1. Flow diagram of experiments.

In the experiments; brick clay, borax waste, fly ash, silica fume and water (18%) were well mixed and the mixtures were molded by using a cylindrical steel mold (23 mmIDx30mm height) at ambient temperature in a universal test apparatus (model Mohr Feddehoft) under 10 bar squeezing pressure. The brick samples were obtained cylindrical in shape. After the molding, the brick samples were left to dry in the atmosphere for 1 day followed by oven drying at 110°C for 10 h and were fired in a metallurgical furnace at 970,1000 and 1030°C for 2 h. The heating rate of the furnace was 200°C/h. The fired bricks were slowly cooled in the furnace closed overnight and tested for their compressive strength using a test machine of 10 tons capacity. Finally, compressive strength, water absorption, porosity, bulk density, firing loss and shrinkage tests (drying and firing) of bricks were determined in according to the Turkish Standard (TS705) tests or modified versions of these tests for mentioned qualities of the bricks (Boncukcuoğlu et.al., 2002).

3. RESULTS AND DISCUSSION

The study was divided into three stages, consisting of mixing the raw materials, the experiment of brick production using these raw materials, testing the properties of fired bricks.

The content of B2O3 in borax waste decreased from 14.09% to 2.80% by using 2.5% Na_2CO_3 solution before the mixing of the raw materials in order to prevent the decrease in compressive strength of bricks. Results of leaching yield are obtained at 80% by soda solutions. It is known that boron compounds in the waste causes the brittleness effects of the building materials (TS705,1979).

In this study, the main aim was to compare the bricks made of brick clay and with those made with borax waste, fly ash, and silica fume addition. Four kinds of bricks containing clay, clay + borax waste, clay + borax waste + fly ash and clay + borax waste + silica fume, were prepared. The mixtures were moulded under 10 bar squeezing pressure by using cylindrical mold. These bricks were dried and fired at selected temperatures of 970, 1000 and 1030°C for 2 hours. After drying and firing, these bricks were subjected to compressive strength, porosity, water absorption, bulk density and loss on ignition tests were carried out and the average of the results were reported here. Then the bricks with comparable compressive strength, porosity, water absorption, bulk density and loss on ignition to that of reference bricks were subjected to other test. The quality of bricks is usually determined on the basis of these testsT

The results obtained are given in Fig.2-7. The compressive strength values of bricks produce from wastes are given in Fig.2. It can be seen from the Fig.2. Firing temperature affected the compressive strength of the bricks. Suitable temperature for the production of bricks observed at 1000°C because of obtaining the highest compressive strength values. Also, compressive strength of the reference brick was found 17.15 N/mm^2. At 1000°C firing temperature, addition of 20% borax waste caused an increase in the compressive strength of bricks. However, 20% fly ash and 10% silica fume additive to brick clay caused a decrease in the strength. At 970°C firing temperature, compressive strength of the bricks was substantially lower than those of the bricks fired at 1000°C. Addition of 20% borax waste improved the compressive strength. It can be seen from the figure, silica fume increased the compressive strength of bricks at 1030°C due to formation of silicate and amorphous phase in the body of bricks. These tests indicated that bricks made of fly ash and silica fume additions with borax waste have no significant effect on the compressive strength.

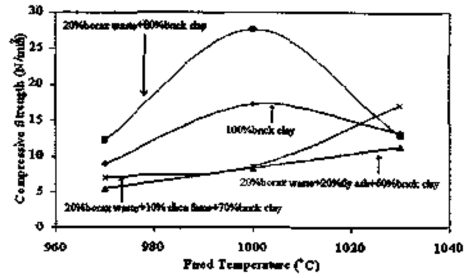

Figure 2. Compressive strength values of bricks.

The bricks fired at 970, 1000, 1030°C were subjected to water absorption tests. The results of these tests are given in Fig.3. Water absorption values of the bricks fired at 1030°C. This indicates that presence of B2O3 in the mixed facilitated glassy structure, which formed by combining silica and alkalis. Glassy mass formation might have filled them or blocked the pores and hence water absorption lowered. It was observed that the water absorption values of the bricks fired at 970°C were higher than other bricks fired at 1000 and 1030°C. At 1000°C firing temperature, water absorption values of the brick clay were lower than the other bricks. Water absorption values of bricks increased with silica fume and fly ash because of having high porosity properties.

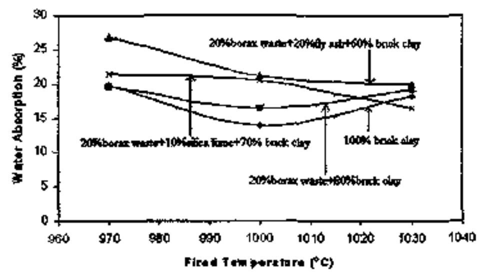

Figure 3.Water Absorption of bricks.

Porosity, take place from the volatile matter resulting from the gasification reactions of carbonate and sulfate minerals in wastes. It can be seen from the Fig.4. Although, addition of fly ash and silica fume increased the porosity of bricks at 970, 1000 and 1030°C, only borax waste as an additive showed similar trend with brick clay. Porosity values of the brick samples were obtained at 1Q00^{0}C firing temperature were lower than the other bricks obtained 970 and 1030°C.

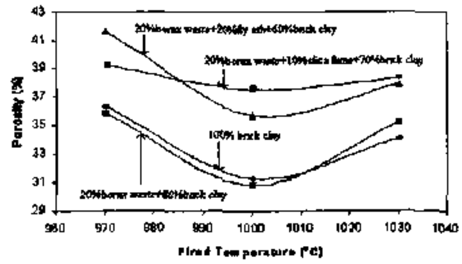

Figure 4. Porosity values of bricks.

Shrinkage by drying of the brick samples with borax waste of 20% fly ash and 10% silica fume are 2.65, 1.00 and 1.10%, respectively, while being 2.60% for brick clay. The drying tests at 110°C indicated that bricks fly ash and silica fume addition show positively effect on the shrinkage properties of brick because of having the very fine particles of them. Firing shrinkage values of the brick were observed the same trend at 1000°C (Fig.5). However, borax waste and silica fume have lower shrinkage at 1030^{D}C. Additions of sUica fume and fly ash were effected the shrinkage negatively due to the oxidized of carbon and conversion of sulfate and carbonates at high temperature.

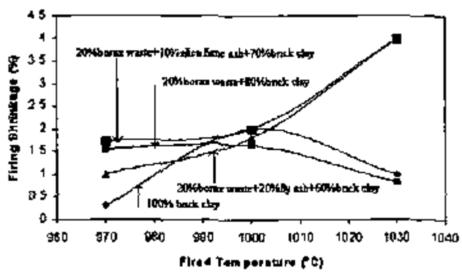

Figure 5. Firing shrinkage of bricks.

Bulk densities of the bricks are changed in the opposite way compared to porosity (Fig.6). It could be seen in Fig.6. That bulk density decreased with addition of silica fume and fly ash as an additive. Addition to the only borax waste to clay showed similar trend with brick clay from the point of view of bulk density.

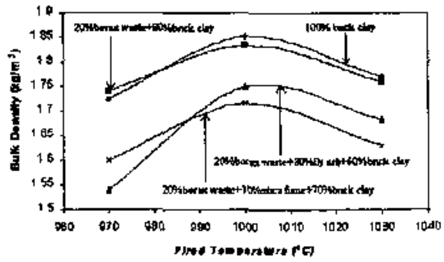

Figure 6. Bulk density of bricks.

The loss on ignition values of brick samples increased with addition of borax waste, fly ash and silica fume (Fig.7). As it could be seen from the figure, firing temperatures has no significant effects on the ignition loss on properties of the bricks. On the other hand, bnck clay has the lowest values among the bricks samples having the mineral matters such as carbonate, sulfate *m* wastes, it is known that these minerals decompose at firing temperatures such as 900-1200°C.

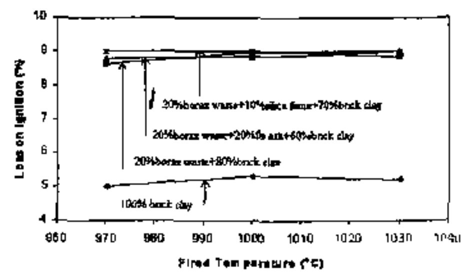

Figure 7. Loss on ignition of bricks.

4. CONCLUSIONS

The possibility of usage borax waste, fly ash and silica fume together with borax waste as an additive has been investigated. The main conclusions are as follows.

1. The bncks obtained by adding borax waste to bnck clay had higher compressive strength than that of the bnck clay sample. The highest compressive strength (27.58 N/mm^2) value has found for the bnck sample containing 20% borax waste (content of 2.80%B_2Oi) at 1000°C fmng temperature. At other tests, addition of the borax waste showed the best result for the same temperature. It seems that

borax waste added building bricks after the applying the leaching process, show good properties particularly strength values and may be become competitive with the building bricks

2. Using fly ash and silica fume as an addition material together with borax waste for the production of building bricks is not viable alternative to clay. Although it was found that the borax waste could be used *to* produce bricks conforming to the standard quality, there weTe some problems in addition of the silica fume and fly ash together with borax waste to brick clay such as higher porosity, higher water absorption, and low compressive strength.

3. The best values obtained at the end of the quality tests were found as IOOO°C firing temperature.

ACKNOWLEDGEMENTS

The authors would like to thank the Turkish Republic Prime Ministry State Planning Organization (Project No.98-DPT-07-01-02) and the Yıldız Technical University Research Fund (Project No. 95-B-07-01-04J for financial supports.

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