



Characterization of ground slag and borax waste and their effects on the compressive strength of briquettes



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HIGHLIGHTS

- Borax waste and ground slag can be used as additive in briquette production together.
- It is determined that compressive strength and bulk density of produced briquettes using borax and ground slag.
- Thermal properties of briquette samples were specified using DTA/TG analysis.
- SEM-EDS analyses were conducted on defining microstructures properties by examined samples.

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ABSTRACT

The usage of briquettes is preferred in the construction industry for many years. The quality of briquettes is directly related with characteristic features of raw materials and their compositions, production procedure, firing method, temperature and duration. There are waste materials such as borax waste having been used for briquette production, however it is not available to combined of both borax and ground slag used in briquette production. In the study, both borax and ground slag were used together as an additive in order to observe effects on the material characteristics of briquette samples. In this scope, compressive strength and bulk density of the samples produced using borax and ground slag were defined. Moreover, SEM-EDS, XRD and DTA/TG analyses of the materials were carried out and discussed. The overall results have concluded that not only higher compressive strength results were obtained using these wastes, but also the usage of waste up to 22% ratio was provided for this study. Consequently, it is determined to be possible using borax waste and ground slag in briquette production.

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1. Introduction

Briquettes are the most common construction materials used for building enclosures. The materials are specially required to have adequate physical and mechanical properties as well as sufficient thermal insulation behavior. Briquette quality significantly depends on properties of raw materials and their compositions, production procedure, firing method, temperature and time. Construction industry generally uses large amount of clay briquettes in most of the buildings [1]. If these briquettes are improved by proper processing, they can have significantly lower thermal conductivity and transmittance properties which mean a lower heat loss through the walls of building [2]. When the pores exist into briquettes, their thermal conductivities are reduced. This can be done by micro pores, like the closed pores created by the addition

of various organic and inorganic pore-making additives into briquette raw material mixtures before briquettes were fired [3].

Some different pore-forming materials such as wood saw dust, polymers, leather residues, polystyrene, organic residues, coal dust, powder limestone, paper-making sludge and mineral additives that act by thermal decomposition and volatilization in briquette body have been widely used [4–12]. Also heat-resistant porous materials such as diatomite, zeolite, vermiculite and perlite have been evaluated in the ceramic briquette structures [13–20].

It is well known that borax is a good fluxing agent. It combines with silica and alkali to form a glassy structure and lower the melting temperature, leading to a stronger body upon solidification [21,22]. The fluxing characteristics of borax have been extensively exploited in ceramic and glass making [23,24]. Waste material of boron mines contains both the clay minerals, the main raw material of briquette production and boron compounds, fluxing agent. Hence, it was thought that using the waste in the production of red briquette will not only remedy the environmental problems

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associated with it, but also might improve quality of briquettes and/or lower the firing temperature leading to cut the cost.

Turkey holds about 63% of total boron reserves of the world with 803 million tonnes [25]. Average boron ores production of Turkey is about 1.3 million tonnes per year. Products such as borax, boric acid and sodium perborate are obtained from these ores [26,27]. Annually, 120.000 tonnes of clay- and fine-wastes are formed in the concentrated tincal and the borax pentahydrate units during production cycles. These wastes were stored in tailing dams. When these wastes are discarded to land, the boron compounds are dissolved by rain causing environmental problems, especially soil pollution [28]. Because higher concentrations are reported to be deleterious for plants, materials with a high boron concentration should be considered pollutants [29]. In order to alleviate the pollution problem at borax plants, several attempts have been made to use these wastes in different ways. In order to prevent this environmental pollution, this waste may be used for producing of briquettes as an additive. On the other hand, one of the most common wastes incorporated into building materials is slag. Due to high demand and flexibility of briquette, different types of waste have been successfully incorporated into fired clay briquette especially slag waste, for example marble slag, stone slag, water treatment slag, sewage slag, desalination slag, textile laundry slag and ceramic slag. The utilization of these wastes in clay briquettes usually has positive effects on the properties such as lightweight bricks with improved shrinkage, porosity, thermal properties and strength [30]. The lightweight briquettes reduce transportation- and manufactured-cost. Moreover, it reduces clay content in the fired clay briquette with this waste incorporation and then reduce the manufacturing cost [31]. This motivates many researches to investigate more potential of different slag to be incorporated into the briquette. Ground slag is also another slag material for using in briquette production. Ground slag has not been used in briquette production although it has been studied related to borax usage in the content of briquette in literature. Accordingly, studies are not available to combined of borax and slag used in the production of briquettes.

As it is clearly seen from the aforementioned studies discussed above, many studies have been conducted to produce briquettes using borax as an additive up to now, however the authors could not detect the study related to use of both borax and ground slag together. Therefore, the present study focuses on usage of both borax and ground slag as an additive in order to observe the effects of these wastes on physical characteristics of briquette samples. In this respect, compressive strength and bulk density of samples using borax and ground slag were defined at first. Secondly, SEM-EDS and DTA/TG analyses of the samples were performed and discussed.

2. Material and methods

2.1. Raw materials

A dewatering sieve waste (TSW) was obtained from Etibor Co. Kirka Borax, Turkey. This waste which is a part of the waste of concentrator that was obtained from ore of tincalconite ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 5\text{H}_2\text{O}$). The TSW consists of tincalconite and clay mixes was collected from the upper part of the dewatering sieve of dissolution units of the Company. The average particle size of the borax waste is 145.02 μm . Ground slag was provided from Isdemir facility known as Iskenderun Demir Celik Factory in Turkey. Its specific gravity and average particle size were 2.80 g/cm^3 and 7.52 μm , respectively. In addition, soil was collected from Manisa region in Turkey. The particle size distribution of the soil was ranging between 0.007 mm and 5.0 mm, and also, its specific gravity is 2.75 g/cm^3 .

2.2. Experimental program

Various tests were conducted to define characteristics of materials in order to prepare proportions of samples. Firstly, hydrometer test was applied to soil that passed from #200 sieve size in order to define the contents of clay, silt and sand. Secondly, thermal properties of the materials were obtained using DTA/TG analysis method (Seiko, Exstar 6000 TG/DTA 6300). Finally, SEM-EDS analyses were conducted on define microstructures properties of the samples (FEI Quanta 450 Feg and JSM-5910LV; EDS model: Oxford-Inca-7274).

2.3. Preparation of sample mixtures

Following the tests were conducted on the materials, No#1–7 mixtures were constituted in order to prepare the briquette samples. For all the mixtures, borax waste amount was kept constant. In addition, ground slag content that was changed between 1% and 20% by weight was mixed with soil and borax waste (Table 1). In order to supply the sufficient fluidity because of preparing the samples easily water content was used as 6% by weight. The compaction pressure was selected as 20 MPa in order to compact to samples. The mixtures were compacted after they were placed to the molds. The diameter and height of the compacted samples were selected as 36 mm. Then, the compacted samples were sintered at 1000 °C temperature. As soon as the temperature of the furnace where the sintering procedure was applied reached to 1000 °C temperature, the samples were taken from the furnace without waiting in the furnace anymore. The bulk densities of the sintered briquette samples were measured, and then the samples were tested for evaluating their compressive strength according to TS EN 771-1 standard [32].

3. Results and discussion

3.1. Characterization of the materials

3.1.1. Hydrometer analysis of soil

Hydrometer analysis was applied to the used soil to show particle size distribution. According to hydrometer analysis results, soil consists of 6.4% sand, 34.6% silt and 59% clay. Results of the hydrometer analysis were presented in Table 2.

3.1.2. DTA/TG analysis of the samples

According to DTA/TG analysis results of the soil shown in Fig. 1, total weight loss of clay was observed as 9%. It can be easily found out from the results that the sample loosed its physical water at 200 °C temperature and loss of water amount is 3% percent. On the other hand, 0.5% weight loss was observed between 200 °C and 300 °C temperatures. The decomposition of the clay minerals and exiting of organic materials were materialized at 400 °C temperature. Moreover, chemical water exiting of the clay minerals was observed between 400 °C and 500 °C temperatures. The weight loss among these temperatures is 4.5% percent. The

Table 1
The prepared mixtures.

Sample	Soil (%)	Ground slag (%)	Borax waste (%)
1	97	1	2
2	96	2	2
3	95	3	2
4	93	5	2
5	89	9	2
6	83	15	2
7	78	20	2

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