International Journal of Innovative Research and Reviews, 2(1):11-15

International Journal of Innovative Research and Reviews

ISSN: 2636-8919

Website: www.injirr.com

doi:

Research paper, Short communication, Review, Technical paper

RESEARCH ARTICLE

An Investigation of Utilization of Ferrochrome Slag in Brick Production

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HIGHLIGHTS

- > Blast furnace slag has economic value and should be removed from being a matter of ordinary waste
- > Building materials can be produced from ferrochrome slag, and may offer some advantages in terms of cost and mechanical properties.
- > Elazığ ferrochrome slag can easily be used in brick and tile production in a controlled manner at the rates determined.

ARTICLE INFO

Received : 05.20.2018
Accepted : 07.10.2018
Published : 07.15.2018

Keywords:
ferrochrome slag,
brick production,
building materials,
industrial waste.

ABSTRACT

Unwanted solid substances released as a result of processes from industrial plants or various production mills are called solid waste, which is also known as ‘slag’. Today, the evaluation of these wastes has a great importance in terms of economic concerns and environmental pollution.

Ferrochrome slag, released during the production of Elazig Etikrom Facility over the last 40 years has exceeded 1 million tons and awaits to be evaluated. In this study, a series of tests about the availability of ferrochrome slag in brick production were conducted and the results are presented showing the availability of brick production using slag.

Contents

1. Introduction

In recent years, the evaluation of industrial waste, and usability of this waste in composite materials production as well as the investigation of its effects on performance in composite materials is one of the important topics in the scientific agenda. Creation of opportunities to use of wastes obtained from iron-steel plants, copper plants, ferrochrome plants, fertilizer plants and paper plants provides multiple benefits [1]. This situation will lead to advantages such as improving building materials, energy-saving, economy, environmental protection and rational use of natural resources [2–6].

In general, the use of blast furnace slag in cement production is a known and expected phenomenon [7, 8]. In this state, the

Cite this article Yıldız İ, Gül R. An Investigation of Utilization of Ferrochrome Slag in Brick Production. *International Journal of Innovative Research and Reviews (INJIRR)* (2018) 2(1):11-15

Link to this article: http://www.injirr.com/article/view/11

use of slag in cement industry is a significant economic factor [7]. On the other hand, if the slag is added as a mineral additive in concrete, it is also known that it improves the workability, extends the set period, reduces the bleeding and permeability, increases the resistance to sulphate, reduces the concrete water requirement and consequently increases the concrete strength [2, 8–10]. Nowadays because of mentioned reasons, blast furnace slag has been removed from being a matter of ordinary waste and is made an intermediate product which has an economic value [11].

Essentially, ferrochrome slag is the production waste of the ferrochrome plant. The large masses obtained as heaps become aggregates when they pass through jaw crushers. Granulated slag is obtained when aggregates are grinded (as shown Figure 1). However, we are working on Elazığ Etikrom facility's production ferrous slag, which is quite different in structure compared to the composition of general slag. With its high MgO content, Elazığ ferrochrome slag cannot be used at high rates in cement production like other blast furnace slags. In this case, ferrochrome slag can only be used as a mineral additive in cement production in small quantities when it is brought to cement level size by grinding.

Figure 1 Appearance of granulated and coarse Aggregate FeCr slag

Currently, studies on how to impart Elazig ferrochrome slag into the industry. In particular, the effect of the slag that contains high amounts of MgO and considering its expansion in concrete, for example, the availability of expanding types of cement production, ferrochrome slag is just one of the issues on the research value [12].

In this study, the chemical structure of the studied ferrochrome slag is discussed first, and then horizontally and vertically perforated bricks which have been produced using slag proportionally, experiments and obtained results were evaluated.

2. Materials and Method

When the blast furnaces of about 1400 - 1700 ºC in the molten slag is cooled slowly in the air, the molten transforms into a gray material, stone-like crystal structure. With amount control of air cooled and has a porous structure is as light as pumice. There is no binding feature of this crystal structure slag [13]. With sudden cooling in water amorphous slag, have started to being granulate structure (approx. particle size 1-7 mm) and a glassy structure is composed of such slags. Because of their siliceous structure, such slags get into the group of pozzolanic additives.

Gebze Institute of Technology efforts for controlling the negative impact of the Elazig ferrochrome, continuously make experiments and tests have been carried out and as a result the slag has an inert situation.

In summary, the ideal composition of the slag in the field of Elazig Etikrom Facility is; SiO_2: 27-31.5%, Al_2O_3: 28-32.5%, MgO: 30-33.5%, Cr_2O_3: 2.5-3%, CaO: 0-2%, FeO: 0-2%.

Rates of each other one of the oxides in the slag is MgO / SiO2 = 1 - 1.2, MgO / M_2O_3 = 0.87 - 1.06 and M_2O_3 / SiO_2 = 1 - 1.2. Here SiO_2: acid character, FeO, MgO, CaO: basic character, while Cr_2O_3 and Al_2O_3 Amphoteric (acid and base as well as the reactant separately) characters [13].

2.1. Production of Brick Used with Slag

The slag material has transferred in a lorry (about 10 tons) from Elazığ Etikrom production site to Tuğsan Soil Industry Corporation / Erbaa / TOKAT site firstly and slag is ground using jaw crushers used in the production of bricks was made available. Aged milled brick soil and ground slag are mixed by volume at rates before entering the mixing tank. The matrix obtained by mixing aged brick soil, ground slag and water are removed from brick patterns as brick a series of in bricks and cooked between 700-950° C, as shown Figure 2. The following schematic is provided as brick manufacturing processes [11].

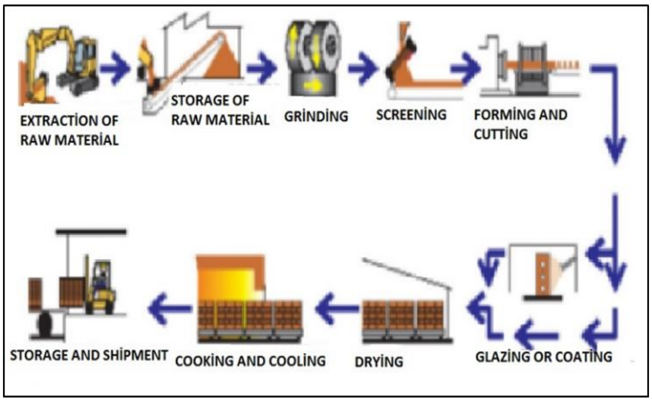

Figure 2 Brick Production Processes

In the first production series, by the volume of 25% ferrochrome slag and 75% brick soil, in the second production series, by the volume of 50% ferrochrome slag and 50% brick soil and in the last production series, by the volume of 75% ferrochrome slag and 25% brick soil have mixed and so enough number of horizontally and vertically perforated bricks were produced.

As a result of the study, three groups of a sufficient number of brick-size 19x19x13.5 cm horizontally and vertically perforated bricks were produced and ready to experiment. Produced samples were subjected to experiments described in TSE EN 771 code in the Materials Laboratory in Faculty of Engineering in Atatürk University. However, 75% of the bricks produced in series 3, due to samples compressive strength classified during the trial were excluded (Figure 3 shows a group of test samples).

Figure 3 One Group Brick Blocks for Tests

The experiments contain the results of; In every Test Stage

TYPE 0; Slag control samples (0%), three-piece, six groups (totally 18 pieces)

TYPE 1; 25% slag blended, three pieces, six groups (totally 18 pieces)

TYPE 2; 50% slag blended, three-pieces samples, six groups (totally 18 pieces).

2.2. Compressive Strength Tests

According to TS EN 771/1 and TS EN 772/1 for the Determination of Compressive Strength of Clay Masonry Units [14]; 18x18x13.5 cm-sized vertically perforated brick samples were dried for 24 hours in an oven at 105ºC, vertical holes and soft wood placed in the title installed in pressure testing machine. Then the load applied with 50 kg / sec loading speed. The results obtained are shown Figure 4 below.

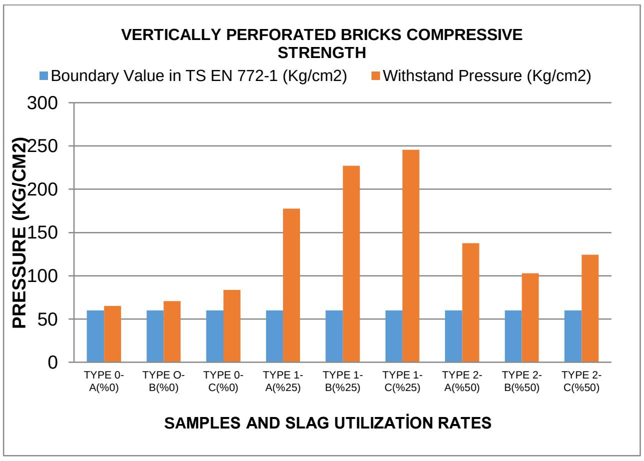

Figure 4 Vertically Perforated Bricks Compressive Strength Test Results

According to TS EN 771/1 and TS EN 772/1 for the Determination of Compressive Strength of Clay Masonry Units [14]; 18x18x13.5 cm-sized horizontally perforated brick samples were dried for 24 hours in an oven at 105 °C, horizontal holes and capped in 4 mm thickness with sulfur set in pressure testing machine. Then the load applied with 50 kg / sec loading speed. The results obtained are shown Figure 5 below.

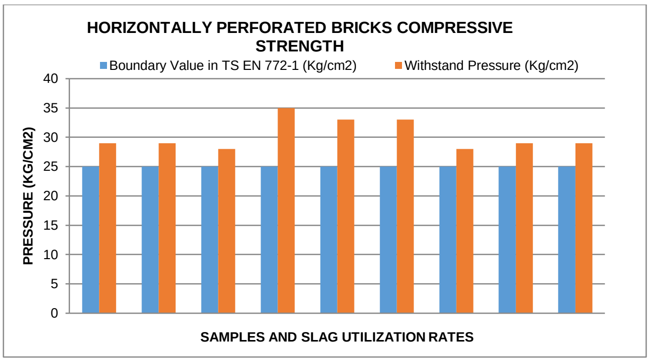

Figure 5 Horizontally Perforated Bricks Compressive Strength Test Results

2.3. Determination of Initial Water Absorption Speed

According to TS EN 771/1 and EN 772/11 for the Determination of Initial Water Absorption of Clay Masonry Units [14]; 18x18x13.5 cm sized vertically perforated brick samples were dried 24 hours in an oven at 105º C, for 1 minute in water for liquid adsorbent. Then weighed. The results are shown Figure 6 below.

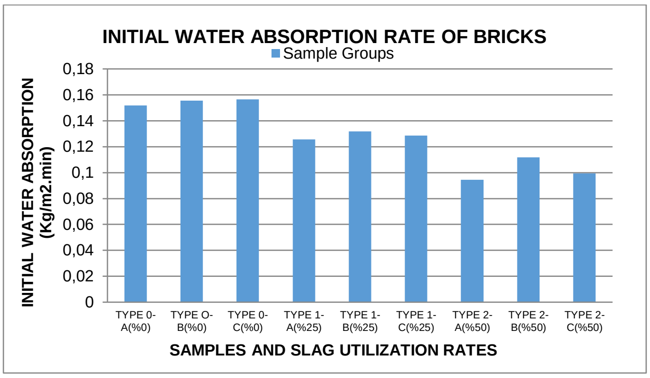

Figure 6 İnitial Water Absorption Speed of Bricks

2.4. Determination of Water Absorption Ratio

According to TS EN 771/1 and TS EN 772/7 for The Determination of Water Absorption Ratio of Clay Masonry Units [14]; for determining the water adsorption in bricks the boiling water method has been used.18x18x13.5 cm sized horizontally perforated brick samples were dried 24 hours in an oven at 105 °C. The water has reached boiling point in 6 hours then after waiting at least 16 hours, then they removed from the water and the surfaces of samples have been dried and weighed. Samples surfaces were dried with a dry cloth and were weighed. The results are shown Figure 7 below.

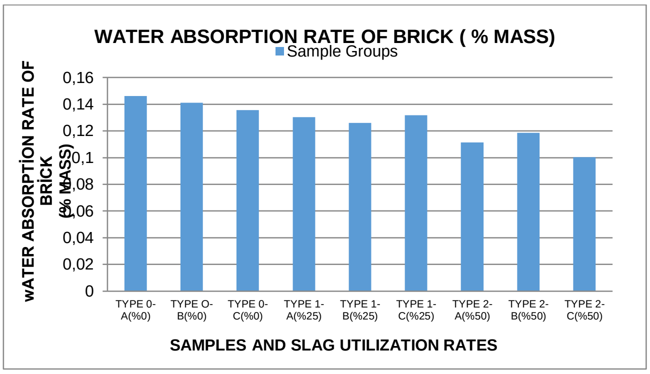

Figure 7 Total Water Absorption Rate of Bricks

2.5. Bricks Porosity and Net Volumes Detection Test

According to TS EN 771/1 and TS EN 772/3, the brick porosity and Net Volume of Clay Masonry Units [14]; 18x18x13.5 cm sized horizontally perforated brick samples were dried 24 hours in an oven at 105 °C. The brick is weighed in floating position as hanged with wire in water and then the bricks have been dried and weighed. The results are shown Figure 8 below.

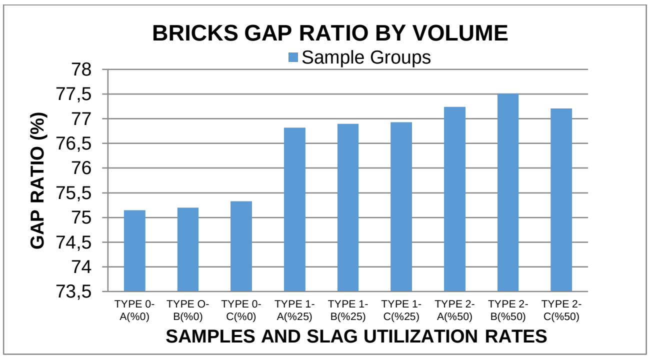

Figure 8 Brick porosity by volume

2.6. Determination of Net and Gross Dry Unit Weights

According to TS EN 771/1 and EN 772/13, The Determination of Net and Gross Unit Weights of Samples [14]; 18x18x13.5 cm horizontally perforated brick samples stored for 3 days in oven at 105 ºC with precision scales and weighed after 24 hours. The results are shown Figure 9 and Figure 10 respectively below.

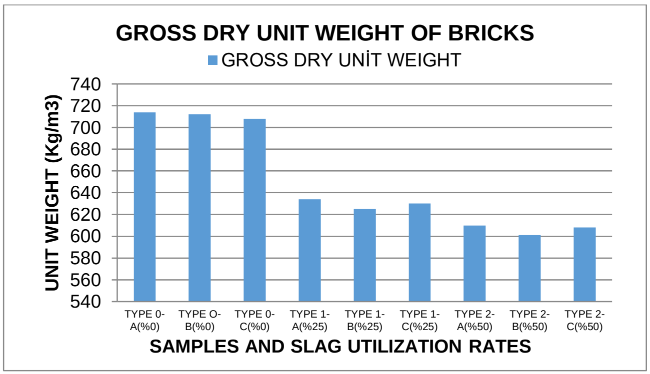

Figure 9 Gross Dry Unit Weight of Bricks

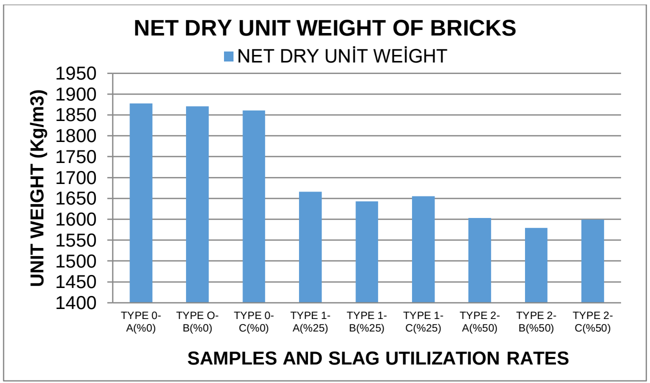

Figure 10 Net Dry Unit Weight of Bricks

3. Results and Discussions

According to the chart for the pressure tests, the results of strength of 25% added slag bricks are very high. The results of strength of 50% added slag bricks are also equal or better than normal bricks. The most important characteristic of bricks is the compressive strength. In this manner, slag additive bricks are very good yield.

When considering initial water absorption speed, it is seen that the rate of first water absorption speed in %25 and % 50 slaggy bricks is lower than normal bricks. These results are quite positive. Because when the first water absorption speed rate and total water absorption rate of the brick is low, it means that it will get less water in its body.

When examined in terms of void(porosity) ratios, it is seen that the void ratios of 25% and 50% slag added bricks are higher than normal bricks. The void ratios in building materials are directly proportional to the thermal insulation. So, as the void ratio increases, the insulation also increases. This means that the thermal insulation of the slaggy bricks will be better than the normal bricks [15].

In terms of unit weight of slag added bricks by 10% lighter than normal bricks. This is a very good result. Because they are lighter than the normal bricks and so the entire structure makes it more secure against earthquakes.

On the other hand, observations made during the baking process of slag-added bricks, and later on, showed that the addition of slag reduces the shrinkage of the bricks during baking. This result is quite favorable for the fact that the bricks do not go beyond the accepted [16].

4. Conclusions

Due to the high proportion of MgO in the inner structure of Elazığ Ferrochrome Slag, the studies for the production of concrete or cement with Ferrochrome Slag has to stay limited since high MgO leads to undesirable expansion in concrete in the medium and long term [6].

In this study, Ferrochrome Slag has been used at a high rate in the production of building materials such as bricks and tiles. In this way, the use of ferrochrome slag in the production of building materials will be more realistic.

Currently, more than 1 million tons of ferrochrome slag is awaiting to be evaluated in Elazığ Facility Field. In the light of this study, more than 1 million tons of ferrochrome slag will be economized. Moreover, the use of ferrochrome slag in brick will bring no additional cost.

The high strength, higher void rate and lower water absorption rate obtained in ferrochrome slag added bricks will also promote the usability of slag in the production of other building materials.

The high MgO content in the Ferrochromium slag is believed to provide the brick a lower water absorption rate. This means that the durability of a slag added brick is better than that of a normal brick.

This study shows us that Elazığ ferrochrome slag can easily be used in brick and tile production in a controlled manner at the rates determined.

Due to the high content of MgO, Elazığ ferrochrome slag is believed to be able to be used in ceramic industry and expanded cement production, whereas further research in this regard is necessary [12].

Acknowledgement

This is article is an expanded version of our paper which has previously been presented at “International Conference on Engineering Education (ICEE) 2013” in Al-Madînah, Saudi Arabia and published under the title “The Use of Ferrochrome Slag in Brick Production” in book of proceedings.

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