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Production of Silica-refractory Bricks from White Sand

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Abstract: At present, no refractories are produced in Jordan, but large quantities are imported for use in the lining of furnaces and kilns in the metallurgical industries.The aim of this study is to initiate a program of research for production of silica-refractory bricks from local materials.The raw material, which has been used in this study was white sand. This sand contains less than 0.5% Fe_2O_3 and is therefore suitable for production of glass. The sand used for production of glass is also suitable for production of silica refractory bricks. The method for production of this bricks consists of mixing the white sand with 2.5 CaO (milklime) which acts as a binder and mineraliser in order to convert the free quartz to tridymite and crystobalite.

Key words: Bricks, Silica, Sand, Materials, Quartz

INTRODUCTION

Silica refractory bricks are used in kiln roof and in exposed sidewalls, because of their high mechanical strength and rigidity at temperatures approaching the melting point. One of the outstanding characteristics of silica bricks is their resistance to corrosion by acid slag and iron oxide, but they are readily attached by basic slag and fluorine.

Silicon dioxide (white sand) was used as a raw material for production of silica-refractory bricks [1]. Silicon dioxide, which is one of the most abundant minerals, occurs in primarily as quartz. In combination with basic oxides it forms a large group minerals known as silicates.

Silicone dioxide has a melting point of 1728°C. Silica, which is by far the most plentiful of all the refractory oxides, is without doubt one of the most important raw materials in the ceramics industry. Silica is polymorphous and the crystalline inversion which takes place on heating introduces definite limitation on the manner in which silica refractories may be used silica refractory bricks posses excellent thermal shock resistance, particularly in certain temperature range.

There are temperature ranges where the resistance to thermal shock is very poor, this is due to the fact that large volume changes take place at elevated temperatures during conversion from one modification to another. The various transformations that take place where crystalline silicon dioxide is subjected to heating can be represented by the following scheme [2, 3].

-quartz 575°C- -Quartz 870°C
-tridymite 1470°C- -cristobalite 1750°C liquid

Of these phases, quartz is the most critical one in as much as it is susceptible to conversion during high temperature service to the less dense crystobalite and tridymite, which is the reason for the expansion taking place.

Modern silica bricks contain very little unconverted quartz. The presence of liquid phase (glass) is another important aspect since it becomes fluid at operating and thereby reduced refractoriness under load. The melting behavior of silica bricks is shown in Fig. 1.

The quartz modifications have relatively close-packed structures and high density, whereas the tridymite and crystobalite forms are comparatively open structured. The great changes in density between quartz and tridymite is responsible for the large expansion that occur during the formation of tridymite. The phase diagram of silica-lime system shows why considerable quantities of lime (CaO) may be used to bond the quartz in silica bricks without loss of refractoriness.

The action of pure lime as a mineralizing agent in the tridymisation of silica bricks raw material at 1250°C is due to the diffusion of calcium ion into silica surface.

Chemical composition and physical properties of quartzite vary in wide ranges. A good quartzite should be gray. Reddish in color indicates the presence of finely distributed iron oxide. Dark to black discoloration is caused by manganese oxides or by organic contamination. Quartz sands of high purity contain less than 0.05% Fe_2O_3, 0.02-0.05% Al_2O_3 and about 0.005% CaO.

MATERIALS AND METHODS

In these experiments we have used quartz sand that used in the glass industry, because there is no known local deposits of quartz-rock.The chemical analysis of representative sample of white quartz sand is shown, SiO_2 (98.6%), Al_2O_3 (0.5%), Fe_2O_3 (0.08), CaO (0.3), MgO (trace), Alkalis (0.2%). The grain size distribution

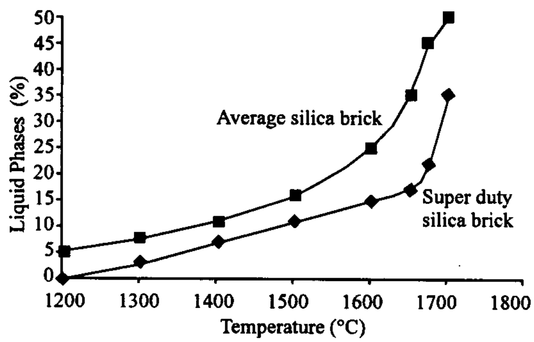

Fig. 1: Melting Behavior of Silica Bricks

of this type of quartz sand is as follows: 0.1 mm (3%), 0.15 mm (3%), 0.177 mm (65%), 0.42 mm (25%), 0.599 mm (2%), 0.71 mm (2%).

For use in the preparation of silica-refractories the sand had to be washed, the clay impurities were removed by ashing the sand continuously with water and detergent and finally with water. The clean sand was then dried at 110°C. A part of the sand was ground in order to pass the 100-mesh sieve to permit the use of various granulometric formulations.

In addition to the chemical analysis the burning characteristics of white sand depends upon the mineralogical composition, which is usually determined by means of x-Ray diffraction (XRD) . The softening point and behavior of white sand was determined in the heating microscope. No deformations were observed in the sample up to temperatures of 1500°C [4].

Sand batches for making silica brick specimens were prepared by adding specified amounts of fine-ground quartz sand to the original coarse sand in order to improve mouldability and the degree of sintering in the finished product. The raw material batches were mixed for about one minute. Then an aqueous solution containing bonding additives (milk of lime) was added and the mixing continued for another four to five minutes [5].

The bonding solution was prepared by mixing the following additives:

* Bonding material such as sulphate lye, molasses or dextrin (about 0.5%).
* Freshly burnt quicklime (CaO) (2-3%) of total mix as a binder and mineraliser to hasten the conversion quartz to crystobalite and tridymite.
* Water (about 7% total mix).

For the semi-dry well mixed, it was able to press specimen cylinders of a height of 40 to 50 mm and a diameter of 50 mm using a special mould.

The pressing cycles have been selected empirically with regard to the quality of the pressed products and the output of the press.

Investigating these cycle has established for the permitted pressing rate to avoid the formation pressing cracks (200-400 kg/cm^2). Hydraulic pressing machine was used. The moulded silica specimens should than be replaced in a special room having a carefully regulated temperature and humidity value in order to attain completely dry specimens, without damage.

Drying silica specimens to ensure complete reaction of CaO with water, then the specimens hardened. Maximum drying temperature was 65°C for 24 h.

The Silica brick specimens were fired in an electrical furnace at 1450°C for 2 h.

The rate of temperature increase was carefully controlled up to 900°C, the temperature was varied at a rate of 5°C per minute in order to avoid cracks formation in the production as result of the volume changes during the quartz inversions taking place at those temperature ranges.

RESULTS AND DISCUSSION

The silica bricks produced in our laboratory had a yellowish-white color. The discoloration of red flex appeared in some of our specimens.

It can be explained by the combination of iron oxide with CaO forming calcium ferrite and wollastonite.

The PCE of silica refractories is SK 34. In this study we produced silica bricks with a softening point in execs of 32. The degree of conversion can be readily determined from data on specific gravity.

The degree of conversion increases with falling specific gravity. Specific gravity of 2.33 indicates complete conversion .

Table 1: Gravity of Silica Bricks

Material density	Firing Temp. (°C)	Fe_2O_3 content (%)	True (g/cm^3)
Silica Brick	1300 (2 h)	1.1	2.59
Silica Brick	1450 (2 h)	1.1	2.38

The specific gravity of silica bricks was between 2.38 and 2.59. The lowest figure was obtained on those bricks which were fired at 1450°C, whilst the highest specific gravity was achieved in bricks fired at lower temperature (1300°C). Bricks with specific gravity of 2.38 meet the requirement of the standard. Water absorption of silica bricks and so that the porosity is directly proportional to water absorption [6, 7] (Table 2). Porosity is of great influence on compressive strength, gas permeability and resistance against liquid glass, molten metals and glass. In most cases compressive strength drops with increasing porosity. Infiltration of foreign material increases with size of pore space. Therefore the standard requires that silica bricks have porosity of between 20 and 24%. The data presented in Table 2, indicated that the bricks tested are

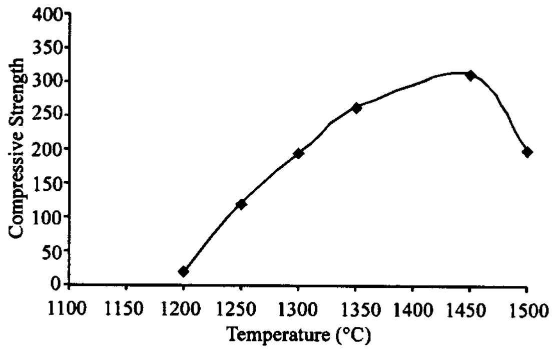

Fig. 2: Relationship between Compressive Strength and Temperature

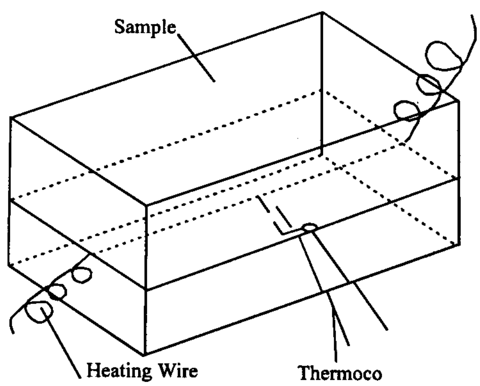

Fig. 3: Thermal Conductivity Meter TC-31

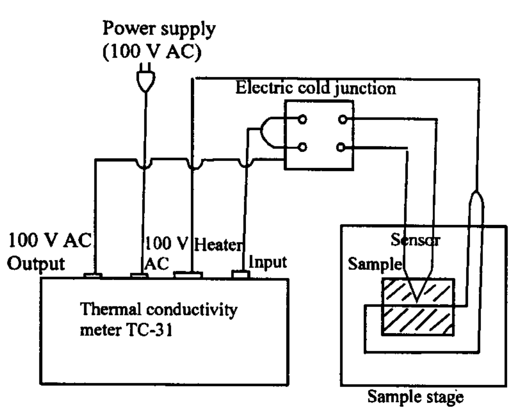

Fig. 4: The Rectangular Specimen with the Hot Wire

Table 2: Water Absorption of Silica Bricks

No.	Sample sand content		Bulk density (g/cm^3)	Porosity (%)	Water absorption (%)
S1	50	50	1.775	23.010	12.48
S2	45	55	1.667	24.300	13.00
S3	40	60	1.638	25.300	14.10
S4	35	65	1.627	26.100	15.10
S5	30	70	1.618	26.400	15.5
S6	25	75	1.591	26.930	16.2
S7	20	80	1.578	27.900	17.3

Conditions: Specimens were fired at 1450°C for 2 h, forming pressure 230 kg/cm^2, each sample contained 25 g, CaO 0.5 g, molasses and 8 g H_2O/ 100 g of Quartz sand.

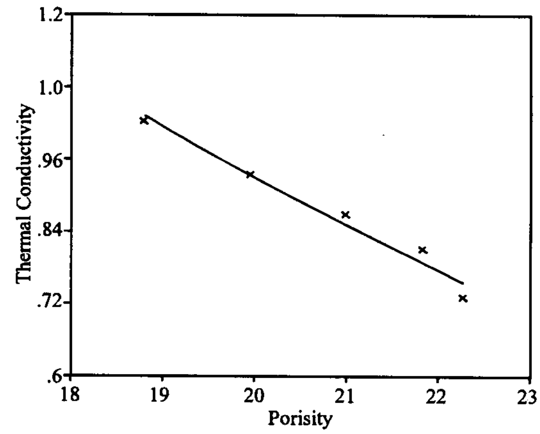

Fig. 5: Relationship between Thermal Conductivity of the Silica Refractory Bricks with the Porosity

in line with these requirements. Figure 2 shows that a rapid increase in compressive strength takes place up to temperature of 1450°C.

After that the compressive strength decreased. This drop is due to increased porosity and due to a loosening of the structure, which is caused by the tridymite conversion and the volume changes accompanying it [8].

The compressive strength of silica bricks at ambient temperature should be 250 kg/cm^2. For the arches the strength should be not less than 300 kg/cm^2 .For the bottom of the furnace permissible strength values are 170 kg/cm^2.

These data originate from frequency distributions for the compressive strength of commercial available silica bricks, which has been found in the literature. In our samples which were fired between 1300 and 1450°C was well above these minimum requirement.

Thermal conductivity of produced silica bricks were determined by the hot-wire method. For this test the thermal conductivity meter TC-31 was used, (Fig. 3). Specimens in rectangular shape (20*10*5 cm) according to this method (Fig. 4) were used [9]. Figure 5 shows a decrease in thermal conductivity by increases in the porosity. The max thermal conductivity of produced bricks is less than 1.0 Kcal/m.h. °C .This is an indication for good thermal insulation capacity.

CONCLUSION

It has been possible to produce silica bricks using a white sand in combination with lime. For the production of silica bricks the following conditions were found to be important for obtaining refractory bricks of suitable quality.

* Mouldablitity and physical properties depend greatly upon the proper granulometric composition. It is necessary to grind part of the sand and to combine ground and coarse sand in proper ratio.

Optimum results were obtained when 1 part by weight of fine sand was combined with 2 parts of coarse sand.

* The recommended mix composition is 7 parts water 2.5 parts CaO (quiklime), 0.5 Part molasse, 100 Parts sand mix.
* Good results are obtained with a molding pressure of 250 kg/cm^2 and a firing temperature of 1450°C. The heating rate of great importance for the success of the burning processes it should not exceed 5°C/mint. After reaching 1450°C the temperature should be held at this level for 2 hr.
* The softening point was higher than PCE-SK31 (1695°C) . Strength properties were well above those required by various standards and in line with the properties found in similar products in the market.

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