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Mechanical and Physical Properties of Silica Bricks Produced from Local Materials

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Abstract: The samples were prepared by the semi-dry method, moulding pressure was 50*N/mm*^{2}. After drying at 110°*C*, the samples were burnt at 1450°*C*. The fired samples were investigated to determine their physical properties, such as specific gravity, porosity, compressive strength, thermal shock resistance and refractoriness under load (RUL). Results obtained indicated that the compressive strength increases with increasing temperature at 1450°*C*. A maximum expansion at temperature below 600°*C* was observed. The test for the shock resistance showed that 9 heat cycles were required at 900°*C* before destruction.

Key words:

INTRODUCTION

Refractories are ceramics materials of pyrometric cone indicator greater than cone 26(1580°*C*). Refractory materials are used in the linings of furnaces, kilns, ovens, melting pots ect. to confine the heat to the ware. While chamotte bricks are largely used in the lining of melting pots and the sintering zones of cement kilns, silica bricks find widespread use in kiln roofs where resistance against vapors and gases. Until this time Jordan and other neghbouring countries have not sofar taken up the production of refractory-bricks.

Silicon dioxide, which is one of the most abundant materials, occurs in nature primarily as quartz. In combination with basic oxides it froms a large group of minerals known as silcates. Silica is also known in other forms such as chert, flint, chalsadony and opal, which are hydrated from of silica (Chester, 1973).
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-refractory bricks possess excellent thermal shock resistance, particularly in certain temperature ranges. 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 temperature during conversion from one modification to another (Shaw, 1972).

Modern silica bricks contain very little unconverted quartz. The presence of a liquid phase (glass) is another important aspect since it becomes fluid at operating temperature and thereby reduces refractoriness under load (Bhaumik, 1986).

The share of the crystalline high temperature modifcations of quartz which exist at room temperature in silica bricks are in the following ranges, 12% quartz, 33% cristobalite, 42% tridymite and 13% glass matrix (Chester, 1973).

In practice, the formation of these modifications is affected by the presence of impurities, so that silica bricks during heating and cooling may be transformed into a large number of combinations of these crystalline forms. The quartz modifications have relatively close-packed structures, and high density, where as the tridymite and crystobalite forms are comparatively open structured. The great change in density between quartz and tridymite is responsible for the large expansion that occurs during the formation of tridymite.The phase digram of silica-lime system shows why considerable quantities of lime 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 tridymitisation of silica brick raw material at 1250 is due to the diffusion of calcium ions into the silica surface (Mohantly, *et al.,*1986).

This work research was carried out to investigate the suitability of silica for production of silica-refractory bricks. The raw material, which has been used in this work was white sand. The method for production of this bricks consist of mixing the white sand with 2.5% CaO (milklime) which acts as a binder and mineralizer in order to convert the free quarts to tridymite and crystobalite

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2. Expermental Procedure

2.1. Raw Materials

2.1.1Qartz Sand

Chemical composition and physical properties regarding suitability for its use in refractories is indicated. Good quartz should be gray. Reddish in colour indicated the presence of finely distributed iron oxide. Dark to black discolouration is caused by manganese oxides or by contaminations. Quartz sand used for production of silica-bricks usually contains not more than 0.5% Al_2O_3 and 0.2% to 1% Fe_2O_3 and 97% to 99%SiO_2.

At this stage, there are no known local deposits of quartzite rock. In our experiments the low grade quartz sand that could not be used in the glass industry was used.

2.1.2Chemical Analysis:

The chemical analysis of a representative sample of white quartz sand is shown below:

Table 1: The white quartz sand chemical analysis

Contituent	(%)
SiO_2	98.6
Al_2O_2	0.5
Fe_2O_3	0.08
Lime	0.3
Msgnesia	*Trace*
Alkalies	0.2

The grain size distribution of this type of quartz sand is as follows:

Table 2: The grain size of white quartz sand

3%	0.1 mm
3%	0.15 mm
65%	0.177 mm
25%	0.42 mm
2%	0.599 mm
2%	0.71 mm

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

Mineralogical analysis:

The (XRD) diagram of the white sand (Fig.1) that the material becomes quartz.

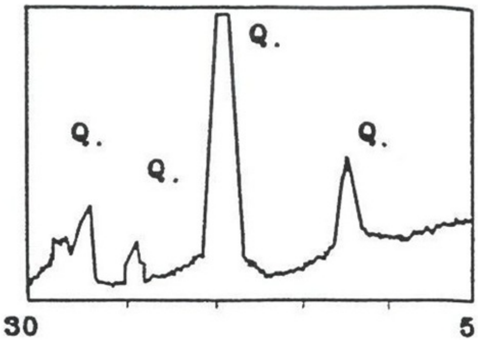

Fig 1: X-Ray diffraction of white sand

2.2. Processing:

Sand batches for making silica brick speciment 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 equeous solution containing bonding additives (milk of lime) was added and the mixing continued for another four to five minutes.

The bonding sollution was prepared by mixing the following additives:

1-Bonding material such as sulphite lye, molasses of dextrin (about o.5%).

2-Freshy burnt quicklime (CaO) (2-3% of total mix) as a binder and as a mineraliser to hasten the conversion of quartz to cristobalite and tridymite.

3-Water (about 7%of total mix).

By the semi-dry well mixing, pressing specimen cylinders of a height of 40 mm to 50 mm and a diameter of 50 mm using a special mould was possible. The moulding pressure was (200-400kg/cm^2).

The molded silica specimen were then 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 was applied in certain conditions to ensure complete reaction of CaO with water, and then the specimens hardened. Maximum drying temperature was 65 $°C$ for 24 hours. The silica brick specimens were fired at 1450 $°C$ for two hours.The rate of temperature increase was carfully 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 product as a result of volume changes during the quartz inversions taking place at those temperature ranges.

The fired bricks were investigated for softening point, specfic gravity, porosity, thermal shock resistance and refractoriness under load.

RESULTS AND DISCUSSION

3.1 Physical properties

3.1.1 Softening point

The softening point determined on silica specimen using a specimen which was similar shape to the standard pyrometric cone. The results show that up to 1700 (sk 32) the shape of the samples remained unchanged.

3.1.2 Specific Gravity:

The decrease in the density of refractory products is primarily a function of the degree to which quartz is converted to tridymite and cristobalite. This is achieved by increasing firing temperature and by the interaction of mineralizing additive. The results obtained are shown in table (3).

Table 3: Specific Gravity of Produced Silica Bricks with Different Firing Temperature

Material	Firing Temperature ($°C$)	Sp- Gravity
Silica Bricks	1300	2.59
Silica Bricks	1450	2.38

3.1.3 Porosity:

Water absorption is the common method of determining the porosity of the bricks. This test was investigated by using the vacuum technique to obtain more accurate results in a shorter length of time.

3.1.4 Thermal Shock- Resistance:

The use of the heat-cycle method as a means of evaluating the spalling resistance of refractories is satisfactory for quality control purposes. Investigations consisting of silica refractory bricks. The bricks were heated for 30 minutes at 900$°C$ in an electric furnace then suddenly placed in cold water. After cooling the specimens were refired in the furnace and left there for 15 minutes. The cycle of cooling and heating was repeated until the specimen broke apart. The results are shown in table (4).

Table 4: The thermal shock resistance of produced silica-refractory bricks

Soaking time (hr.)	Cycles
6	6
12	12
18	14
24	18

3.1.5 Compressive Strength:

This property often serves as a guide for estimating other properties such as the degree of sintering, firing temperature and the purity of materials. The strength of refractories is also of value in determining the ability to withstand handling and transporting. The test equipment used for this purpose is hydraulic pressing machine. The results are shown in table (5).

3.1.6 Refractoriness Under load:

Refractory bricks have a tendency to shrink when subjected to heat. The shrinkage takes place in the direction of the load. The tendency of refractories to distort under load when exposed to elevated temperatures is an important characteristic of the material. To a certain extent the softening point under load governs the maximum service temperature. The load resistance test of silica- bricks refractories is measured on a specimen, which is heated under load of $2 kg/cm^2$. The amount of deformation is graphically determined at the end of the test.

Discussion:

The silica bricks produced had a yellowish white colour. The discolouration of red reflex appeared in some of specimens. According to (Chester, 1973) it can be explained by the combination of iron oxide with CaO forming calcium ferrite and wollastonite.

According to (Shaw, 1972). the PCE of silica refractories is Sk 34. In our work silica bricks with a softening point in excess of 32 were produced.

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 a complete conversion. As indicated in table (3) the specific gravity of silica bricks was between 2.38 and 2.59.

The lowest specific gravity (2.38) was obtained on these bricks which were fired 1450°*C*, whilst the highest specific gravity (2.59) was achieved in bricks fired at lower temperature (1300˚°*C*). A lower specific gravity value (2.38) meets the requirement of the standard refractory bricks.

Table (6) gives the results of the water absorption of silica bricks and shows that the porosity is directly proportional to water absorption. Porosity is of great influence on cold compressive strength, gas permeability and resistance against liquid slag, molten metals and glass. In most cases, compressive strength drops with increasing porosity.

Infiltration of foreign material increases with size of the pore space. Therefore the standard requires that silica bricks have a porosity of between 20 and 24%.The data presented in table (6) indicated that in bricks tested are in line with these requirements.

The results in table (5) indicate that absolute compressive strength values increase greatly with increasing firing temperatures. Fig. (2) shows that a rapid increase in compressive strength takes place up to temperature of 1450°*C*.

Table 5: Shows the results of compressive strength of produced sampled

Soaking time (hr.)	Compressive Strength (kg/cm^2)
6	155.5
12	205.4
18	302.96
24	415.83

Table 6: Shows the physical properties of produced silica bricks

No.	Firing Temp. (°*C*)	Bulk Density (gm/cm^3)	Water Absorption (%)	Porosity (%)	Compressive Strength (kg/cm^2)
1	1200	1.87	11.70	32.0	111.6
2	1250	1.88	11.55	30.4	158.1
3	1275	1.90	11.35	29.2	167.4
4	1300	1.93	11.22	26.30	210.5
5	1400	1.95	11.1	25.80	285.6
6	1450	1.97	10.70	23.50	356.8
7	1500	1.96	10.80	24.6	290.5

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. The compressive strength of silica bricks at ambient temperature should be $250 kg/cm^2$. In our samples which were fired between 1300 and 1450°*C* was well above these minimum requirements.

The results of the test for thermal shocks resistance of produced silica bricks show that the number of heat cycles at 900°*C* before destruction was 9. The explanation is that bricks with high content of silica are more subject to volume changes due to the quartz conversion into its various modifications. The volume changes which accompany there conversion lead to a loosening of the structure and to a lower resistance against thermal shock.

The curve shown in fig.(3) gives length changes as a function of temperature (Schmidt-Reinhoz and Schmidt, 1986). The following are the important points on this curve:

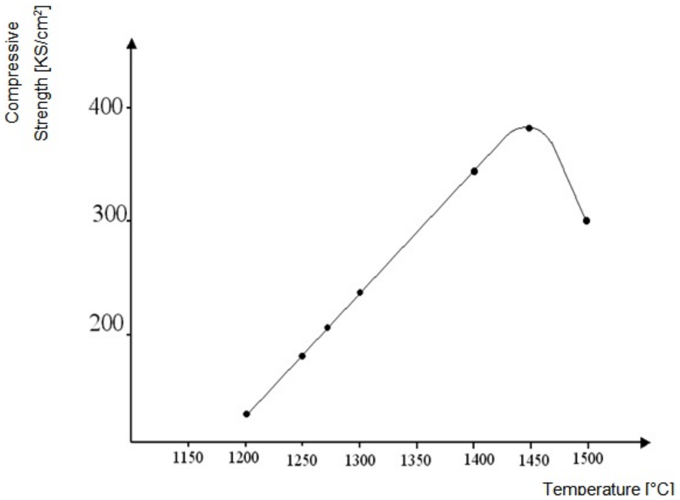

Fig 2: Relation between compressive and temperature.

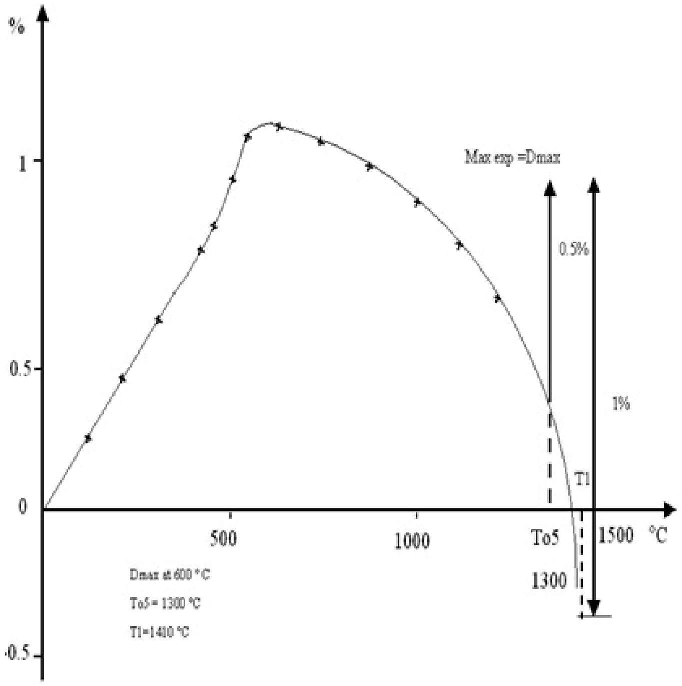

Fig 3: Refractoriness under load.

1. $D_{\max}$ - is the maximum expansion value of the specimen.
2. T_{05} - is the starting temperature of softening range.
3. $T_{1.0}$ is the final temperature of the softening range.

The maximum expansion which occurs at temperature below 600 $°C$ is due to the large volume changes due to the conversion of quartz to tridymite at this temperature. T_{05} was 1300 $°C$ and $°C$ was 1410 $°C$.

Conclusions:

1.It has been possible to produce silica bricks of adequate quality using white sand in combination with lime.

2.For the production of silica bricks the following conditions were found to be of importance for obtaining refractory bricks of suitable quality.

(a)The recommended mix composition is:

1.7 percent of water
2.2.5 percent of CaO (quick lime)
3.0.5% molasses
4.100% sand

(b) 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 process. It should not exceed 5°C /minute. After reaching 1450°C the temperature should be held at this level for 2 hours.

(c) The softening point was higher than PCE-Sk 31 (1695°C). Strength properties were well above those required by various standards and in line with the propereties found in similar products on the market.

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