Manufacturing of Silica Refractories from Locally Available Sand

Md. Tusar Ali, Iqubal Hossain, Md. Abdul Gaffer

***Abstract:** The investigation implies the use of silica sands, available in Bangladesh, as raw materials for silica bricks manufacturing and compare their properties with specification requirement in order to use these raw materials in manufacturing silica bricks to support the application in lining of induction furnaces and kilns, ladles in metallurgical industries and to replace the imported silica brick. This silica sands containing silica, alumina and excess amount of iron-oxide has been suitable for these bricks made by employing a simple hand mould pressing and sintering process. The production of silica refractory bricks from local sand have been remarkably changed by the addition of various amount of additives. The method for the preparation of these bricks has consisted of mixing the local sand with CaO (slurried lime). This lime acts as a binder and mineralizes in order to convert the free quartz to tridymite and crystobalite. The various properties of silica bricks are found to change with the addition of lime.*

***Keywords:** Silica %, Refractory, Refractoriness and CaO (slurried lime)*

I. INTRODUCTION

High mechanical strength and rigidity at temperatures approaching the melting point of silica refractory bricks has drawn attention to the application in kiln roof and in exposed sidewalls. Corrosion resistance caused by acid slag and iron oxide is one of the outstanding properties of silica, but they are readily attached by basic slag and fluorine. Silicon dioxide as a raw material (white sand) was used for the production of silica-refractory bricks, which is one of the most abundant minerals, occurs in primarily as quartz [1]. In combination with basic oxides it forms a large group mineral known as silicates. Silica having a high melting point of 1728^{o}C is by far the most plentiful of all the refractory oxides. As a result it is defined as one of the most important raw materials in the ceramics industry without any confusion. Silica is polymorphous and the crystalline inversion which takes place on heating introduces definite limitation on the manner in which silica refractories may be possibly utilized. Silica bricks have excellent thermal shock resistance, particularly in certain temperature range. Large volume changes take place at elevated temperatures during conversion from one to another modification because of being very poor resistance to thermal shock in the temperature ranges. The various transformations can be held where crystalline silica is subjected to heating is represented by the following scheme [2, 3].

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α-Quartz 575^{o}C → β-Quartz 870^{o}C → Tridymite 1470^{o}C → Cristobalite 1750^{o}C liquid

Quartz as the most critical one of these phases has been susceptible to conversion during high temperature service to the less dense tridymite and crystobalite, which is indicated as more responsible to the expansion happened. Very little unconverted quartz and the presence of liquid phase (glass) in modern silica bricks are considered as the important aspects since it operates to become fluid and thereby refractoriness reduces under load.

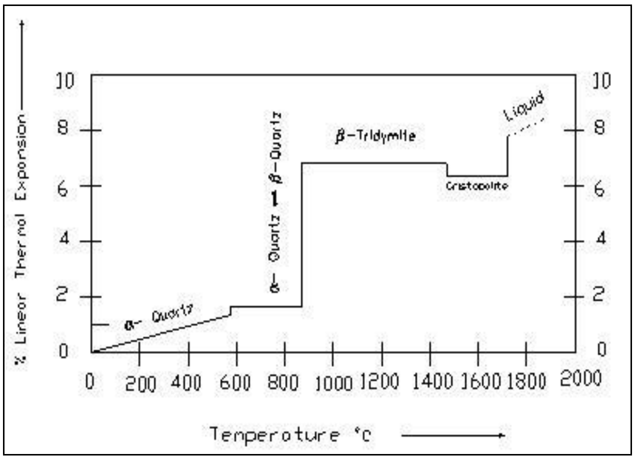

Fig. 1 Allotropic Changes in Silica (Quartz) Mineral and Associated Thermal Linear Expansion

Allotropic changes in silica (quartz) mineral and associated thermal linear expansion is shown in Fig. 1. The quartz modifications have relatively close-packed structures and high density, whereas tridymite and crystobalite forms are comparatively open structure. The large expansions occur during the conversion of quartz into tridymite and result in the great changes in density between quartz and 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. Pure lime acts as a mineralizing agent in the tridymisation of silica bricks raw material at 1250^{o}C because calcium ion diffuse into silica surfaces.

The chemical composition and physical properties of quartzite show the variation in wide ranges. A good quartzite should be gray. The presence of finely distributed iron oxide is indicated by reddish in color. Manganese oxides or organic contamination causes dark to black discoloration. High purity quartz sands consist of less than 0.05 % Fe_2O_3, 0.02-0.05 % Al_2O_3 and about 0.005 % CaO.

II. MATERIALS AND EXPERIMENTAL METHOD

In these experiments, two types of local sand were collected. For use in the

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preparation of silica refractories, both the sands had to be washed with water continuously, the clay with various kinds of impurities were removed by washing the sand continuously with water and finally with water. This clean sand was exposed to the sun dry for a number of weeks for being completely dried. A part of the selected sand was ground in order to pass the 30-mesh sieve to permit the use of various granulometric formulations. Then a chemical analysis was carried out to determine the percentage of silica by using the various granulometric formulations [4]. Firstly, 50gm sand with NaOH was taken in a platinum crucible in a furnace at 650ºC to form basic medium. K_2CO_3, Na_2CO_3 were not taken because these are very dangerous for platinum crucible. HCl was added to the basic media to form chloride ion (aluminum chloride, silicon tetrachloride…..). Chloride ion products react with Sulfuric acid and convert to silicic acid. Sulfuric acid was added to form completely silicic acid. This solution was then filter with pulp. Finally the pulp was combusted. Similarly, this procedure was followed for the both samples. The chemical analysis of representative samples of local sand is shown in Table 1.

Table 1 Chemical Analysis of Representative Samples

Type of sample	% Silica without washing	% Silica with washing
Sample-A	73.2	78.6
Sample-B	64.5	70.1

From the table 1, it is observed that the sample A contains more silica % than that of sample B. That's why sample A was selected for this work. The completely dry washed sand and various percentages of additives were taken together in a smooth plastic plate so that they were mixed very well to maintain uniform mixture. Then the twelve green specimens were made separately by using 5%, 7% and 10% of binder with the addition of 5 cm^3 of water. Water is added to the mixture to provide sufficient bonding among the particles so that these can be held together during moulding. The specimens were prepared in a rectangle shape by hand moulding process. A mould of rectangle shape with a rectangular base and a hammer were used for the preparation of these specimens. The die was split into two parts in order to facilitate the removal of these specimens. The dimensions of these specimens such as length, width and height were measured in green condition. These specimens were firstly sun dried for two weeks and dried at 100^oC in an oven furnace. Drying silica specimens to ensure complete reaction of CaO with water, and then the specimens hardened. Maximum drying temperature was 100^oC for eight hour. Again, the measurements of these specimens were taken after completing oven dried. Then the volume of the specimens was calculated. The drying shrinkage value was obtained from the taken two measurements before and after oven dried.

The temperature was varied at a rate of 5^oC per minute and approximately six oven dried specimens were fired at 1100^oC. The structures of the specimens became collapsed during the period of handling. Repeatedly, six oven dried specimens became fused when operated at 1300^oC for 5 hour.

Fig. 2 Collapsed Structures Of Specimens Fired at 1100^oC

Again, total twelve numbers of green specimens were prepared by the following procedure. In the same way as above, the green specimens was processed at 100^oC in an oven and at 1200^oC in a furnace and got the desired bricks. The dimensions of the manufactured bricks such as length, width and height were measured before and after firing the oven dried specimens at 1200^oC. Desired structures of bricks fired at 1200^oC for 5 hour is shown in Fig. 4. The various tests were carried out on these selective specimens to determine the different properties such as shrinkage, porosity and compressive strength in the manufactured silica bricks.

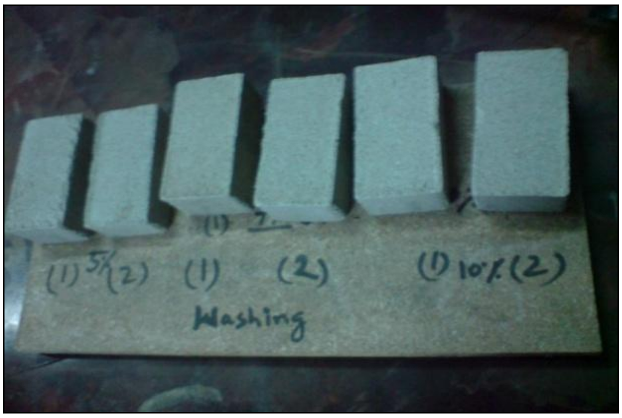

Fig. 3 Desired Structure of Silica Bricks Fired at 1200^oC for 5 h

III. RESULTS AND DISCUSSION

The main purpose of this experiment is to analyze the percentage of silica and the economical temperature range of the refractory bricks manufactured from locally available sand in which temperature silica bricks are sustainable with the desired properties. The rate of temperature increase was carefully controlled up to 1100^oC; the temperature was varied at a rate of 5^oC per minute in order to avoid cracks formation in the production as result of the volume changes during the quartz inversion taking place at those temperature ranges. The specimens were fired in various ranges of temperature. Firstly, the specimens were fired at 1100^oC for 5 hours. The specimens became collapsed during handling because no diffusion occurs and no chemical bonding form at this temperature. As a result, the vulnerable structure was formed. Secondly, the specimens were fired at 1300^oC. In this case, the specimens became fused

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because the presence of alumina and other impurities made the fusing point decrease although the melting point of pure silica is approximately 1400°C.

From the Fig. 4, it is observed that the drying shrinkage has reduced after sun dry and oven dry at 100°C for both the washed and as received specimens. Different types of pores within structures are filled up with the particles of additives. But, the washed specimens show less shrinkage than that of as received specimens because the presence of more clay and impurities is found in the as received one.

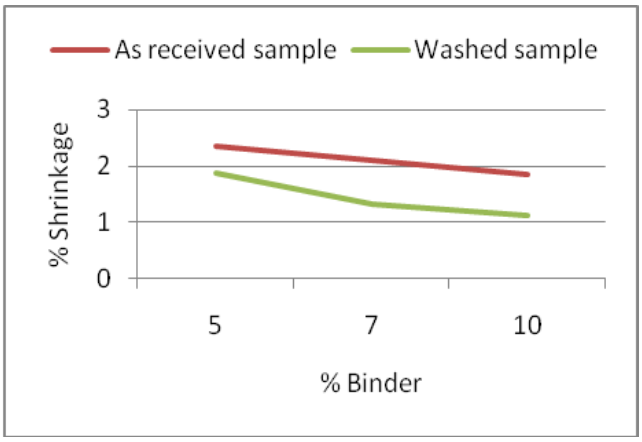

Fig. 4 Relation Between Binder and Drying Shrinkage Of Specimens' Oven Dried at 100°C

The effect of binder on the firing shrinkage of bricks fired at 1200°C is shown in Fig. 5. Firing shrinkage for both the washed and as received specimens gradually decreases with the addition of binder because the various types of pores within the structures are filled up with the particles of binder. Sufficient sintering temperature is also more responsible to form bonding among the particles of silica and additives. The gap from atoms to atoms minimizes with the addition of particles of various additives. The washed specimens show less firing shrinkage than that of the as received specimens because the as received specimens consist of small amount of clay, impurities, no water and almost all types of volatile materials have been blown out at 1200°C.

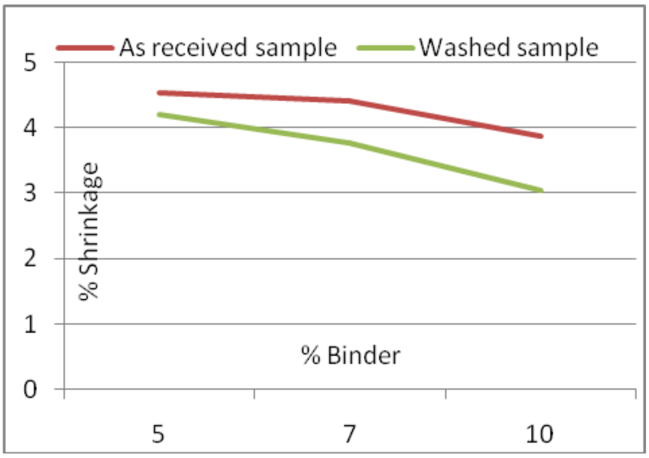

Fig. 5 The Effect of Binder on The Firing Shrinkage of Bricks Fired at 1200°C

Effect of binder (lime) on the average porosity of the silica bricks fired at 1200ºC is shown in Fig. 6. The porosity for washed and as received specimens has reduced constantly because the voids among the particles of sand are filled up with the addition of the particles of binder (lime). But, regarding the matter of 10% binder, the porosity of washed specimens has increased due to non-uniform mixture or non-uniform pressing of a hammer.

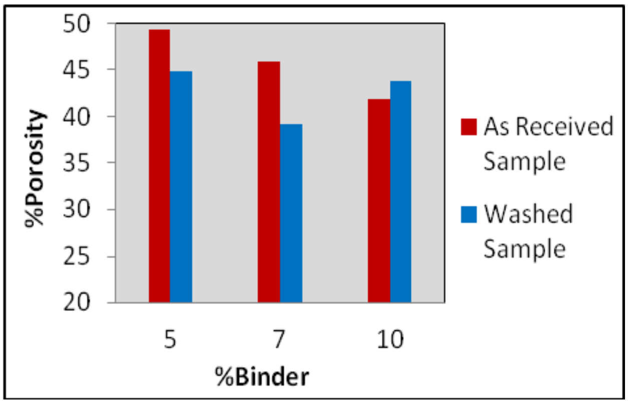

Fig. 6 Effect of Binder (lime) on Average Porosity of the Silica Bricks Fired at 1200ºC

Effect of binder (CaO) on the average cold crushing strength of the silica bricks fired at 1200ºC is shown in Fig. 7. Usually, the greater cold crushing strength is obtained for the washed specimens than that of the as received specimens. It is due to the presence of a fewer amount of impurities in the washed specimens. Consequence, the bonding amongthe particles of sand and lime is relatively stronger and results in a relatively higher cold crushing strength. But a slightly fluctuation of strength is observed for the washed specimens whereas the compressive strength drop for the addition of 7% lime. This drop is because of increasing porosity and due to a loosening of the structure, which is caused by the tridymite and crystobalite conversion [5] and it has happened because of non-uniform mixing and pressing. The volume changes accompanying it strength increase constantly with the addition of binder percentage [6, 7]. It is supposed to be sufficient sintering temperature to form bonding stronger among the particles of silica and additives. Sintering which is more responsible process, starts with bonding among particles as the materials heat up. Bonding involves diffusion of atoms where there is intimate contact between adjacent particles leading to the development of grain boundaries. This stage results in a relatively large increase in strength and hardness, even after short exposures to an elevated temperature [8].

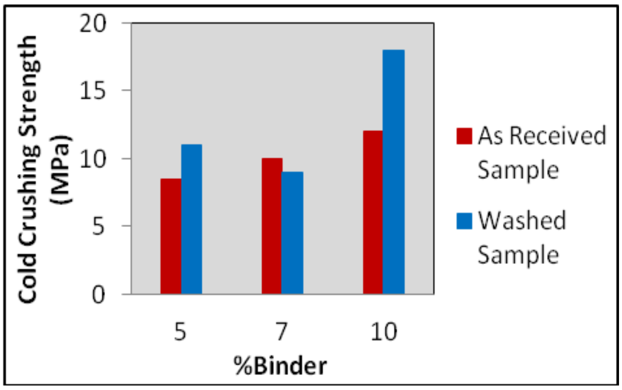

Fig. 7 Effect of Binder on the Average Cold Crushing Strength of the Silica Bricks Fired at 1200ºC

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IV. CONCLUSION

It is possible to produce silica refractory bricks of suitable quality with a combination of local white sand and lime (CaO). The drying and firing shrinkage and porosity result in reduction constantly with increasing the amount of binder for the washed and as received specimens but as received specimens show a slightly fluctuation of porosity and more shrinkage than that of washed specimens. The cold crushing strength for both the washed and as received specimens is found to increase with the addition of lime but the washed specimen's show more strength than that of the as received specimens.

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