Proceedings of the International Seminar on Mineral Processing Technology - 2006, Chennai, India. pp. 320 - 327.

Development of a Beneficiation Flow Sheet for Processing Silica Sand from Chertala Area of Kerala

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Abstract

The silica sand from Chertala area of Alappuzha district has been reported to be of good quality. Presently, it is mined and transported to destinations inside and outside the State without any processing. A project on beneficiation/value addition of this sand was taken up as per the request from Directorate of Industries and Commerce, Govt. of Kerala.

Objective of the project is to develop a flow sheet for the total utilization of all fractions of this sand. The aim is to value add the same to produce special grade glass making sand according to BIS specifications (IS:488-1980), a suitable fraction for foundry application as per IS:3018-1977 and also to recover the finer fractions of sand and heavy minerals which are below 180μm and constitutes about 14% by weight. However, only the first two objectives are covered in the present work.

Representative samples of raw sand were collected from three locations from the coastal tract of Vembanattu backwaters. Samples are labeled as A (Panambukattuveli Mines), B (Hyma Mines) and C (Palakkal Mines). Preliminary chemical analysis showed that while samples A and B contained 96.3 and 96.7 % of SiO_2 *the corresponding value for C is higher i.e., 98.4%. Since C was purer than A and B, only the latter two are taken for processing studies. The silica values are almost identical for these two samples, and hence, these were blended on equal weight basis.*

The blended raw sample analysed 96.5% SiO_2 *and ancillary impurity minerals were assayed as 0.327%* Fe_2O_3*, 0.345%* TiO_2 *and 0.936% of* Al_2O_3*. This was dry-sieved using a set of 10 number of standard +GF+ test sieves with top screen as 1400 μm and bottom one as 63μm and chemical analysis were carried out in order to understand the mineral distribution in each fraction. While the silica content gets reduced, the assay of impurity minerals gradually increased as the fractions become finer and finer.*

In order to value-add the sand, wet sieving was done followed by chemical analysis of desired fractions (Actual desired fractions are –600,+300μm = 50%, Max. and –300,+125μm =50%, Min.). Special grade glass sand requires minimum 99% SiO_2 *with a maximum permissible iron content of 0.02%. Since these fractions were in the ratio 1:3.2 respectively in the raw sand, same proportion was maintained in the desired fractions also. It could be seen that the high percentage of iron, titania and other minerals in the desired fractions was mainly due to the higher content of these minerals particularly in –180,+125μm fraction which constitute about 6.3% by weight. Hence this fraction was eliminated. Thus the wet-sieved 'modified desired fractions' now constitute only –600,+300 and –300,+ 180μm which was about 80% of the total raw sand. The wet sieved 'modified desired fractions' (WSMDF) analysed 99% silica, 0.03%*

Fe_2O_3, 0.09% TiO_2 and 0.39% Al_2O_3. This satisfies only Grade I specifications (SiO_2 –98.5% Min. and Fe_2O_3 - 0.04% Max.). In order to further value add WSMDF, the same was subjected to attrition followed by magnetic separation. Attrition for 15 minutes using PE075 mill with magnesia stabilized alumina attrition media liberated some more iron minerals from the sand particles. Sieving on 125μm sieve removed most of the iron impurities and the small percentage of over-ground silica sand. In the subsequent wet magnetic separation using a Carpco high intensity magnetic separator, remaining iron minerals were captured and removed. Incidentally, the magnetic portion (iron impurities) was found to contain all particles below 45μm. The attrition media is separated from the sand sample before feeding to the magnetic separator. Tests at optimum conditions gave a non-magnetic fraction (sand product) which analysed 99.5% silica with 0.017% Fe_2O_3. The product is found to satisfy all other specifications such as loss on ignition (LOI), TiO_2 etc. as per BIS standards for special grade glass sand. The modified desired fractions without subjecting to attrition and magnetic separation was found matching with IS specifications for foundry sand application also.

Based on the laboratory studies, a flow sheet for producing special grade glass sand has been designed which consists of unit operations such as scrubbing with water, wet screening in two stages at 600 and 300 & 180μm (single deck and double deck vibrating screens), attrition, screening using 600μm screen to remove the attrition media, wet screening using a 125 μm screen so as to remove over-ground sand and the iron impurities together, wet magnetic separation to remove the final traces of iron minerals and finally dewatering using hydrocyclones and spiral classifiers.

Keywords : *Silica sand, beneficiation, magnetic separation, attrition, screening.*

INTRODUCTION

Perhaps the first mineral man started to use in his earlier days of civilization should be silica. Hard rock such as quartzite and hard minerals such as quartz, flint, chert etc had been commonly used by man in Palaeolithic Age as weapons. In Neolithic or New Stone Age, man appears to have learnt the art of grinding, grooving and polishing stones like flint, quartz, chert etc.

Of all the non-metallic minerals, silica sand has the most diversified use. This is because of its common occurrence around the world, distinctive physical characteristics such as hardness, chemical and heat resistance as well as low price. Silica bearing rocks and minerals such as quartz, quartzite, silica sand together with other varieties of silica like agate, amethyst, jasper, flint etc. are used in a host of industries such as glass, ceramics, foundries, ferro-alloys, abrasives, refractories, ornamentation etc. One of the first to use silica sand is the glass industry. At least 4000 years ago, long before iron was smelted, glass-making was already a known craft. The oldest known specimens of glass was obtained from Babylon (2600 B. C.) and from Egypt (2500 B. C.). It could be conclusively proved that the glass-making was well established in these countries by around 1500 B. C. (IBM, 1993)

The silica sand is an assemblage of individual silica grains in the size range upto 2 mm. Sand can be formed in nature by natural weathering of sandstone and quartzite or mechanically by crushing a sandstone /quartzite or by a process of flotation whereby the various constituents in a pegmatite or kaolin mixture are separated. The occurrence of silica sand in world is widespread and extensive. Good quality silica sand reserves are situated in UK, Germany, Belgium, France, Brazil etc. Silica sand deposits are available almost in all the states of India. Important deposits are in Andhra Pradesh, Bihar, Goa, Gujarat, Haryana, Karnataka, Kerala, Madya Pradesh, Rajasthan, TamilNadu and Uttar Pradesh. Haryana is the leading producer followed by UP and Maharashtra. In Kerala silica sand occurs mainly in Alappuzha and Kollam districts in the coastal belt. The total reserves are estimated to be 105 million tons out of which most of the silica sand production is reported from Alappuzha. The important producing areas are Panavally, Pallipuram, Thycattussery and Kokkathamangalam in Chertala Taluk. The estimated reserves is about 103 million tons in this area.

The uses of silica sand depend on its mineralogy, chemistry and physical properties. It is mainly used for making glass and glass fibre, silicon carbide, sodium silicate, Portland cement, silicon alloys and metals, filter media in water treatment, sand paper and also for foundry sand, hydraulic fracturing, sand blasting, paint and a host of other applications.

Impurities usually present in the silica sand are free and coated iron oxides, clay, titania and smaller amounts of sodium, potassium and calcium minerals. The iron, being the most detrimental impurity, can be reduced by a number of physical, physico-chemical or chemical methods, the most appropriate method depends on the mineralogical forms and distribution of iron in the ore (Taxiarchaou et al., 1997; Farmer et al., 2000; Ay and Arica, 2000). Upgrading of silica sand requires partial removal of iron, and other minerals which are detrimental to its end use. While much of the liberated impurities can be reduced or removed by physical operations such as size separation (screening), gravity separation (spiral concentration), magnetic separation etc., some times, physico-chemical or even chemical methods are to be adopted for the effective removal of iron which may be in intimate association with the mineral.

The open cast mining of Chertala silica sand is being carried out for many decades. However, no concentrated effort is made so far for processing and value adding the same so that the State gets a better revenue for its mineral resource. The present work is aimed at the total utilization of the sand by separating and concentrating the available minerals in the raw sand.

EXPERIMENTAL

Feed Material

The feed material is a blended (50:50) sample of representative raw sands from two deposits at Chertala, Kerala viz., Panambukkattuveli and Hyma mines. About 100 Kgs. of each of the sample is mixed by centre displacement method so as to obtain apparently a uniform blend. The blended raw sample was characterized by XRD and chemical analysis. XRD pattern showed the presence of ilmenite, rutile, anatase, zircon, sillimanite besides large presence of silica. The sample analysed 96.5% SiO_2, 0.327% Fe_2O_3, 0.345% TiO_2 and 0.936% of Al_2O_3. The petrological and microscopic studies at Directorate of Mining and Geology, Govt. of Kerala (DMG) revealed that iron oxides are present both in free form and as well as stains mainly on the surface of the silica sand grains (DMG report, 1998). No reagent was used for the processing tests.

Apparatus

A standard set of +GF+ dry sieves, a few number of BS sieves for wet-sieving were used. The attrition was done using a PE075 agitated ball mill from Netzsch, Germany. A 3x4L, wet high intensity magnetic separator from Carpco was used for magnetic separation tests.

Procedure

The blended raw sample, at first, was subjected to dry sieve analysis using a set of +GF+ test sieves for a fixed period. Later on, the blended raw sand was wet-sieved using 600,300,180 and 125 test sieves so as to isolate the 'desired fractions'(Desired fractions are –600,+300μm = 50%, Max. and –300,+125μm =50%, Min.). Since the iron and titania contents were high in –180,+125 fraction, this was eliminated. The 'modified desired fractions' now consists of –600,+300 and –300,+180 micron only. This modified desired fractions are further subjected to attrition milling followed by magnetic separation to obtain a product sand suitable for special grade glass making as per BIS specifications (IS:488-1980). The modified desired fractions (with out attrition and magnetic separation) was also tested for raw material testing in foundries and found to satisfies BIS specifications (IS:3018-1977). Table 1 give the specification for glass making sand while Table 2 gives that for raw material testing in foundries.

Table 1: Indian Standard Specifications for Glass Making Sand – 2nd Revision [IS 488: 1980]

Sl No.	Characteristic (% by mass)	REQUIREMENT			
		Special Grade	Grade 1	Grade 2	Grade 3
1	Loss on ignition, Max.	0.5	0.5	0.5	0.5
2	Silica (as SiO_2), Min.	99.0	98.5	98.0	97.0
3	Iron Oxide (as Fe_2O_3), Max.	0.02	0.04	0.06	0.10
4	Aluminium Oxide (as Al_2O_3), Max.	*	*	*	*
5	Titanium Dioxide (as TiO_2), Max.	0.10	0.10	0.10	*
6	Manganese Oxide (as MnO)	To pass the test	To pass the test	To pass the test	To pass the test
7	Copper Oxide (as CuO)	To pass the test	To pass the test	To pass the test	To pass the test
8	Chromium Trioxide (as Cr_2O_3)	To pass the test	To pass the test	To pass the test	To pass the test
* These requirements shall be as agreed to between the purchaser and the supplier					

Table 2: Indian Standard Specifications for Standard Silica Sand for Raw Material Testing in Foundries [IS 3018: 1977] – Grain Fineness Grading

Sl. No	IS Sieve, Microns	Percent Retained
1	600	1.0, Max.
2	425	9 to 14
3	300	20 to 30
4	212	30 to 40
5	150	15 to 25
6	106	2.0, Max.
7	75	1.0, Max.
8	Pan	0.1, Max.

RESULTS AND DISCUSSIONS

Preparation of Special Grade Glass Making Sand

Dry Sieving

The dry sieving of the blended raw sand sample (Table 3) was carried out in order to understand the fractional mass distribution as well as fractional mineral distribution by chemical analysis. Results showed that about 12% is above 710μm which has to be discarded as oversize. The weight fraction below 120μm is only about 0.7% which contains a good percentage of black heavy minerals (>20% TiO_2). About 80% of the material is in the size range –500, +180μm which is, incidentally, within the desired fractions for glass making sand. The fractional chemical analysis revealed that the silica assay remains more or less constant at about 96.5-97.5% up to 180μm, but drastically reduces below this size towards lower values. Ancillary mineral impurities such as heavy minerals (TiO_2), clay/ sillimanite (Al_2O_3) and salts of calcium and sodium etc, on the other hand, showed an increase towards finer fractions. The reduction of percentage of silica in –180,+125 μm and below is primarily due to the increased presence of clay and heavy minerals in these fractions.

Table 3: Dry Sieving and Fractional Chemical Analysis of Blended Raw Sand Sample

Sieve Size, μm	%Wt.	SiO_2	Fe_2O_3	TiO_2	Al_2O_3	CaO	Na_2O	K_2O	LOI
-1440,+1000	0.3	......	....	......	....	....	......	....	....
-1000,+710	2.8	97.5	0.299	0.145	0.978	0.260	0.317	0.059	0.271
-710,+500	9.2	97.4	0.237	0.091	0.395	0.202	0.243	0.026	0.281
-500,+335	20.3	97.4	0.270	0.092	0.166	0.234	0.309	0.042	0.306
-335,+250	38.9	96.8	0.559	0.148	0.912	0.193	0.252	0.036	0.229
-250,+180	21.4	96.5	0.243	0.236	1.098	0.217	0.242	0.039	0.197
-180,+125	6.3	92.3	2.000	2.895	10.18	0.394	0.538	0.142	0.400
-125,+90	0.7	68.3	11.3	20.1	24.5	1.150	0.989	0.163	1.17
-90	0.1	49.4	14.5	21.6	25.6	1.141	0.862	0.249	1.43

Wet Sieving

Wet sieving was carried out in tune with the requirements for glass making sand and hence the sieves were selected as mentioned in the procedure. The data is given in Table 4. Analysis showed that the iron content in first two desired fractions are below 0.03% while that of the third fraction is more than 16 times of the first two; i.e., about 0.48%. The titania was also found very high in this fraction. This was also found to constitute about 13% by weight fraction. In order to reduce the influence of iron in the 'actual desired fractions', it was decided to eliminate the third fraction. It could be seen that even removing this, the fractional proportion for glass making sand is maintained within specified limits. Thus the 'modified desired fractions' for glass making now constitutes only –600,+300 and –300,+180 microns. These fractions were in the weight ratio 1:3.2 respectively and is found to be about 80% of the total raw sand.

Table 4: Wet Sieve Analysis of Blended Raw Sand Sample Characterization of 'Desired Fractions'

Sieve Size, μm	%Wt.	SiO_2	Fe_2O_3	TiO_2
+600	6.0	....	....	......
-600,+300	18.9	99.4	0.0275	0.078
-300,+180	60.7	98.9	0.0293	0.092
-180,+125	12.7	96.5	0.4791	0.345
-125	01.7	......	......	......

The 'modified desired fractions' analysed 99% SiO_2 and 0.028% Fe_2O_3 and 0.09% TiO_2. The characterization of this material is given in Table 5. Though the same satisfies grade 1 sand (Minimum 99% SiO_2 and maximum 0.04% Fe_2O_3 and 0.1% TiO_2), quality was not enough for special grade sand. Hence the modified desired fractions from wet sieving was subjected to further processing.

Table 5: Characterisation of 'Modified Desired Fractions'

Sieve Size,	%Wt.	SiO_2	Fe_2O_3	TiO_2	Al_2O_3	LOI
μm	(% w/w)					
-600,+300	18.9	99.4	0.0275	0.078	0.15	0.34
-300,+180	60.7	98.9	0.0293	0.092	0.51	0.42
Combined	79.6	99.1	0.028	0.090	0.37	0.36

Attrition and Magnetic Separation

Since the combined iron was found to be mainly as coating on the surface of the sand grains, it was decided to go for attrition followed by magnetic separation. Attrition tests carried out by varying the slurry solid content from 10% to 50% showed that the optimum solid concentration is about 45%. The attrition was not possible above a solid loading of above 50%. Similarly, a time of about 15 minutes was found to get an iron value below 0.02% which was the specification for the special grade glass sand. Standard conditions were maintained for the magnetic separation. Salient data are given in Table 6 and 7 and corresponding plots in Figs. 1 and 2.

Table 6: Influence of Solid Loading on Attrition and Impurity Removal

Solid loading, Wt%	Non-magnetic product		
	%SiO_2	%Fe_2O_3	%TiO_2
15	99.3	0.0210	0.046
35	99.6	0.0156	0.044
45	99.6	0.0131	0.040
55	99.6	0.0122	.....
60	Could not subject to attrition due to high friction		

Fixed conditions: Attrition time –10minutes

Magnetic separation : Magnetic field (equivalent currents in Amp.) – 3.2

Medium : Iron balls (diameter of 6.3 mm)

Table 7: Influence of Attrition Time on Impurity Removal

Attrition time, minutes	Non-magnetic product		
	%SiO_2	%Fe_2O_3	%TiO_2
5	99.45	0.0250	0.050
10	99.52	0.0193	0.048
20	99.56	0.0153	0.050
30	99.51	0.0105	0.006

Magnetic separation : Magnetic field (equivalent currents in Amp.) – 3.2

Medium : Iron balls (diameter of 6.3 mm)

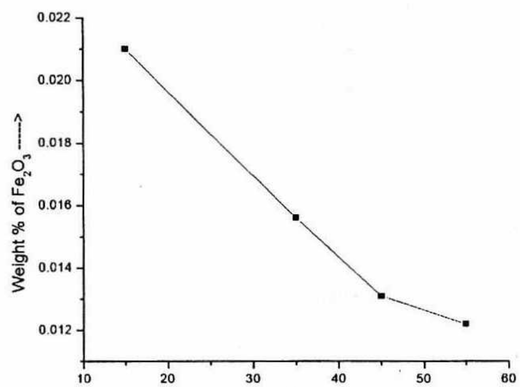

Fig. 1: Influence of Solids Loading on Attrition and Impurity Removal

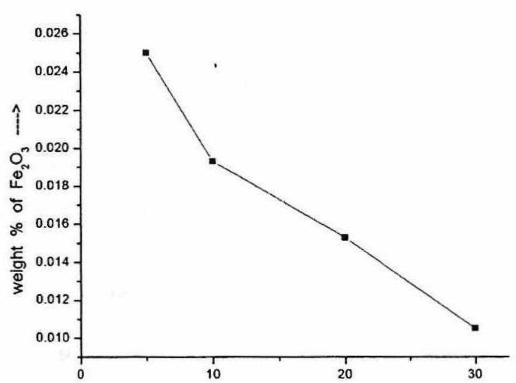

Fig. 2: Influence of Attrition Time on Impurity Removal

PREPARATION OF FOUNDRY SAND

The modified desired fraction was subjected to different tests to check its suitability for using the same as raw material testing in foundries. It has been seen that the same satisfies the specifications for the uses as foundry sand.

Table 8: Tests for the Suitability of the Sand Sample for Foundry Applications

Sl. No.	Tests	Sample	As per IS Specifications
1	Grain size	Wt. %	Wt. %
	+ 600 μm	0.55	1.0, max.
	-600, +425 μm	14.38	9-14
	-425, + 300 μm	20.70	20-30
	-300, + 212 μm	48.50	30-40
	-212, +150 μm	12.28	15-25
	-150, + 106 μm	1.85	2.0, max.
2	Clay content, %	0.05	0.1
3	Acid Demand value, mg/100 g of sand	0.4	8.0
4	Grain Shape (Degree of Angularity)	1.4	1.4 – 1.5

SUGGESTED COMMERCIAL FLOW SHEET

Based on the laboratory processing studies conducted on the blended sand sample collected from Chertala area of Kerala, a beneficiation flow sheet is suggested as follows.

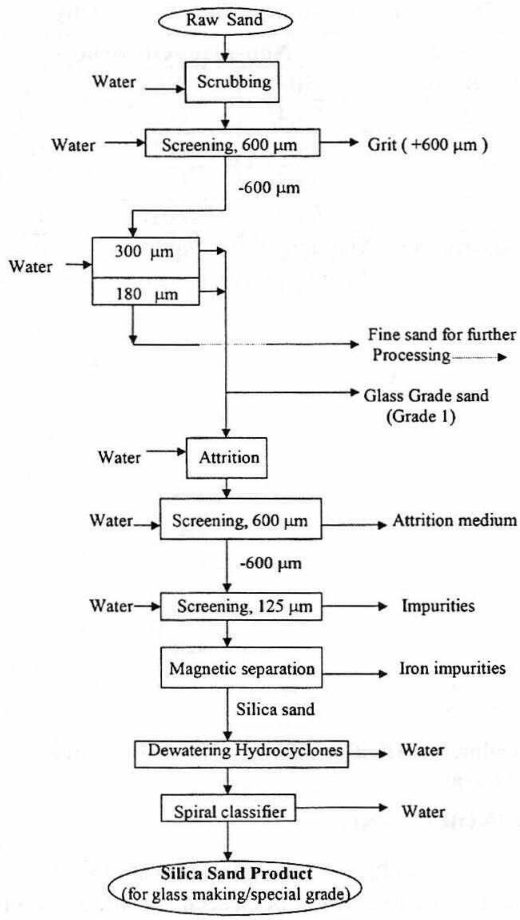

Fig. 3: Integrated Flow Sheet for the Processing of Silica Sand for Special Grade Glass Making

The sand collected from the two mines is either blended in any proportion or taken individually and is first wet-screened using a single deck vibrating screen having a 600 μm screen. The oversize is discarded while the undersize is pumped to a second stage double deck vibrating screen fitted with 300 and 180 μm screens. While the fraction below 180 μm is taken out separately, the modified desired fractions are sent to the attrition mill. The attrition can be done either in batch or continuous way. The attrited sand slurry is screened using a vibrating screen fitted with 600 μm screens. Once the attrition media is removed , the slurry is, again, passed through 120 μm screens so as to remove the slimes which contains a major portion of the liberated iron and some broken attrition media as well as over-milled silica sand particles. This slurry is passed through wet magnetic separators to remove the remaining iron impurities. The non-magnetic slurry from the magnetic separator is sent to hydrocyclones for first stage de-watering and finally to a spiral classifier for final dewatering. The integrated flow sheet is given in Fig. 3.

CONCLUSION

Laboratory processing studies carried out on a sand sample from Chertala region of Kerala shows that the main impurity is iron and titania minerals. While wet sieving removes a fraction of these contaminating minerals, attrition and magnetic separation is required to upgrade the same to special grade glass making sand. The wet-sieved sample with out subjecting to attrition and magnetic separation is found to satisfy the specifications for foundry sand also. Based on the laboratory study, a commercial beneficiation flow sheet is also suggested for the up-gradation of this sand.

ACKNOWLEDGEMENT

The authors are grateful to the sponsors, Directorate of Industries and Commerce, Govt. of Kerala for the financial support for the work. They are also thankful to Prof. T. K. Chandrashekar, Director, RRL, Trivandrum for the permission to publish the same.

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