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BENEFICIATION STUDIES ON BEACH PLACER SAMPLE FOR STEEL MAKING INDUSTRIES

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Abstract

Beneficiation studies were carried out on the Talashil beach placer sample of South Maharastra Coast, India. The sample contains magnetite, ilmenite, rutile, hematite, goethite and chromite as opaque minerals in the sample. The total heavy minerals fraction reaches 53.8 % by weight whereas the total magnetic minerals are 56.9%. It is observed that the 2nd stage DHIMS magnetic fraction contains 65.2 % Fe_2O_3 with an over all yield of 37.8 % and a 86 % recovery from a containing 26.8 % Fe_2O_3 feed. This product can be used in the pellet feed for steel making after suitable blending with high-grade iron ore fines.

Key words: *Beach placers, Maharastra coast, Magnetic and high tension separation.*

1. Introduction

Heavy minerals occurring in the beach placer commonly known as “black sands” (due to the colour of ilmenite and/or rutile/magnetite) are known to occur in different parts of the world. In India, these black sand deposits are known to occur along the West coast (Maharastra, Goa, Karnataka and Kerala) as well as along the East coast of India (Parts of West Bengal, Orissa, Andhra Pradesh and Tamilnadu). Occurrences of black sands along Maharastra coast were known for a long time [1 – 9]. However, these studies were restricted to geological, geophysical and geochemical characteristics of placer minerals and there is no literature on the feasibility studies for beneficiation. Hence, the present study is taken up for detailed mineralogical studies and its consequences for beneficiation.

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2. Materials and methods

The "as received" samples were thoroughly mixed and a representative bulk sample was prepared for beneficiation studies. The particle size analysis of the sample was carried out using standard sieves. Sink-float studies were carried out using bromoform (Specific gravity 2.89). In order to recover total magnetic minerals, different types of dry drum magnetic separators were used. The rare earth drums (6T and 14T), permanent magnetic separators of laboratory model Box Mag Permaroll, magnetic separator (Dry Low Intensity Magnetic Separator, DLIMS and Dry High Intensity Magnetic Separator; DHIMS) were also used to recover total magnetic minerals. Carpco High Tension laboratory device was used to separate conducting minerals (ilmenite) from other magnetic minerals (magnetite, chromite etc.,). X-ray diffraction (XRD studies) using PANanalytical (X'pert) powder diffractometer, (scan speed-1.2°/min from 6° to 40°, under Mo Kα radiation (wavelength 0.71Å) was used to identify the mineral phases in the corresponding fractions.

3. Characterisation studies

3.1. Physical characterisation

Physical characteristics and chemical composition of the bulk sample is presented in Table 1. The TiO_2 and Fe_2O_3 content are respectively 14.2 % and is 26.8 % in the feeding sample.

Table 1. *Physical and chemical analysis of the bulk sample*

Physical characteristics	
Nature of the sample	Free flow grains, black to brownish colour
Bulk density (g/cc)	2.2
Specific gravity	2.9
Porosity, %	24.1
Angle of repose, degree	32.44
Chemical characteristics	
TiO_2	14.2 %
Fe_2O_3	26.8 %

The particle size analysis of the sample is given in Table 2. Most of the particles are accumulated in size range of 300-90 micrometers. The fines (-75 microns) are 1.6 % by weight.

Table 2. *Size analysis of the bulk sample*

Size in microns	Weight %	Cumulative weight % passing
-1000+500	0.8	100.0
-500+300	5.2	99.2
-300+210	35.8	94.0
-210+150	11.0	58.2
-150+90	41.6	47.2
-90+75	4.0	5.6
-75+53	0.8	1.6
-53	0.8	0.8
Total	100	-

The sink–float data on four representative samples of the bulk are given in Table 3.

The total heavy fraction varies from 53.1 to 55.2 %.

Sink-float data on close size fractions given in Table 4 what indicates that the maximum amount (37.8 %) of total heavy minerals ranges from 150 to 90 micrometers. The total amount of heavy minerals present in the different size fractions of the sample is 53.2 % by weight.

Macrosopically the sample consists of dark (opaque as well as silicates) and light coloured (silicate) minerals and is mostly medium to fine grained.

The representative bulk sample was subjected for magnetic separation studies and heavy media separation. Heavy media separation studies indicated that the total heavy mineral content is 53.8 % while the total magnetic mineral content is 56.9 %. X-ray diffraction pattern studies of the magnetic, non-magnetic, sinking as well as floating fractions (Fig. 1) of the sample confirmed the microscopic findings.

4. Beneficiation studies

4.1. Studies on DLIMS and Electrostatic separation

In order to recover minerals by low intensity magnetic separation, such as magnetite and ilmenite, dry low intensity magnetic separator (6T) was used.

Table 3. *Sink-float studies on the four representative bulk samples*

Details	Sample 1	Sample 2	Sample 3	Sample 4	Average
	In weight %				
Sink	53.0	54.4	55.2	53.1	53.2
Float	47.0	45.6	44.8	46.9	46.8
Total	100.0	100.0	100.0	100.0	100.0

Table 4. *Results of sink-float studies on close sized fractions*

Size, μm	Feed weight %	Sink- float	Weight %	Weight distribution % (THM)
-1000+300	6.0	Sink	10.0	0.6
		Float	90.0	
		Total	100.0	
-300+150	46.5	Sink	21.9	10.2
		Float	78.1	
		Total	100.0	
-150+90	41.6	Sink	90.9	37.8
		Float	9.1	
		Total	100.0	
-90+53	4.8	Sink	96.7	4.6
		Float	3.3	
		Total	100.0	
Total	99.2			53.2

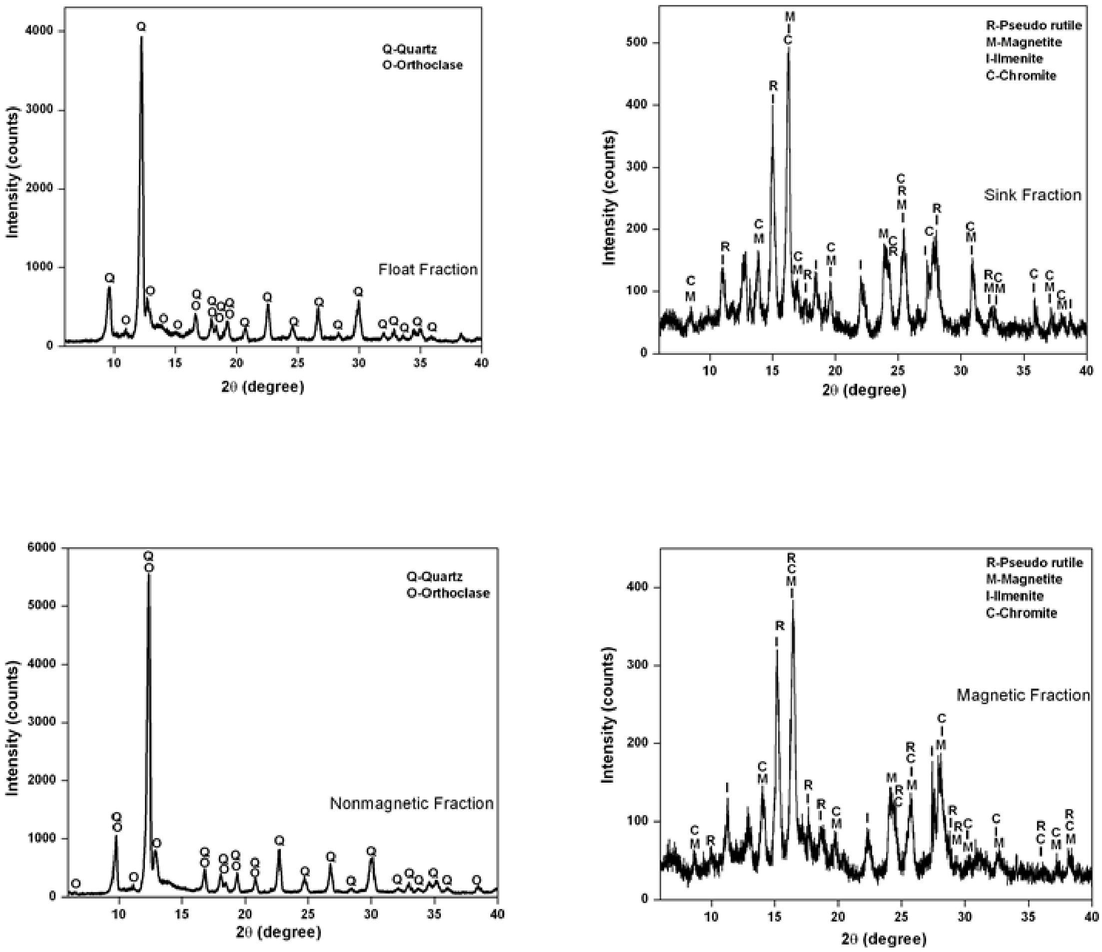

Figure 1. *XRD pattern of sink-float as well as magnetic and non-magnetic products*

The results of DLIMS are given in Table 5 and the data indicate that the magnetic fraction reaches 26.1 % by weight with 66.3 % Fe_2O_3 and 25.6 % TiO_2. This low intensity magnetic fraction was further subjected to Carpco high-tension separator, to recover ilmenite as conducting fraction and magnetite as non-conducting fraction. It is observed from the data (Table 6) that both the conducting fraction and non-conducting fraction contain from 66.9 % to 65.2 % Fe_2O_3 and 24.7 % to 27.3 % TiO_2. Thus the data indicate that both the fractions contain minerals with high iron and titanium content, it can be concluded that the ilmenite (conducting fraction) may contain magnetite within the structure or magnetite (non-conducting fraction) may contain ilmenite within the structure.

Table 5. *Results of dry low intensity magnetic separator (6T)*

Details	Weight, %	TiO_2, %	Fe_2O_3, %	Recovery, Fe_2O_3, %
Magnetic	26.1	25.6	66.3	65
Non-Magnetic	73.9	10.2	12.8	35
Total	100.0	14.2	26.8	100

Table 6. *Results of HTS on LIMS magnetic fraction*
Feed: LIMS magnetic fraction, wt. dist: 26.1% (Table 5)
Drum speed: Minimum speed (100 rpm)

Details	Weight, %	Weight distribution, %	TiO_2, %	Fe_2O_3, %	Recovery, Fe_2O_3, %
Conducting	64.9	16.9	24.7	66.9	42
Non Conducting	35.1	9.2	27.3	65.2	23
Total	100.0	26.1	25.6	66.3	65

The non-magnetic fraction of DLIMS was ground to a d_{80} passing size of 50 microns and subjected to a dry high intensity magnetic separation (14T). The results of magnetic and non-magnetic fractions of DLIMS are given in Table 7. It is observed from the data that the magnetic fraction contains 65.2 % Fe_2O_3 and 25.1 % TiO_2 and the non-magnetic fraction contains 1.7 % Fe_2O_3 and 7% TiO_2. The combined product (Table 8) obtained from DLIMS and DHIMS contains 39 % by weight with a 65.9 % Fe_2O_3 amount and a 96 % recovery. These data can clearly be seen from the flow-sheet where the mass balance is shown (Fig. 2).

Table 7. *Results of DHIMS on LIMS Non-magnetic ground product*
Feed: LIMS Non-magnetic fraction, wt. dist: 73.9% (Table 5)
Drum speed: Minimum speed (100 rpm)

Details	Weight, %	Weight distribution, %	TiO_2, %	Fe_2O_3, %	Recovery, Fe_2O_3, %
Magnetic	17.5	12.9	25.1	65.2	31
Non Magnetic	82.5	61.0	7.0	1.7	4
Total	100.0	73.9	10.2	12.8	35

Table 8. *Combined products of DLIMS and DHIMS magnetic fractions*

Details	Weight, %	TiO_2, %	Fe_2O_3, %	Recovery, Fe_2O_3, %
Magnetic-1	26.1	25.6	66.3	65
Magnetic-2 (ground product)	12.9	25.1	65.2	31
Total	39.0	25.4	65.9	96

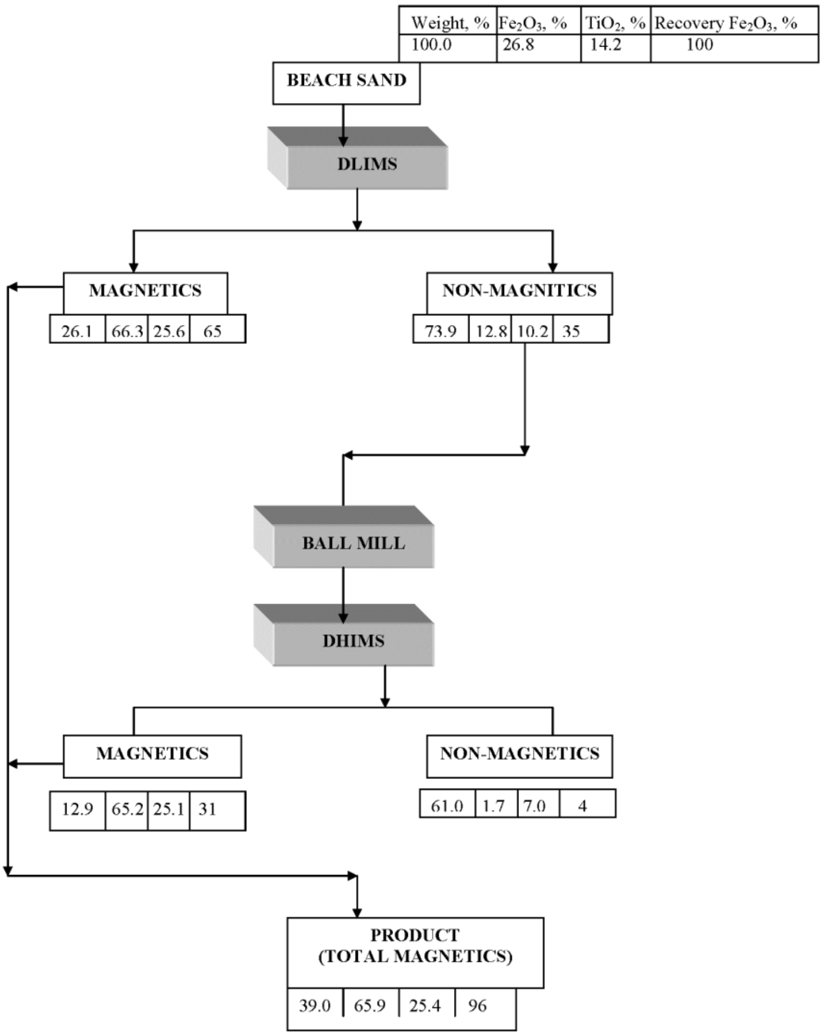

Figure 2. *Recovery of iron values from the beach sand in combination of dry low and high intensity magnetic separators*

4.2. Studies on Dry High Intensity Magnetic Separation

The results of Dry High Intensity Magnetic Separation (DHIMS) studies on four representative samples are given in Table 9. The data indicate that the total magnetic mineral percentage varies from 55.2 % to 56.7 % only. The results of DHIMS on close size fraction are given in Table 10 which indicates that most of the magnetic minerals are present in the 150-90 micrometers particle size fraction. At this size range, the total amount of magnetic minerals is 38.5 % by weight. This observation is almost similar to the studies of sink float (Table 4).

Table 9. *Dry high intensity magnetic separation studies on "as received" sample*

Details	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average
	In weight %					
Magnetic	56.4	56.5	56.7	55.2	55.9	56.1
Non-magnetic	43.6	43.1	43.3	44.8	44.1	43.9
Total	100.0	100.0	100.0	100.0	100.0	100.0

Table 10. *Results of DHIMS on close size fraction*

Size, µm	Feed Weight, %	Magnetic separation	Weight, %	Weight distribution, % (TMM)
-1000+300	6.0	Magnetic	16.0	1.0
		Non-magnetic	84.0	
		Total	100.0	
-300+150	46.8	Magnetic	26.6	12.4
		Non-magnetic	73.4	
		Total	100.0	
-150+90	41.6	Magnetic	92.6	38.5
		Non-magnetic	7.4	
		Total	100.0	
-90+53	4.8	Magnetic	93.6	4.5
		Non-magnetic	6.4	
		Total	100.0	
Total	99.2			56.4

The data on total heavy minerals estimated by sink and float tests from the total magnetic and non-magnetic minerals are given in Table 11.

The data indicate that the total magnetic fraction in the sample is 56.9% by weight, in which the bromoform sinking minerals weight for 93.6 %.

The weight distribution of total heavy minerals in magnetic fraction is 53.3 % and in non-magnetic fraction 0.5 % by weight. Thus the total heavy minerals from magnetic and non-magnetic fractions account for 53.8 % by weight, which represents to the THM present in the feeding material.

Table 11. *Results of magnetic (DHIMS) separation followed by sink float data*

Details	Wt, %	Sink-float Wt, %	THM, %
Magnetic	56.9	Sink 93.6 Float 6.4 Total 100.0	53.3
Non-Magnetic	43.1	Sink 1.3 Float 98.7 Total 100.0	0.5
Total	100.0	- -	53.8

Similarly, the total conducting minerals estimated by HTS tests on total magnetic minerals reaches 56.9 % (Table 12).

Table 12. *Results of HTS on DHIMS magnetic fraction Feed; 56.9% weight*

Details	Wt, %	Wt distribution, %
Conducting	95.8	54.5
Non-Conducting	4.2	2.4
Total	100.0	56.9

The data indicate that the total conducting minerals in the magnetic fraction reach 95.8 % by weight and the weight distribution of total conducting minerals in the magnetic fraction is 54.5 % by weight. Thus the data on sink-float; magnetic separation and conducting separation of minerals (Tables 4 to 8) indicate that 94 to 96 % are magnetic and conducting minerals, present in total heavy minerals (53.8 %).

It is important to mention here that magnetite is a magnetic and non-conducting mineral, whereas ilmenite is a magnetic and conducting mineral. Thus the THM fraction may constitute a titano-magnetite concentrate.

4.3. Continuous DHIMS Studies

Results of continuous DHIM separator (Magnetic field; 1.5T) on "as received" sample (Table 13) indicate that the magnetic fraction represents 55.9 % by weight with 25.1 % TiO_2 and 50.0 % Fe_2O_3. The non-magnetic fraction contains 0.6 % TiO_2 and 1.9 % of Fe_2O_3 which can be rejected. The size and chemical analyses of magnetic minerals (weight contribution 55.9 %) given in Table 14 indicate that the TiO_2 content increases when the particle size decreases and this is significant from particle sizes below 210 micrometers.

Table 13. *Results of dry high intensitymagnetic separator*

Details	Wt, %	TiO_2, %	Fe_2O_3, %
Magnetic	55.9	25.1	50.0
Non-Magnetic	44.1	0.6	1.9
Total	100.0	14.3	28.8

Table 14. *Size and chemical analysis of close sized fractions of DHIMS magnetic fraction*

Size, µm	Weight, %	TiO_2, %	Fe_2O_3, %
-420 + 300	2.1	3.54	30.0
-300 + 210	12.3	9.30	34.4
-210 + 150	32.6	21.30	50.8
-150 + 100	45.6	31.03	51.5
-100 + 75	2.8	38.90	53.1
-75	4.6	35.20	50.3
Total	100.0	25.02	50.0

Hence, the magnetic fraction was ground to a d_{80} passing size of 50 micrometers and further subjected to DHIMS, the results are given in Table 15. The data indicate that the end product (2nd stage DHIMS magnetic fraction) contains 65.2 % Fe_2O_3 with an over all yield of 37.8 % and 86 % recovery. It is also observed that this product contains 24.7 % TiO_2.

However, this product can be used in the pellet feed for steel making after suitable blending with high-grade iron ore fines. These data can clearly be seen from the flow sheet with mass balance shown in Fig. 3.

Table 15. *Effect of grinding on DHIMS magnetic separator*
Feed: DHIMS magnetic fraction, Weight Distribution: 55.9% (Table 13)

Details	Weight, %	Weight, Dist., %	TiO_2, %	Fe_2O_3, %
Magnetic	67.6	37.8	24.7	65.2
Non-magnetic	32.4	18.1	25.9	18.2
Total	100.0	55.9	25.1	50.0

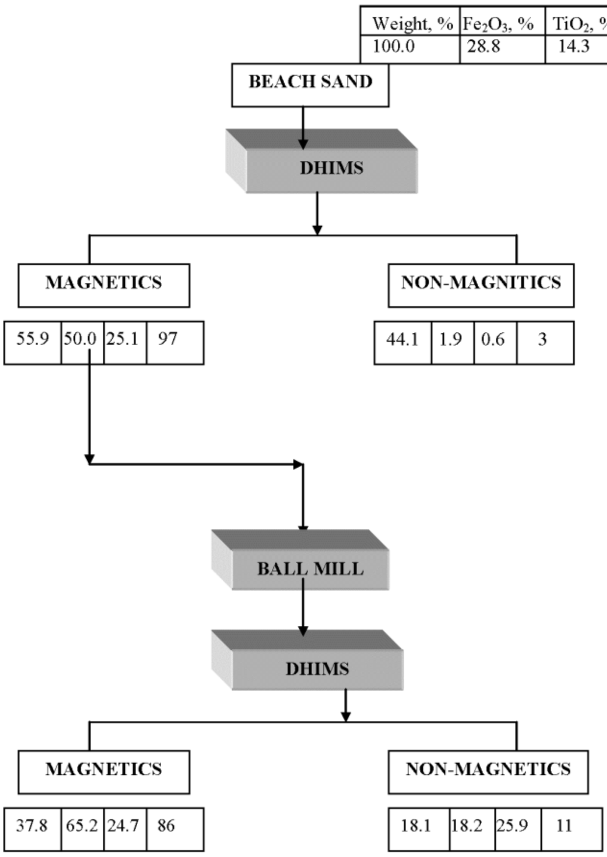

Figure 3. *Recovery of iron values from the beach sand by using dry high intensity magnetic separators*

5. Discussion and Conclusions

The present detailed mineralogical studies and its relevance for the beneficiation of beach sand mineral samples of Talashil area, South Maharastra Coast, India, reveal the following conclusions:

Physical and chemical analysis of the bulk sample indicates that the sample contains 53.2 % of total heavy minerals and this fraction contains 56.9 % of total magnetic minerals. The TiO_2 and Fe_2O_3 contents are respectively of 14.2 % and 26.8 % in the feeding sample.

The total magnetic fraction obtained from the bulk sample by DHIMS reaches 55.9 % by weight, with 25.1 % TiO_2 and 50.0 % Fe_2O_3, whereas the total conducting minerals estimated by HTS tests on the bulk sample is 54.5 % by weight. Thus, the results of magnetic separation at high and low intensity, high tension separation and effect of grinding on these products reveal that physical beneficiation methods do not show any significant separation of TiO_2. The response for iron separation reveals that the 2^{nd} stage DHIMS magnetic fraction contains 65.2 % Fe_2O_3 with an over all yield of 37.8 % and a 86 % recovery. This product can be used in the pellet feed for steel making after suitable blending with high-grade iron ore fines.

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