

### IRON ORE RESOURCES AND BENEFICIATION PRACTICES

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#### INTRODUCTION

Iron and steel industry provides foundation for industrial development of a country. The per capita consumption of steel is considered as one of the important parameters of a nation's prosperity. Iron ore is the basic raw material for iron and steel making. The world reserves of iron ore are estimated to be around 370 billion tonnes. The principal minerals of iron are the oxides (hematite and magnetite), hydroxide (limonite and goethite) and carbonate (siderite). In nature the commercial deposits are mostly of bedded type, although deposits of magmatic, contact metasomatic and of a replacement nature also exist. In many cases, ground water circulation and weathering have resulted in concentration of the ore from primary sources. The major iron ore producing countries in the world are the Australia, Brazil, Canada, China, India, USA, Russia, Kazakhstan, South Africa, Ukraine and Sweden. Pre Cambrian banded iron formations containing 30% or more of iron are the predominant sources of iron.

The primary product from iron ore is pig iron, produced by smelting in a blast furnace. The requirements of economic blast furnace operation set the specifications for marketable iron ores and agglomerates. The requirements differ in different parts of the world and also to some extent from furnace to furnace depending upon the quality of fluxes and fuels available and on the end use of pig iron. The principal impurities associated with iron ores are silica, alumina, sulphur and phosphorous. In general, as per the price-quality consideration, marketable ores should contain maximum iron with minimum gangue. In particular one looks for minimum contents of  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$  because of the ratio of acid ( $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ) to basic ( $\text{CaO}$ ,  $\text{MgO}$ ) constituents of the gangue has influence on furnace operation. It is desirable to burden a furnace to attain minimum slag volume, consistent with effective fluxing of gangue and with optimum elimination of elements such as sulphur and alkalis in the slag. It may be worth mentioning that for hematite ores, typical lump grades are over 62.5 Fe. Pellets for blast furnace charge contain about 65% Fe and <5%  $\text{SiO}_2$  while for direct reduction, average iron is more than 67% with silica plus alumina less than 2%. Due to the demand of ores with higher contents of iron and low level of impurities, today in majority of the cases the run-of-mine ore is processed to varying degrees before the shipment. Depending upon the mineralogical composition, beneficiation involving gravity and magnetic separations and flotation are being practiced in countries like Australia, China, South Africa, USA etc. for concentration of low grade ores to meet stringent industrial specifications.

India is one of leading producers of iron ores in the world and it can meet the growing demand of iron and steel industry in the country and also sustain considerable foreign trade. As per the National Steel Policy, India will be producing 110 million tonnes of steel by 2019-20. This would require about 190 million tonnes of iron ore for domestic steel production in addition to meeting the demand on foreign trade. Indian iron ores are rich in iron content but generally contain high alumina which is undesirable for its use for iron making. The high alumina of iron ores is not favourable for the efficient operation of blast furnace. For an efficient operation of blast furnace, the alumina/silica ratio in the ore feed should be <1.0 and alumina should be <2%.

But most of the Indian hematitic ores, which are used for iron and steel making, show a reverse trend. Alumina bearing minerals are more or less intergrown with the iron oxide minerals and in general the liberation takes place in the fine size ranges. Most of the iron ore mines in India are operated by selective mining for maintaining a high grade (60% Fe). With the availability of high grade ores and the economic reasons, a simple washing scheme has been industrially adopted for beneficiation of Indian iron ores. It helps in removal of adhering clay and silica to produce free flowing lumps and sand. But it has limitations in reduction of impurities and sometimes desired alumina/silica ratio is not achieved. The present beneficiation practice also generates fines and slimes varying from 10 to 25%. These slimes are accumulated along iron ore mines all over the country causing environmental pollution problems besides losses of iron values. Considering the increasing demand of quality iron ores, limitations of the current beneficiation scheme in particular for processing of low grade ores and the conservation of iron ore resources, there is need to develop and adopt suitable technology for beneficiation of Indian iron ores.

## IRON ORE : RESOURCES AND PRODUCTION

The world iron ore reserve base is estimated to be around 370 billion tonnes. Fig. 1.1 shows country-wise reserves and production of iron ore for the year 2004. Though iron ore deposits are distributed around the world, as it is evident the major iron ore producing countries are Australia, Brazil, China, India, Russia, Ukraine and USA. Earlier the global iron ore market was mostly developed countries including Japan but with high industrialisation in Asian countries, especially in China and Republic of Korea and India, there is increasing consumption in these countries.

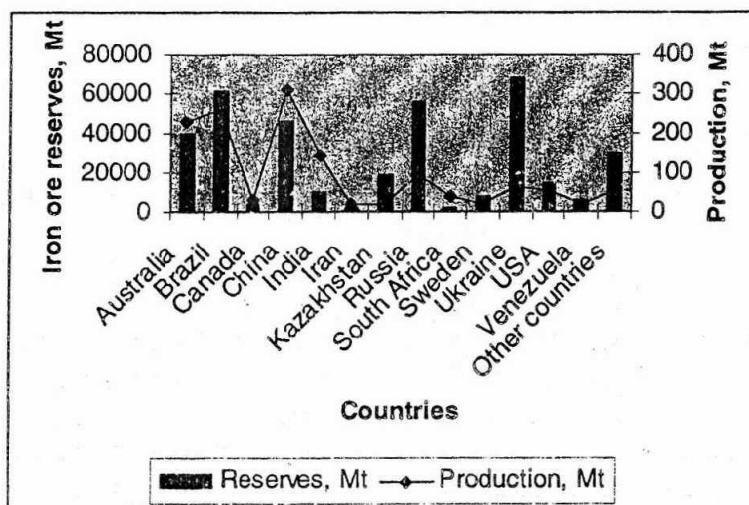


Fig. 1.1: World iron ore reserves and production by major countries

As it is evident from Table 1.1, India has large reserves of iron ore and is one of the leading producers and exporter of iron ore in the world. As it is shown, hematite and magnetite are the two important iron ores, of which hematite is the major resource. Hematite type Indian deposits belong to the precambrian iron ore series and the ore being mainly confined in banded iron ore formations. Magnetite type ore occurs either as igneous origin or the metamorphosed banded magnetite-silica formation possibly of sedimentary origin. About 60% of hematite ore deposits are found in Eastern Sector while about 80% magnetite ore deposits occur in Southern Sector, specially in Karnataka. The geographical distribution of banded iron formation in India is shown in Table 1.2.

Table 1.1: Iron ore reserves in India (as per UNFC system as on 01.04.2005)

| Iron ores | Quantity, million tonnes |
|-----------|--------------------------|
| Hemanite  | 14,630                   |
| Magnetite | 10,561                   |
| Total     | 25,191                   |

Table 1.2: Distribution of iron ore resources in India

|        |                                                                                   |
|--------|-----------------------------------------------------------------------------------|
| Zone A | Singhbhum, Keonjhar, Cuttack (Jharkhand & Orissa)                                 |
| Zone B | Bastar, Durg, Chandrapur (Madya Pradesh & Maharashtra)                            |
| Zone C | Bellary-Hospet belt (Karnataka)                                                   |
| Zone D | Goa, Ratnagiri, North Kanara                                                      |
| Zone E | Metamorphosed banded iron formation along the West Coast (Karnataka, Kerala etc.) |

There has been a steady growth, particularly from 1960 onwards and a rapid growth in iron ore production in India since the last decade. The production of iron ore consisting of lumps, fines and concentrates was 142.7 million tonnes during 2004-05. This showed an increase of 16% over the preceding year. The phenomenal growth in production of iron ores reflects on the growth of steel industry.

## CHARACTERISTICS OF INDIAN IRON ORES

The hematite ores range from massive type through a porous laminated type to a fine soft powder and are generally classified under the following categories : (a) Massive, (b) Laminated - soft and hard, (c) Lateritic and (d) Powdery/Blue Dust. The chemical analysis of the different varieties of iron ore is Figs. 1.2-1.7 show typical photographs of different types of iron ores in Barsua Iron Ore Mines of SAIL. shown in Table 1.3 while Table 1.4 summarises the mineralogical characteristics.

Table 1.3: Chemical analysis of hematitic ore

| Ore Type       | Fe %      | SiO <sub>2</sub> % | Al <sub>2</sub> O <sub>3</sub> % |
|----------------|-----------|--------------------|----------------------------------|
| Massive        | 63.2-69.0 | 0.34-4.19          | 0.50-3.66                        |
| Hard Laminated | 56.8-66.6 | 0.81-5.73          | 1.00-7.14                        |
| Soft Laminated | 57.0-65.5 | 1.20-8.60          | 1.10-9.00                        |
| Lateritic      | 56.0-61.5 | 1.00-6.88          | 3.72-10.85                       |
| Blue Dust      | 64.0-69.0 | 0.64-2.12          | 0.35-2.49                        |

Table 1.4: Mineralogical characteristics of hematitic ores

| Ore type  | Iron bearing minerals                              | Gangue minerals                  | Other features                                                                    |
|-----------|----------------------------------------------------|----------------------------------|-----------------------------------------------------------------------------------|
| Massive   | Hematite,<br>Goethite,<br>Martite and<br>Magnetite | Quartz, Clay                     | Steel grey in colour,<br>Specific gravity >5, High<br>crushing strength           |
| Laminated | Hematite,<br>Goethite,<br>Limonite                 | Clay, Gibbsite,<br>Quartz, Chert | Laminated structure,<br>Specific gravity 4.2-4.7                                  |
| Lateritic | Goethite,<br>Limonite,<br>Hematite,<br>Ochre       | Clay, Gibbsite<br>Silica, Ochre  | Dull lusture, Rich in<br>alumina, Friable nature                                  |
| Blue Dust | Hematite,<br>Goethite                              | Quartz, Clay                     | Generally blue/dark black<br>or cherry red in colour,<br>Powder form, Low alumina |



Fig.1.2: Folding of iron ore and shale (~800 m).



Fig.1.3: Hard laminated ore with shovel and dumper.



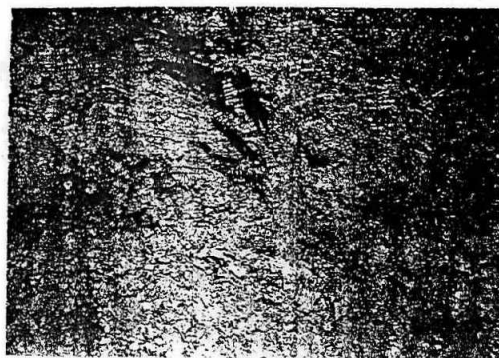
Fig.1.4: Friable ore band in between BHJ intermediate shale and ochre on the top.



Fig.1.5 : Transitional ore with lateritic ore in the foreground (~800 m).



*Fig.1.6: Blue dust with shale band in transitional zone (~780 m).*



*Fig.1.7 : Shaly thin laminated ore partially leached and washed.*

As found from the petrological studies and shown in Table 1.4, hematitic ore basically consists of varying amounts of hematite, goethite, martite and magnetite in association with quartz and clay as the gangue forming minerals. Although Indian iron ores are considered to be rich in iron content but they contain high alumina. Due to preferential association of iron oxide mineral with finely disseminated alumina bearing minerals (kaolinite, gibbsite) than with siliceous minerals, the  $\text{Al}_2\text{O}_3/\text{SiO}_2$  ratio is generally more than 1. Alumina is mainly contributed by clay (kaolinite, montmorillonite, illite, alunite), lateritic material and gibbsite and some alumina occurs as solid solution in iron oxide minerals viz., goethite and limonite. Silica is mainly contributed by quartz and the associated clay. The adverse ratio of  $\text{Al}_2\text{O}_3/\text{SiO}_2$  in Indian iron ores has always been a problem in improving the blast furnace productivity.

Studies show that even below 75 micron, significant portion of alumina minerals remain locked with iron oxide minerals and in several cases grinding to the extent of 15-20 micron is required to achieve a fair liberation. Typical photographs showing the mode of occurrence of iron and gangue forming minerals in Indian iron ores are shown in Figs. 1.8-1.11. Results on liberation studies carried out on two low grade iron ore samples, namely S1 and S2, crushed to 2 mm are shown in Fig. 1.12. As it can be seen, liberation of iron bearing minerals increases with decrease in particle size and about 80% liberation is achieved below 100 micron. Magnetite ores are of low grade (30-40%Fe) with quartz as the main gangue. These ores are finely disseminated and need even finer grinding for liberation of valued minerals from gangues.



*Fig.1. 8: Cut surface of lump showing banding of hematite (H) in association with jasper (J), quartz (Q) and clay (yellow), X 7, Close-up view under Stereo microscope.*



*Fig. 1.9 : Fresh exposed surface of lateritic ore showing oolitic texture, X7, Close up view under stereo-microscope.*



Fig. 1.10 : Cut surface of lump showing erosional cavities and vug filling of ochery clay (C) and Siliceous gangue (white) X 7, Close up view Under Stereo microscope.



Fig. 1.11 : Lamellar and veins of gangues and their intimate association with hematite X 150, Plane polarised reflected light.

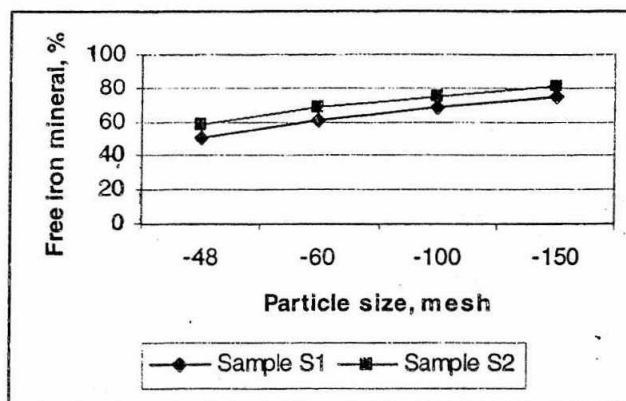


Fig. 1.12: Liberation of iron bearing minerals with decreasing particle size

## SPECIFICATIONS OF IRON ORE AND DELETERIOUS EFFECT OF ALUMINA

In India, blast furnace route dominates the bulk of steel production and the performance of blast furnace is greatly influenced by the quality of raw materials. The broad specifications of iron ore in Indian plants have been as follows : Fe 62.5-65%,  $\text{Al}_2\text{O}_3$  2-3.5%,  $\text{Al}_2\text{O}_3 + \text{SiO}_2$  4-5% and  $\text{Al}_2\text{O}_3/\text{SiO}_2$  ratio 1.2 to 2.0. However, for better blast furnace productivity and slag flowability, the iron ore should contain iron as high as possible and  $\text{Al}_2\text{O}_3/\text{SiO}_2$  ratio <1.0 and  $\text{Al}_2\text{O}_3$  <2.0%. Normally alumina content in iron ores lies in the range of 1.5-2.5% in the lump and 2.5-5% in the fines used for sinter making as against world practice of alumina below 1%. Sinter produced from such iron ore fines (-10 mm) is extremely high in alumina compared to sinter from other countries where the alumina in the burden seldom exceeds 2%. Alumina has an adverse effect on sinter properties like Reduction Degradation Index (RDI). Burden in the Indian blast furnaces is slow moving with a longer residence time for sinter/ore. Under these circumstances RDI is even more important. It is estimated that the drop in sinter alumina from 3.1 to 2.5% can improve RDI of sinter by at least 6 points. This would in turn lower blast furnace coke rate by about 14 kg/thm and increase productivity by about 3%. Figs. 1.13 and 1.14 show the effect of alumina on sinter RDI and in turn on the productivity.

The lumps containing about 2% and fines containing about 4% alumina coupled with alumina input through coke and other raw materials result in 22-26% alumina content in the blast furnace slag. Blast furnace slag at this level of alumina is generally viscous. As a consequence, problems connected with blast furnace permeability are frequently encountered. This impairs the upward flow of reducing gases and decreases reduction kinetics of iron oxide. Viscous slag is also not

conducive to efficient desulphurising. High alumina loading in Indian blast furnaces has prompted the operators to resort to 9-10% MgO in blast furnace slag to make it fluid. Thus lowering of alumina content in iron ore is essential for an efficient operation of blast furnace.

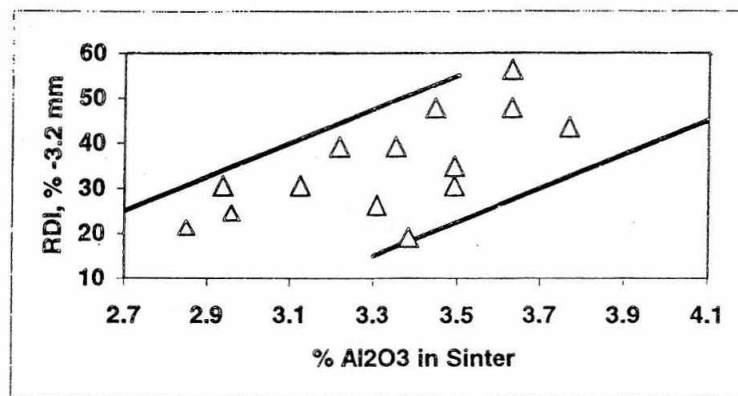


Fig. 1.13 : Effect of alumina on RDI for plant sinter.

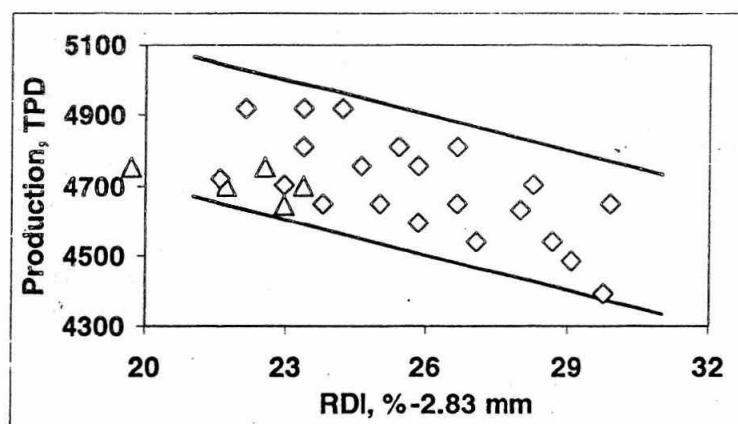


Fig. 1.14 : Effect of sinter RDI on blast furnace productivity.

## IRON ORE BENEFICIATION METHODS AND PRACTICES

Depending upon the origin and mineralogical characteristics of the ore, the beneficiation methods vary from simple crushing and screening to complex concentration processes. Different types of iron ores and the followed for their concentration are given below. However, a given iron ore sample may fall in-between and accordingly the concentration process has to be tailored based on detailed characterisation and beneficiation, all fines, soft friable ores and some ores that are difficult to reduce are converted to sinters or pellets to improve their reducibility and flow characteristics through the furnace.

### Direct Shipping Ore

These are high grade ores and do not need concentration. These are directly used for iron making through blast furnace route. But the ore has to be crushed to meet the size requirement of blast furnace before shipment.

## **Simple to Wash Ore**

Such ores essentially consists of coarse and fine granular particles alongwith clayey gangues adhered to the surface of iron bearing minerals. The separation involves scrubbing of the ore in a log-washer or classifier followed by screening to remove coarse ore particles from the fines. The fines are usually rejected where as the sand product is the concentrate.

## **Ore Requiring Grinding and Concentration**

In this case the iron bearing minerals are closely associated with gangues and needs grinding for their liberation. The suitability of the beneficiation methods depends upon the liberation characteristics and the nature of the minerals to be separated. Difference in the physical properties of the minerals and the methods used for the concentration of iron ore samples are outlined below :

### ***Specific gravity***

Difference in specific gravity between iron bearing and gangue minerals has been utilised for the concentration of iron ores. The common gravity separators used for iron ore concentration are jigs, heavy media separator, spirals and shaking table. Floatex density separator and the modern centrifugal separators like Kelsey jig, multi-gravity separator, Falcon and Knelson separators are being studied for recovery of iron values from fines and slimes.

### ***Magnetic properties (low and high intensity with wet and dry type)***

Depending upon the nature of iron bearing minerals, a low or high intensity magnetic separator or a combination of the two can be used for processing of a given iron ore. Particularly, for the recovery of magnetite a low intensity separator with a magnetic field intensity of 1000-2000 gauss in the concentration zone is considered suitable. For the weakly magnetic minerals like hematite and limonite a high intensity separator with an intensity of 7000-20,000 gauss is used.

### ***Reduction roasting and magnetic separation***

Para-magnetic iron ore, consisting primarily of hematite, limonite or siderite can be converted to magnetite by a reduction roasting process. The reduction roasting process is followed by a low intensity magnetic separation for recovery of magnetite. Generally, the high requirement of heat makes the process uneconomical.

### ***Electrostatic separation***

This technique makes use of the difference in electrical conductivity between iron oxides and gangue minerals. The main use is in the final cleaning of concentrate to produce high grade product. Despite of some limitations, it has the advantage of high selectivity of separation.

### ***Froth flotation and selective flocculation***

Concentration of iron ore by froth flotation is carried out in two ways – 'direct' or 'reverse'. In case of direct flotation, iron oxide is floated using anionic reagent or cationic reagents, usually amines. Organic reagents like starch or gum are used as depressant for iron oxides. Many efforts

have been put in to develop the process for treating fine grained hematite type iron ores. The process basically consist flocculation of iron oxides, removal of fine silica by desliming followed by amine flotation of siliceous gangues. Column flotation is another development which is being utilised for beneficiation of fine grained iron ores. Column cells are reported to give better metallurgical performance over conventional mechanical cells.

Beneficiation methods employed for concentration and exploitation of some of the low grade iron ore deposits abroad are presented in Table 1.5 .

*Table 1.5 : Beneficiation methods employed for concentration of low grade iron ores*

| Beneficiation methods                | Concentration Plants                                                                                   |
|--------------------------------------|--------------------------------------------------------------------------------------------------------|
| HMS                                  | Sishen South, South Africa                                                                             |
| Jigging (fine ore)                   | Beeshoek, South Africa                                                                                 |
| HMS, Cones and Cyclones              | BHP Billiton, Newman, Australia                                                                        |
| Jigging, spiral and WHIMS (fine ore) | BHP Billiton, Australia and Finucane Island, Australia                                                 |
| HMS and WHIMS                        | Tom Price, Australia                                                                                   |
| Flotation                            | Empire Cleveland Cliffs, USA; Groveland Mine Hanna Mining Co., USA; Tilden Mine Cleveland Cliffs, USA. |

## **PRESENT SCENARIO OF IRON ORE BENEFICIATION IN INDIA**

Since its inception in early fifties, NML has been engaged in R&D in beneficiation and agglomeration of iron ores and fines for utilisation in iron and steel making. Detailed characterisation, laboratory and pilot scale beneficiation and agglomeration studies were undertaken on iron ore samples from various captive mines supplying iron ores to the various public as well as private sector undertaking such as SAIL, TISCO, NMDC etc. Based upon these studies, as per the industrial need, know-how was provided for installation of various iron ore washing and agglomeration plants in the country (Table 1.6).

Most of the Indian iron ore mines are operated by selective mining for maintaining a high grade iron ( $\text{Fe} > 60\%$ ). There are 13 ore processing plants in the country (excluding Goa and Jharkhand) and the ore is either treated in dry or wet circuits. The dry circuit consists of washing and screening, while the wet circuit consists of crushing, scrubbing and wet screening and classification. The prime function of beneficiation is to improve the iron content and to decrease the alumina/iron ratio.

Washing and/or wet screening are essential for aluminous and sticky ores. Washing ensures separation of clayey matter from lumps and fines and improves the handling properties particularly in monsoon season. The sticky nature of the ore due to the presence of clayey matter poses serious problem in transportation. The final products are lump (generally 10-40mm in

size), classifier sand as sinter feed (0.15-10 mm) and -0.15mm slime. Hydro cyclones are used to recover iron values from slime. With rich ROM feed to the washing circuit, Hydrocyclone underflow can be processed through filters or slow speed classifiers to recover high grade micro fines. Slow speed classifiers in combination with hydrocyclone can either be utilised for dewatering or recovering micro fines.

The general flow-sheet for wet processing of hematite-goethite iron ores is shown in Fig 1.15. The treatment lump size varies from -30 + 10 mm to -150 + 10 mm from mines to mines. For mixed hematite and magnetite ores, the beneficiation essentially involves crushing, grinding, magnetic separation, gravity separation by spirals and final concentration by flotation. Capacity and the basic ore processing schemes used in major Indian iron ore mines are shown in Table 1.7. Flow-sheet for processing of Joda and iron ores are schematically shown in Figs. 1.16 and 1.17 respectively.

Table 1.6: Iron ore Washing and Agglomeration Plants based on NML's know-how

| Iron ore mines        | Steel plant/Purpose     |
|-----------------------|-------------------------|
| Noamundi              | TISCO                   |
| Dalli-Rajhara         | Bhilai Steel Plant      |
| Barsua                | Rourkela Steel Plant    |
| Goa                   | Indian Iron & Steel Co. |
| Bolani                | Durgapur Steel Plant    |
| Kiriburu              | Bokaro Steel Plant      |
| Bailadila             | Export                  |
| Donimalai             | Export                  |
| Kudremukh             | Export                  |
| Kanjamalai            | Salem Steel Plant       |
| Daitari-Ganndhamardan | Paradip Steel Plant     |
| Goa Iron ore          | Export                  |

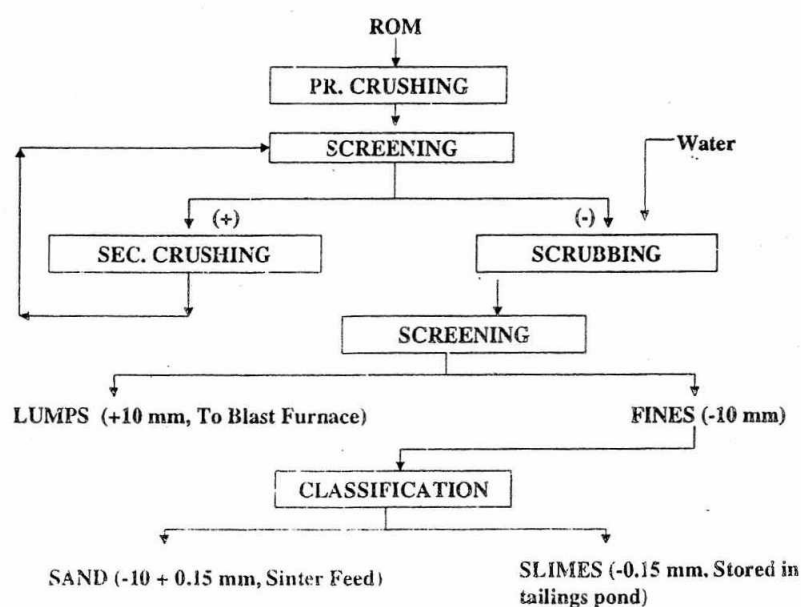


Fig. 1.15 : General flow-sheet for wet processing of hematite-goethite iron ores.

Table 1.7.: Capacity and beneficiation schemes of major Iron Ore Processing Plants in India

| Plants                 | Ore type  | Capacity, MT/year | Beneficiation circuit    | Wet circuit                                                             |
|------------------------|-----------|-------------------|--------------------------|-------------------------------------------------------------------------|
| Barsua (SAIL)          | Haematite | 2.5               | reening                  | Scrubbing, wet screening, classification and jigging                    |
| Bailadila-5 (NMDC)     | Haematite | 6.0               |                          | Wet screening and classification                                        |
| Bailadila-14 (NMDC)    | Haematite | 6.0               |                          | Wet screening and classification                                        |
| Bolani (SAIL)          | Haematite | 2.0               | reening                  | Scrubbing, wet screening and classification of part of fines            |
| Daitari (OMC)          | Haematite | 2.5               | reening                  | Wet screening and classification                                        |
| Dalli (SAIL)           | Haematite | 2.5               |                          | Scrubbing, wet screening and classification                             |
| Donimalai (NMDC)       | Haematite | 4.0               | reening                  | Wet screening and classification                                        |
| Gua (SAIL)             | Haematite | 2.4               |                          | -                                                                       |
| Joda East (Tata Steel) | Haematite | 0.8               | dry screening<br>reening | Scrubbing, wet screening, classification and dewatering                 |
| Kiriburu (SAIL)        | Haematite | 5.0               | reening                  | Wet screening, dewatering and classification                            |
| Meghataburu (SAIL)     | Haematite | 5.0               | reening                  | Wet screening, classification, hydrocycloning and slow speed classifier |
| Noamundi (Tata Steel)  | Haematite | 4.18              |                          | Scrubbing, wet screening, classification and dewatering                 |
| Rajhara (SAIL)         | Haematite | 2.8               |                          | -                                                                       |
| Kudremukh (KIOCL)      | Magnetite | 19.7              |                          | Magnetic separation and flotation                                       |

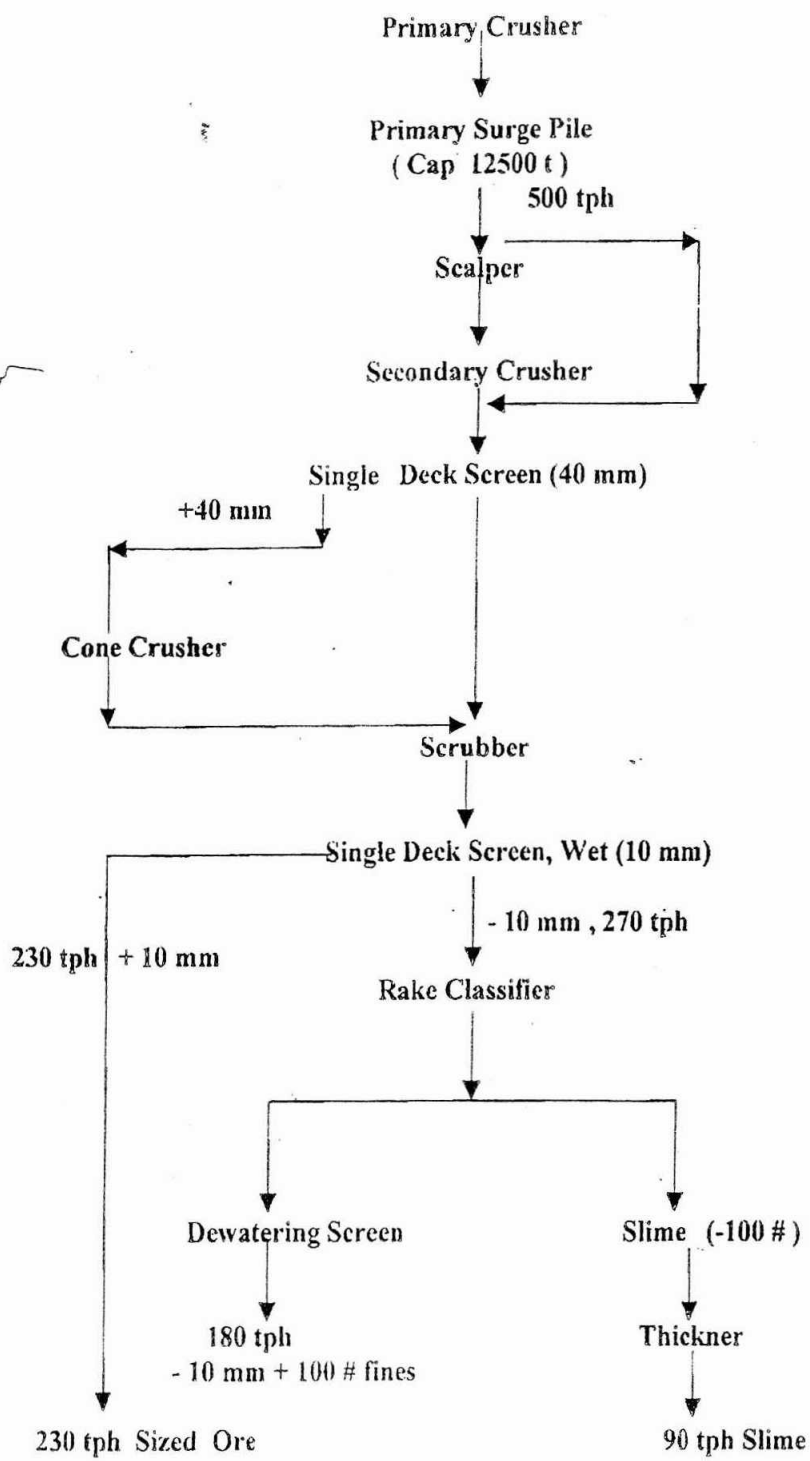


Fig. 1.16 : Flow-sheet of Joda Iron Ore Washing Plant (Tata Steel)

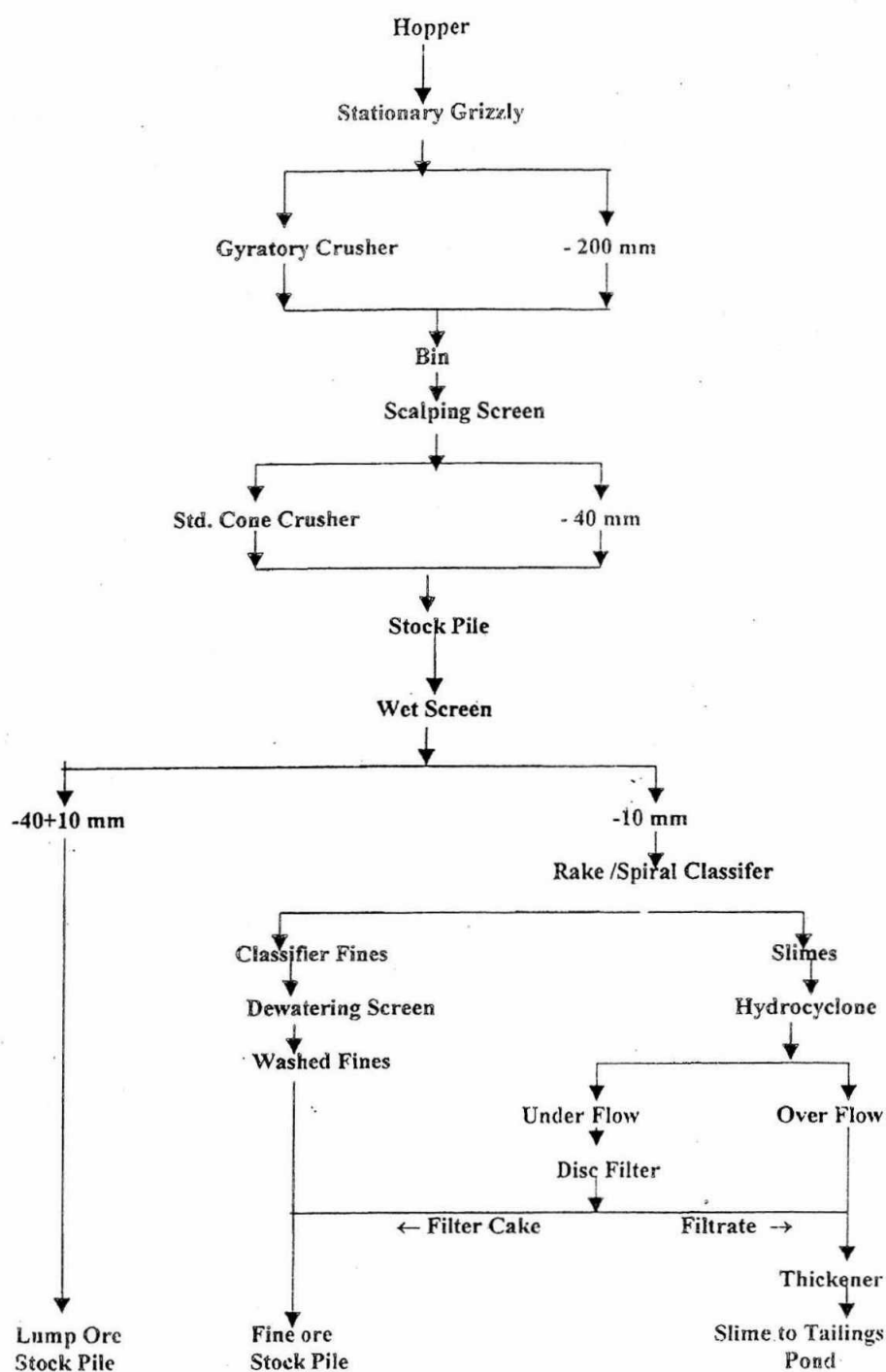


Fig. 1.17 : Flow diagram of iron ore processing at Meghataburu (SAIL).

## LIMITATIONS OF CURRENT BENEFICIATION PRACTICE AND SCOPE FOR IMPROVEMENT

As mentioned above, the present scheme of iron ore beneficiation and the reduction of alumina broadly comprises crushing ore to the required size followed by scrubbing and/or wet screening and classification to separate slimes from fines. The scheme was developed for processing of high

grade ores with comparatively liberal product's quality norms and targeted for utilisation of lumps and fines only. But with the changed scenario, particularly considering the increasing demand for high grade iron ore for iron making, lowering of alumina content to the specified level and the need of processing of low grade feed, the present beneficiation circuits have limitations. By this process, although the adhering clay matter is removed, the  $\text{Al}_2\text{O}_3$  content is not significantly lowered. One of the most important aspects in the beneficiation of Indian iron ores is their complex nature from the standpoint of elimination of alumina. The general mode of occurrence of aluminous minerals in the ore is as coating on lumps, as cavity fillings or as lateritic material. Laterites containing over 8% alumina exists as a constituent phase with iron oxide. Quartz occurs as bands with hematite in BHQ/BHJ as inclusions, adherent and vug fillings. By washing, alumina present as clayey material as well as fine silica can be partially removed whereas laterite is not affected by washing. Thus there is preferential removal of silica over alumina, which naturally increases the alumina/silica ratio in the washed product. The present iron ore washing scheme also generates slimes (10-25% by weight) with relatively high alumina content. These slimes stored in tailings ponds pose severe environmental pollution problems.

Considering the need of controlling the alumina content of the charge to blast furnace coupled with the complexity of the beneficiation of Indian iron ores, considerable R & D efforts have been made at NML to develop a suitable process for meeting the requirement of low alumina content of iron ore. In order to meet the requirement of low alumina content of iron ore and also taking care of environment pollution problems and the need of resource conservation, total processing of iron ore covering lumps, fines and slimes is recommended. In view of the gradual shift from lumps to fines (sinter) in Indian blast furnace and the recent developments in the area of beneficiation, there is enough scope to design an integrated flow-sheet consisting of processing of lumps, fines and slimes. In particular gravity based beneficiation techniques like heavy media separation, jigging, spiralling, cycloning, enhanced gravity separation (centrifugal separators), magnetic separation, flotation and column flotation have enough potential for treating Indian iron ore lumps, fines and slimes. Blue dust having high iron and low gangue content and beneficiated fines need to be utilised by through agglomeration. The studies show that there exist scope to design and develop integrated processes for beneficiation and agglomeration of low grade iron ores, fines and slimes for rational utilisation of available resources.

## CONCLUDING REMARKS

With over 25 billion tonnes of ore reserves India is one of the leading producers and exporters of iron ores in the world. Although Indian iron ore is rich in iron, but it contains high alumina which is not favourable for efficient operation of blast furnace. Beneficiation of iron ores for reduction of alumina is imperative for efficient operation of blast furnace. Due to the complex nature of the association of iron and alumina bearing minerals, the present beneficiation schemes have limited success in reducing alumina to the desired level in medium/low grade ores and this has come as a challenge to Indian Iron & Steel industry. Considering the increasing demand of quality iron ores and limitations of current beneficiation circuits, there is a need to adopt improved technology for beneficiation of low grade ores. In the light of recent developments, modification of current beneficiation schemes will be helpful in lowering the alumina content of the product. In view of the resource conservation and environment protection, total beneficiation of iron ores and utilisation of dumped fines and slimes need to be encouraged.

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