# A Beneficiation Scheme for Reduction of Alumina in Iron Ores from Barsua

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## Abstract

In order to improve blast furnace productivity by reducing the alumina of iron ore fines from the present level of 3.3-3.9% to the desired level of 2.5%, a detailed characterisation followed by beneficiation studies comprising crushing, dry screening, washing, gravity separation of fines and slimes, on the seven individual 'type' and a 'composite' iron ore samples from Barsua Iron Mines were carried out at NML, Jamshedpur to find the amenability of beneficiation and develop a flow-sheet. Based on the findings from the studies, two conceptual flowsheets were designed. The first one consisted of crushing the composite sample (62.26% Fe, 2.01% $SiO_2$ and 4.22% $Al_2O_3$) to 25 mm followed by wet processing comprising scrubbing & wet screening at 8 mm and classification of -8mm fraction into sand (+100#) and slime (-100#). The -8+1 mm fraction of the sand would be subjected to jigging and -1mm+100 # fraction to tabling. The cyclone underflow obtained by treating the slime would be subjected to tabling as well. The yield of the combined concentrate of fines would be 28% and analyse 64.09% Fe, 1.9% $SiO_2$ and 2.95% $Al_2O_3$. The +8 mm lumps, 45% by weight would analyse 63.69% Fe, 1.52% $SiO_2$ and 3.8% $Al_2O_3$. Based on mainly grade and physical characteristics of individual type samples, the Second Flowsheet consists of separate proportioning, blending and treatment of two group of ores viz., Direct Ore (Friable, Mineable Transitional and Blue Dust) and Beneficiable Ore (Soft Laminated , Lateritic , Hard Laminated and Massive). The flowsheet consists of dry processing of Direct Ore (29% by weight with 63.55% Fe, 1.69% $SiO_2$ and 2.45% $Al_2O_3$) and wet processing of Beneficiable Ore (71% by weight with 61.39% Fe, 2.22% $SiO_2$ and 5.09% $Al_2O_3$). The Dry Circuit would consist of crushing the Direct to -25 mm and screening at 8 mm. The lumps and fines would weigh 8% and 21% and analyse 62.62% Fe, 1.79% $SiO_2$ and 2.92% $Al_2O_3$ and 63.9% Fe, 1.65% $SiO_2$ and 2.27% $Al_2O_3$ respectively. The Beneficiable will go through the wet circuit as described for the first flowsheet. The washed lump would be 36.43% by weight and analyse 63.4% Fe, 1.38% $SiO_2$ and 4.05% $Al_2O_3$. The combined lumps from Dry Circuit and Wet Circuit would be 44.43% by weight and analyse 63.25% Fe, 1.45% $SiO_2$ and 3.85% $Al_2O_3$.The combined fines from Dry Circuit and Wet Circuit (without concentrates from slime) would weigh 35.62% and analyse 64.1% Fe, 1.59% $SiO_2$ and 2.56% $Al_2O_3$. The yield will improve by an additional amount of 5-6% with slight increase in $Al_2O_3$ (2.85%) if table concentrates from cyclone underflow and overflow are recovered. Although quality or quantity of lumps remain almost same in both the cases, there is substantial improvement in grade and yield of fines in the second flowsheet.

**Keywords:** Barsua, Iron Ore, Alumina, Washing, Gravity separation, Magnetic separation, Hydrocyclone

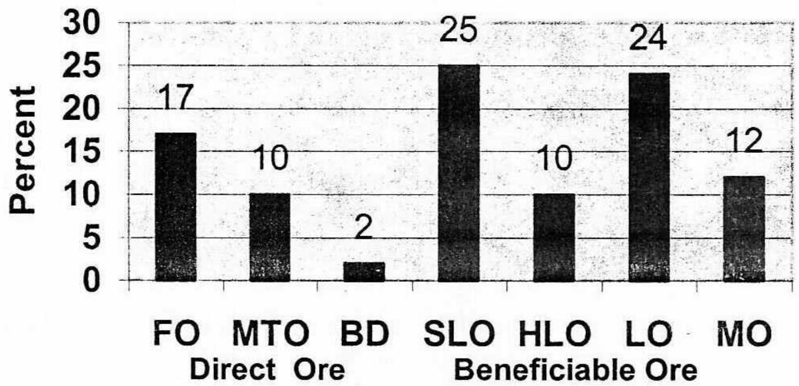
## Introduction

In iron making, the adverse effect of alumina on reducibility, coke rate, productivity and blast furnace operation is well established and with the characteristic high alumina present in Indian iron ores as leteritic and/or clay gangue has always been a problem to bring down the alumina content preferably below 2.5% in the fines and slimes. To meet the present day demand of Rourkela Steel Plant it is desirable that the alumina content should be brought down around 2.5% from current level of 3.3-3.9% in the fines. In this connection, an exclusive study was undertaken by NML to study the deposits at Barsua and suggest a suitable strategy. Field visits were made and representative samples of all the 'Type samples' were collected. Besides the 'Type samples' a 'Composite sample' prepared from the 'Type samples' were subjected to detailed physical and mineralogical characterisation studies followed by bench scale beneficiation studies. The 'Composite sample' was prepared based on the proportional availability and minability of different type ores. Based on the findings of the beneficiability characteristics of individual and the Composite sample, two alternate flowsheets have been suggested.

## Samples

Seven 'Type samples' were collected and their ratio in the 'Composite sample' is given below in Fig 1. Depending upon the chemical, physical and mineralogical characteristics, the samples were marked as Direct or Beneficiable.

Fig 1: Blending ratio in Composite




FO=Friable , MTO=Mineable Transitional, BD=Blue Dust
SLO=Soft Laminated, HLO=Hard Laminate, LO=Lateritic, MO=Massive

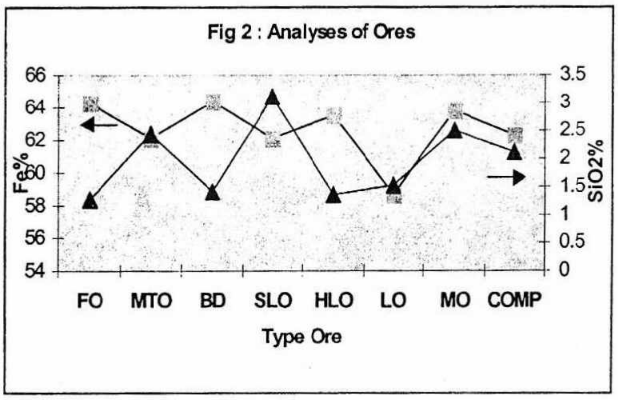
## Experimental

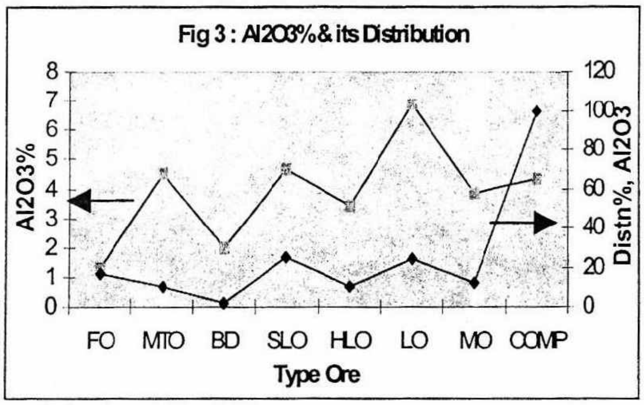
Detailed physical, physico-chemical, mineralogical studies and chemical analysis were carried out on each type sample. Beneficiation studies on each individual type sample as well as composite sample broadly comprised of crushing to different top sizes, washing, gravity and magnetic separation.

## Results and Discussion

### Chemical Analysis of the Samples

Chemical Analysis (Fe & $SiO_2$%) of the as-received Type Samples and Composite Ore made from Type Samples are given below in Fig 2 while Fig 3 depicts Al2O3% in ores and its distribution in the composite ore.




### Mineralogical Characteristics

All ore types were, in general predominantly made up of hematite and goethite associated with magnetite, quartz and gibbsite and kaolinite as minor to traces. Goethite was found to occur as vug-filling. Extensive alteration of anhydrous minerals to hydrous iron oxide minerals was also noticed. The ore has undergone limonitisation by weathering.. Presence of BHQ was also noticed. Besides vug filling, clayey material was also found as trapped inside iron oxide minerals. The coating and encrustations of argillaceous ans siliceous materials on iron minerals remained even after washing. In MTO laminated texture was noticed with vug-filled gangue while in SLO, lamination and banding were prominent feature with patches of limonitic material. In LO, colloidal clay was found as in-filling with rims of limonite. In HLO, the argillaceous and arenaceous impurities at places were found along the fractures of hematite. The abundance of ore minerals and gangue varied from type to type; the lateritic type being richest in gangue.

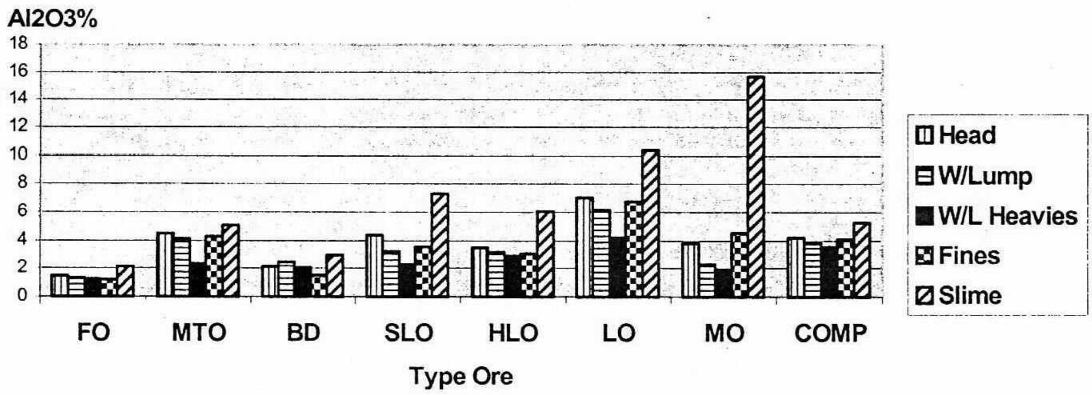
### Physical & Physico-chemical Properties

Average bulk density of crushed samples was found to be around 2.0 t/$m^3$. Angle of repose varied between 41-48° in the moisture range of 5-12%. Decripitation values varied from 12 to 20. -25 mm samples exhibited lower values than that from -50 mm samples. Crushing strength was highest for massive ore (27.9 kg/sq. mm). Shatter tests indicated that a fall of material from a height of 6m could produce 2% additional fines. Screenability tests indicated that blinding of screens occur at moisture range of 7.5-12.5%.

**Beneficiation Characteristics**

Of all the samples, lateritic ore analysed highest alumina of 6.87% followed by soft laminated and mineable transitional ore (4.5%). Alumina is lower than 2.5% in friable ore as well as blue dust. The yields of +10/8 mm lumps from dry screening of composite ore were in the range of 48.3-55.8% and analysed about 4.0% $Al_2O_3$. The yields of washed lumps varied between 45.0-52.2% with marginal lowering of alumina in the lumps. Heavy media separation of washed lumps at a specific gravity of 3.0 produced heavies with improvement in alumina level in some of the individual type samples but in the composite sample improvement was marginal Washing could reduce the $Al_2O_3$ content in washed fines (-10/8+2/1 mm) in some individual type ores but it remained at about 4% in composite ore. This may be attributed to the presence of lateritic material in it. The yield of washed fines in composite ore ranged from 25.9 to 36.8%. $Al_2O_3$ content in Head sample and different products of washing are indicated in Fig 4.

Fig 4 : Al2O3 in Washed Products




Heavy liquid test of -10/8+2 mm fraction of washed fines indicated that rejection of aluminous material was appreciable thereby indicating possibility of substantial enrichment in quality by jigging. Accordingly, jigging of -10/8+1 mm fraction produced concentrate having alumina content of about 3.4% (Fig 5).

Fig 5: Al2O3% in HLS Heavies & Jig Conc.

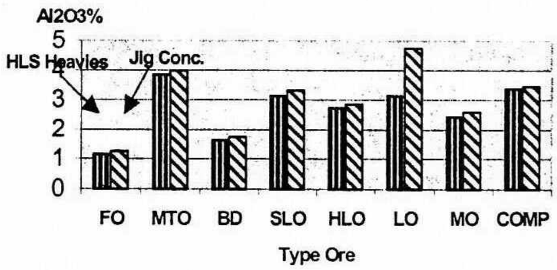
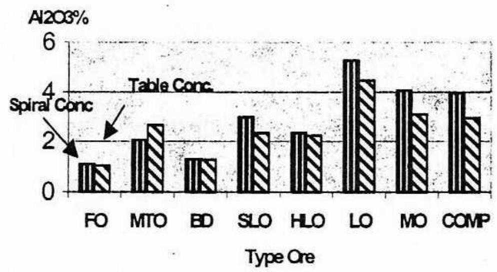
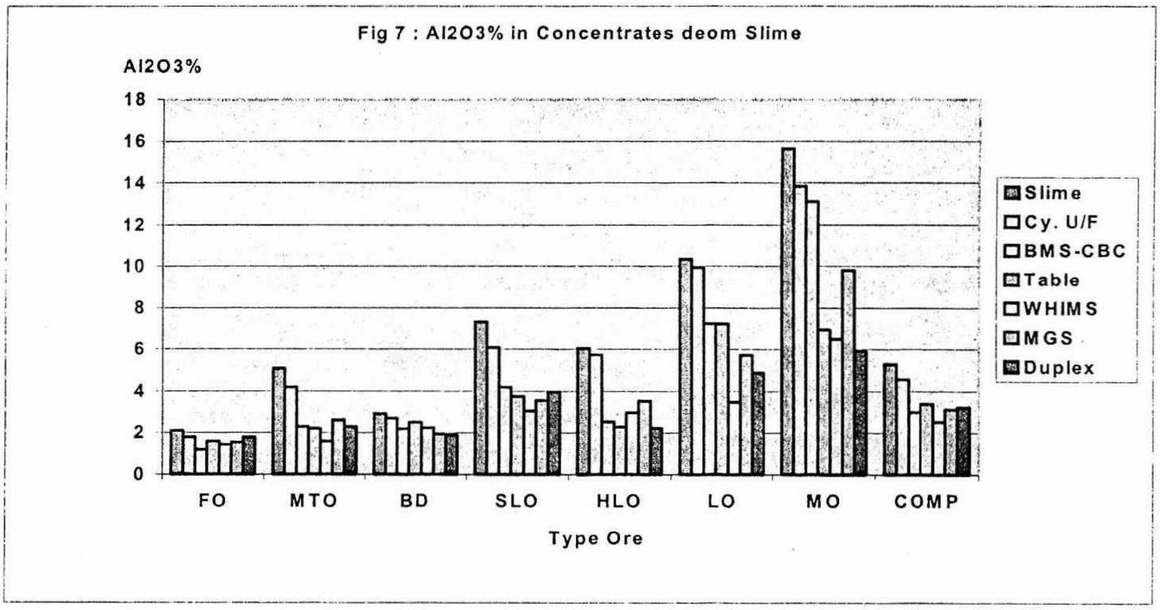



Fig 6: Al2O3 % in Spiral & Table Conc.




Spiralling of -2/1+0.15 mm fraction of washed fines yielded product of varying $Al_2O_3$ content in type ores but it remained at around 4% although substantially reduced from the original level. On the other hand, tabling of the same fraction could produce concentrate with 2.95% $Al_2O_3$ . Results are depicted in Fig 6. It may be noted that earlier studies have established the efficacy of spirals similar to tables provided spirals could be run continuously for sufficient length of time for stabilisation.

Washing of type samples produced slimes 7.5-32% by weight with 2-16% $Al_2O_3$ against 19-21.6% by weight in case of composite ore with alumina of about 5%. It may be noted that the alumina was very high in slime generated by lateritic & massive ore i.e., 10.45 & 15.55 % respectively. Hydrocycloning of the sample was carried out to separate the ultrafines as overflow. The underflow was subjected to BMS-CBC, Multi-Gravity Separator, Wet high intensity magnetic separator and Duplex concentrator. The product obtained was having in general 2.55 to 3.99% $Al_2O_3$ with yield varying between 4.9 to 10.9% (Fig 7) Out of all, MGS and WHIMS seem to perform better than others. Earlier studies on other iron ore slimes have also indicated similar findings. The overflow was subjected to only Multi-Gravity Separation and certain marginal amount could be recovered.



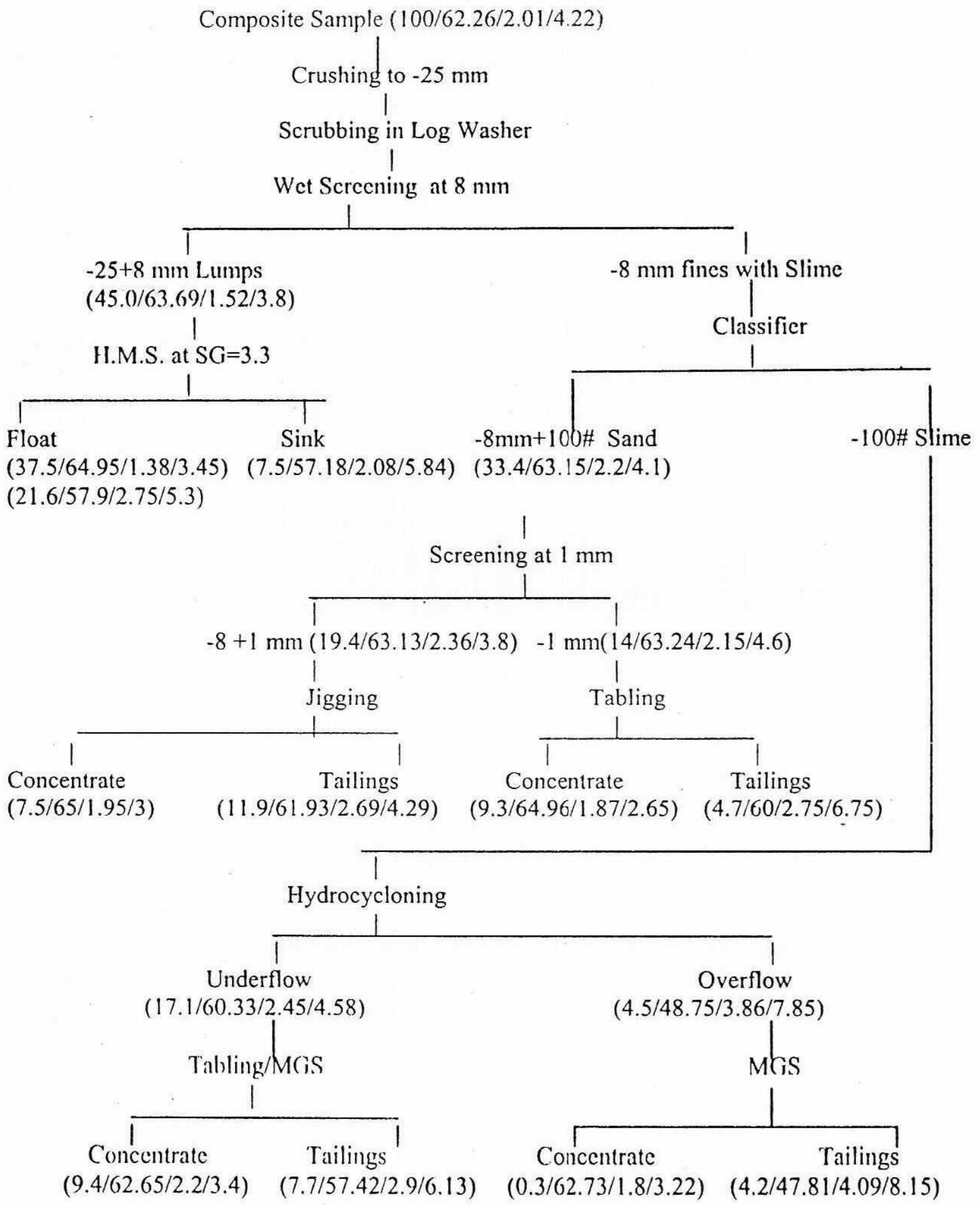

## Development of Flowsheet

### First Flowsheet

Based on the above findings, two schematic flowsheets were prepared. In general, it was found that crushing to a smaller size led to better liberation and results are somewhat improved. The **first Flowsheet** deals with processing of the Composite sample analysing 62.26% Fe, 2.01% $SiO_2$

and 4.22% $Al_2O_3$ in wet circuit. The material is crushed to -25 mm size and subjected to scrubbing and wet screening at 8 mm and classification of -8 mm fines to classifier sand ( -8mm+100# ) and Slime (-100#). The +8 mm lump, 45% by weight would contain about 3.8% $Al_2O_3$ . This product can be processed reduced by Batac Jig or else crushed to -8 mm and mixed with -8mm fines. -8 mm+100# washed fines containing 4.1% $Al_2O_3$ is to be sized to +1mm and -1 mm fractions and subjected to jigging and tabling to produce concentrates having $Al_2O_3$ of 3% and 2.65% respectively from the above two fractions. Slimes generated (21.6% by weight) will contain 5.3% $Al_2O_3$ and hydrocycloning, would bring down the $Al_2O_3$ from 5.3 to 4.58 in the cyclone underflow. This, when subjected to tabling using a fine deck will be able to bring down the $Al_2O_3$ level from 4.58 to 3.4. Use of MGS instead of Table would produce better concentrate with more yields. Use of MGS would be useful again in recovering some values from the cyclone overflow. The fines comprising jig concentrate, table concentrate and MGS concentrates from Cyclone Underflow and Overflow would be 28% and analyse 64.09% Fe, 1.9% $SiO_2$ and 2.95% $Al_2O_3$. Some additional yield is expected when the Jig Tails are ground and treated in a table.

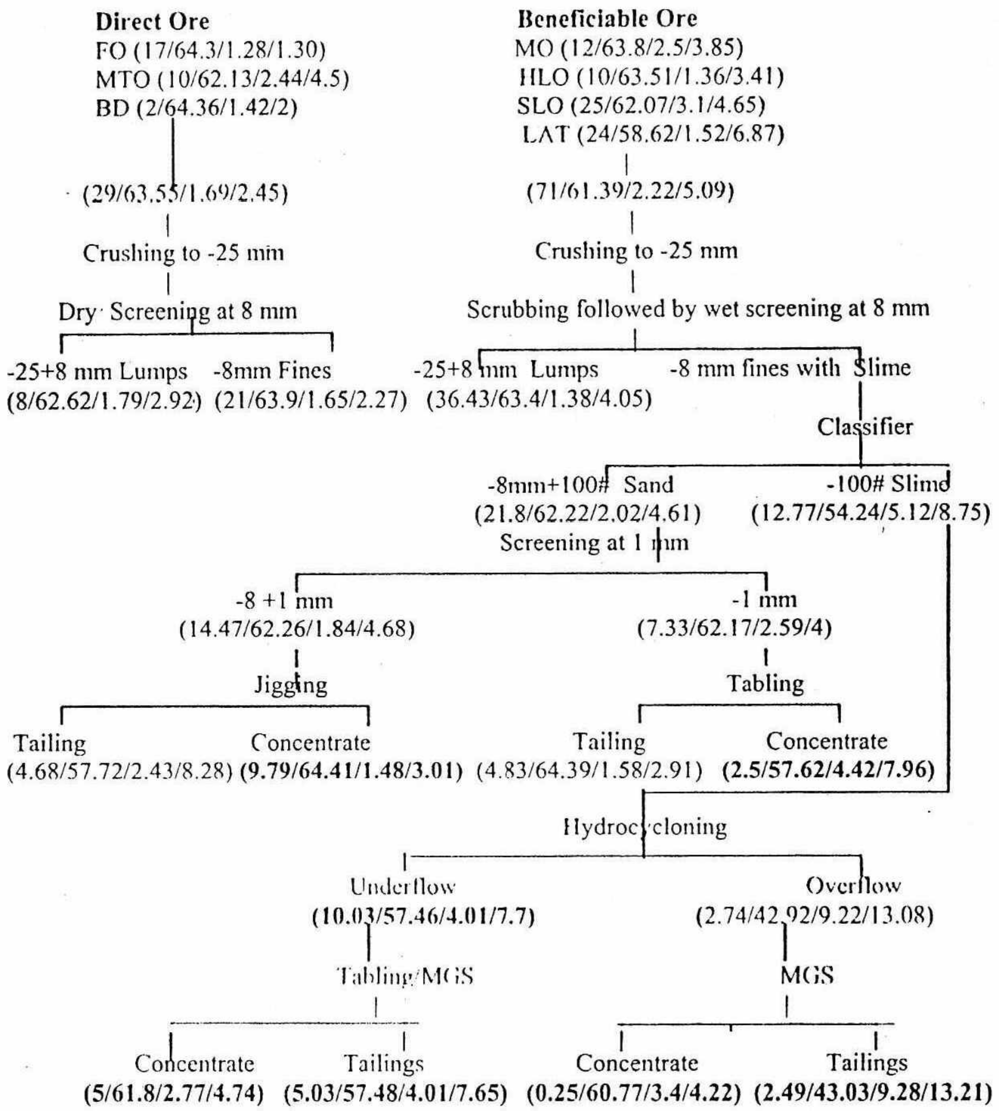
**Flowsheet 1: Wet Processing of the Composite Iron Ore Sample**



## Second Flowsheet

The components of Direct ore viz., Friable Ore, Mineable Transitional Ore and Blue Dust are relatively richer in grade and their fines contain less than 2.5% $Al_2O_3$ and therefore they do not need any processing. Blue Dust put in the wet circuit reports to slime. The proposed **Second Flowsheet** consists of separate proportioning and blending of Direct Ore and Beneficiable Ore. The Dry Circuit would consist of crushing the Direct ore (29% by weight with 63.55% Fe, 1.69% $SiO_2$ and 2.45% $Al_2O_3$) to -25 mm size and screening at 8 mm. The lumps would weigh 8% and analyse 62.62% Fe, 1.79% $SiO_2$ and 2.92% $Al_2O_3$. The -8 mm fines would be 21% by weight and analyse 63.9% Fe, 1.65% $SiO_2$ and 2.27% $Al_2O_3$. The beneficiable Ore would weigh 71% and analyse 61.39% Fe, 2.22% $SiO_2$ and 5.09% $Al_2O_3$. This would go through the wet circuit as described for Flowsheet 1. The washed lump from the wet circuit would be 36.43% by weight and analyse 63.4% Fe, 1.38% $SiO_2$ and 4.05% $Al_2O_3$. The combined lumps from dry circuit and wet circuit would be 44.43% by weight and analyse 63.25% Fe, 1.45% $SiO_2$ and 3.85% $Al_2O_3$. The Combined fines from Dry Circuit and wet Circuit (without Concentrates from Slime) would weigh 35.62% and analyse 64.1% Fe, 1.59% $SiO_2$. Products, their yield and analyses as per Flowsheet 1 & 2 are recorded in Table 1 & 2 respectively.

**Flowsheet 2: Dry Processing of Direct Ore & Wet Processing of Beneficiable Ore**




**Legend: Wt(%), Fe(%), SiO2(%), Al2O3(%)**

**Table 1 : Products from the Flowsheet 1**

| Product | Wt(%) | Fe(%) | $SiO_2$(%) | $Al_2O_3$(%) |
|---|---|---|---|---|
| -25+8 mm Washed Lump | 45.0 | 63.69 | 1.52 | 3.80 |
| -8 mm Fines :Combined Conc of Jig, Table, MGS Concs. of Cyclone Underflow & Overflow | 28.0 | 64.09 | 1.90 | 2.95 |

**Table 2 : Products from the Flowsheet 2**

| Product | Wt(%) | Fe(%) | $SiO_2$(%) | $Al_2O_3$(%) |
|---|---|---|---|---|
| -25+8 mm Washed Lump (Dry Screened + Washed) | 44.43 | 63.25 | 1.45 | 3.85 |
| -8 mm Fines : (Combined Conc of dry fines and concentrates of . Jig and Table (Wet Circuit) | 35.62 | 64.10 | 1.59 | 2.56 |

## Conclusions

Although the Second Flowsheet involves separate proportioning and blending of Direct Ore and Beneficiable Ore, the former needs crushing and sizing only and no further wet processing. The Beneficiable ore has to be wet processed. The combined fines concentrate is superior in grade and yield than that from wet processing of entire material. However, the +8 mm lumps in either case is not of desired grade due to improper liberation. HMS test was encouraging for washed lumps of Beneficiable Ores. Jigging by Batac Jig of the washed lumps may be tested, although the floats need further crushing and subsequent treatment. In view of the above, the washed lumps of the beneficiable ores from the second circuit may be crushed to -8 mm and treated along with -8 mm washed fines. Of course, by this, the lumps will not be available but the grade of overall concentrate can be brought down to near 2.5%.

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