BX04 - A Process for Development of Calcined Bauxite from Ferruginous Bauxite

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Abstract

In India, the resources of high-grade bauxite suitable for non-metallurgical applications (refractive, abrasive, chemical) are very limited. In general, calcined bauxite is manufactured from high alumina, low iron bauxite. The specification required is very stringent concerning chemico-mineralogical composition. The bauxite should contain low iron oxide (Fe_2O_3 < 5 %) and high alumina (Al_2O_3 > 55 %). Due to this, India is importing specific quality bauxite to fulfill the requirement of the industry. For the present study, the ferruginous lateritic bauxite sample was collected from the Eastern ghat deposit and characterized. The bauxite contains high iron oxide (Fe_2O_3 15–25 %) and moderate alumina (Al_2O_3 44–49 %). Mineralogically it is gibbsitic in nature with hematite and alumino-goethite being dominant iron oxide minerals. JNARDDC has conducted experiments to convert ferruginous bauxite into high alumina bauxite. The beneficiation tests have been done for the elimination of iron oxide by physical and chemical methods. After the removal of iron oxide from raw bauxite, pellets/ granules of beneficiated low iron bauxite have been prepared. The calcination tests have been done on parameters such as temperature, residence time, and heating-cooling rate. The calcined granules (calcined bauxite) have been characterized and properties determined. It contains 82 % Al_2O_3 and 1.9 % Fe_2O_3 with corundum, and mullite as major minerals. The bulk density of developed calcined bauxite is 2.7-3 g/cm^3. The results indicate that calcined bauxite can be developed from ferruginous bauxite. In this paper, an attempt is being made to highlight the status of high-grade bauxite resources in India and the process for the conversion of calcined bauxite from ferruginous bauxite.

Keywords: Ferruginous bauxite, Beneficiation, Calcination, Product, Calcined bauxite.

1. Introduction

India is endowed with 3 896 million tonnes of resources of Lateritic Bauxite deposits and placed 6th in terms of bauxite production. The geological and geomorphological features of lateritic bauxite deposits of India are unusual from region to region. The high-level deposits are located at an elevation of 900-1300 m above the mean sea level (e.g. Eastern ghat & coast, Chhattisgarh, Jharkhand, Western ghat, etc.) and on the other hand low level deposits with an altitude of 50-350 m above msl (Gujarat, coastal Maharashtra, West coast, etc.) [2, 7, 10, 14]. The characteristics of these deposits vary in context with geology, morphology, physical, chemical mineralogy and minor elements. JNARDDC have been evaluated lateritic bauxite deposits of India. The details of geological, morphological, chemical and mineralogical characteristics are given in Table-1 [5, 6, 7, 13, 15, 16]. In general, calcined bauxite is manufactured from high alumina low iron bauxite. In current scenario, the reserves of high-quality bauxite are limited and getting exhausted. The Eastern ghat (Odisha) bauxite is good quality (gibbsitic) with very less impurity as compared to other Indian bauxites. However, a major impurity is the presence of the high amount of iron oxide. An attempt is being made to convert the ferruginous bauxite into high alumina bauxite. The successful conversion of ferruginous bauxite into calcined bauxite, resulting in reducing the import of bauxite.

Table 1. Characteristics of lateritic bauxite deposits (India).

Region/ State	Parent rock Nature of deposit	Chemical & Mineralogical Feature	Remarks
Central India Chhattisgarh and Madhya Pradesh	Deccan Trap, Upper Rewa Sandstone, Vindhyan Sandstone; Mostly high level, occurs as discontinuous lenses or tabular bodies within laterite occurrences	Moderate to high alumina and high titania Mixed gibbsitic boehmitic and boehmitic type with 0.5-3% diaspore	Hard in nature (BWI 14–19 kWh/t) Laterites occurs above the bauxite zone and or sandwiched in horizon Non-metallurgical grade bauxite deposits are small & unexplored
Maharashtra	Mainly Deccan Trap Basalt High level and low level (coastal) mostly pockets, lenses and blanket type	Medium to high Al_2O_3, low silica, TiO_2 (2–6 %) and devoid of CaO Gibbsitic (coastal) & mixed gibbsitic boehmitic type (high level)	Hard in nature (BWI 14–18 kWh/t) Laterites underlain by bauxite zone High grade bauxite deposits (non-metallurgical grade) are in pockets
Jharkhand	Deccan trap, Granite gneiss; High level-blanket type	Moderate to high alumina and high TiO_2 (Mixed gibbsitic boehmitic type	Hard in nature (BWI 16–18 kWh/t) High grade bauxite deposits (non-metallurgical grade) are small
Eastern ghat & coast Odisha A. P.	Khondalite and Charnockite; high level lateritic type, which occur on plateau tops as blanket covers	Moderate Al_2O_3 (42–46 %), high Fe_2O_3 (20–30 %), low silica (1–3 %) & titanium Fully Gibbsitic, minor amount of boehmite	Soft in nature (BWI 9–12 kwh/t) Laterites occurs above bauxite zone Mostly metallurgical grade; high grade bauxites are in pockets Endowed with 70% of the total resources (India)
Gujarat	Deccan Trap basalt, argillaceous and calcareous sandstone and Limestone. Low level mainly pockety and boundary	Kachchh - High Al_2O_3, low SiO_2 and CaO Sabarkantha & Kheda Low-moderate Al_2O_3, high TiO_2 & moderate CaO Gibbsitic, with some amount of boehmite & diaspore	Hard in nature (BWI 14–19 kWh/t) Reserves of high grade (plant grade-PG) bauxite are exhausting. The resources of low to medium grade bauxite is abundant.
Western Ghats & Coast Kerala	Charnockite, Sandstone of Varkala and Quilon formation; Low level (Coastal) Pockets in laterite	Medium Al_2O_3, at places high SiO_2, low TiO_2 and traces of CaO Gibbsitic, part of silica as quartz	Moderate (BWI 13–16 kWh/t) High grade bauxite is in pockets
Karnataka	Deccan trap basalt, Dharwarian meta sediments, Granite gneiss; irregular lenses in the laterites	Medium Al_2O_3, SiO_2 low TiO_2 and traces of CaO Gibbsitic at places mixed gibbsitic-boehmitic	Moderate to hard (BWI 13–17 kWh/t) High grade bauxite exposed at some places
Tamil Nadu	Charnockite High level deposits	Moderate alumina & high silica Gibbsite major mineral	Moderate (BWI 10-14 kWh/t)

Goa	Dharwar to Deccan Trap metabasalts Low level (Coastal) occurs as irregular patches within the laterite horizon	Medium Al_2O_3, SiO_2, low TiO_2 & CaO Gibbsitic, boehmite as minor mineral Silica as kaolinite & quartz	Moderate to hard (BWI 14–16 kWh/t) Limited resources of high-grade bauxite with deposits.

2. Status of Bauxite Deposits

The high alumina and low iron bauxite occur only in the states of Chhattisgarh, Gujarat, Jharkhand, Maharashtra and Madhya Pradesh with scattered deposits in Karnataka, Tamil Nadu, Odisha, and Andhra Pradesh. Most of the high-grade bauxite deposits in Gujarat State (Kachchh & Jamnagar) are exhausted. Some of the high-grade bauxite deposits located in Central India are not accessible due to forest and tribal problems. On the other hand, good quality bauxite reserves located in Eastern ghat & coast region, suitable for metallurgical industry, are mostly lying unused. The scarcity of high-grade bauxite in the Country can partly be resolved by making available these deposits for non-metallurgical industries and also encouraging existing mines, to separate out value-added high-grade ore [4, 11, 16]. Our geotechnological evaluation work on Indian bauxite deposits indicates the high-grade bauxite deposits are located in the following regions (Table 2) [6, 7, 12, 13, 15].

Table 2. High grade bauxite deposits (India).

State	Districts	Deposits	Remarks/ Status
Gujarat	Kachchh, Jamnagar	Wamoti, Naredi, Wandh, Goniasar, Ratadia, Bhatia, Nandana	Mostly exhausted (approximate 70%)
Chhattisgarh, Madhya Pradesh	Bastar, Surguja, Balrampur, Jashpur, Katni	Kuye, Narmadapur, Barima, Kandraja, Pathrai, Gopatu, Piprapat, Kutku/Samri, Dumarkoli, Pandrapat	Some deposits are unexplored, small
Maharashtra	Kolhapur, Satara, Raigad, Ratnagiri	Gargoti, Ringewadi, Velas, Khujare, Hunerveli, Kuravadi, Male	Small deposits, group of deposits can be explored
Jharkhand	Lohardaga, Latehar, Netarhat, Gumla	Gurdari, Taimu, Amtipani, Kujam, Lupungpat, Pakhar	Partially explored
Western ghat (Karnataka, Tamil Nadu)	Belgaum, Salem, Nilgiri	Paduvare, Jamboti, Tinnanur hill	Resources are scanty
Eastern ghat (Odisha & A.P)	Koraput, Kalahandi, East Godavari	Kutuki, Karnapadikonda, Chadgiri, Dumkonda	Mostly metallurgical bauxite (gibbsitic), high grade ore exposed in pockets

The world production of bauxite is 384 million tonnes (2021) and is expected to increase by around 2 % (390 million tonnes) in the current year [21]. Australia continued to be the major producer and accounted for about 27 % share in total production, followed by China (34 %), Guinea (22%), Brazil (8.5%), Indonesia (5.5 %), India (5%), Jamaica (2 %) and Russia (2 %) and Keeping in view the exploration activities and export statistics, the drastic increase in the production of bauxite in Guinea is expected and takeover China in the current year.

Out of 31 000 million tonnes of world bauxite reserve, only 5 % is a non-metallurgy grade (India-111 mt) [4]. China and Guyana main sources of calcined bauxite for refractories with some quantities from Brazil and India [16, 20].

At present, the production of bauxite in India is in the order of 18-22 million tonnes [5, 21]. From the last two years, the production is steady however, it will increase appreciably due to the initiative of the government on auctioning, mineral policy, exploration of activities industry, commissioning of new plant, etc. It is estimated that the aluminium metal requirements in India may go up to 10 million tons per annum including re-cycled metal in the next 10 years. [1]. The imposition of ban on mining in the large bauxite deposits of Andhra Pradesh choked the growth of alumina production in this state. India is heavily dependent on imports to meet its requirement of low iron bauxite, at present, importing calcined bauxite. The import and export of bauxite ore depend on various factors such as the production of bauxite, raw material quality, export duty, etc. The raw bauxite used for producing abrasive and refractory products must fulfil much more rigid compositional requirements than the crude ore that is commonly used for aluminium production. The chemical analysis of typical raw bauxites used by the non-metallurgical industry is presented here as Table 3.

Table 3. Chemical analysis of typical raw bauxite.

Grade	**Major Oxides (%)**			
	Al_2O_3	**SiO_2**	**Fe_2O_3**	**TiO_2**
Refractory	Min. 58 - 61	Max. 1.5 - 5.5	Max. 2	Max. 2.5
Abrasive	Min. 55	Max. 5	Max. 6	Min 2.5
Chemical	Min. 55 - 58	Max. 5 -12	Max. 2	0 – 6
Calcined	Min. 55	Max. 7.5	Max. 4	Max. 4.5

3. Calcined Bauxite

India is a minor producer of non-metallurgical bauxite, despite having the occurrence of high-grade bauxite in central India and West coast. Calcined bauxite possesses characteristics such as high alumina (Al_2O_3 85%), low iron oxide (Fe_2O_3 3%) with typical mineralogy and properties includes bulk density (2.8-3.5 g/cm^3), refractoriness, particle size, etc. Calcined bauxite is classified by the major end-use in refractory and abrasive.

The prime factor driving the growth of the global calcined bauxite market is its extensive use for brown fused alumina, further used for the production of refractory materials. The calcined bauxite market size was valued at USD 1.6 billion in 2022. The calcined bauxite market industry is projected to grow from 1.68 billion in 2023 to 2.5 billion by 2032 exhibiting a compound annual growth rate (CAGR) of 5.15 during the forecast period (2023-2032). Calcined bauxite demand is expected to increase over the forecast period due to market drivers like large scale application of brown fused alumina and nonferrous refractory materials [9]. In the world, the calcined bauxite market is dominated by region Asia pacific, North America and Europe.

The global calcined bauxite market, by application encompasses the following areas:

- Metallurgy
- Refractory Materials
- Road Surfacing
- Abrasives
- Others

Other calcined bauxite uses are:

- Anti-skid road surfacing
- A relatively expensive road surfacing aggregate so only used in limited high wear areas near traffic lights and pedestrian crossings.
- UK traditionally seen as significant market, with other abrasive minerals used elsewhere.
- Welding requires a very well calcined product with a very low LOI and extremely low phosphorous, sulphur and carbon.
- Anti-skid/anti-slip protection.

- High friction surface treatment.

3.1 Development of Calcined Bauxite

Keeping in view the limited resources of high-quality bauxite and increase in the import of bauxite, it is necessary to develop process for the development of calcined bauxite from inferior ferruginous grade. An attempt has been made to develop calcined bauxite from ferruginous bauxite of East coast deposit. For the research studies, the sample of bauxite was collected from Eastern ghat (Panchpatmali) deposit of Odisha. The chemical analysis shows that the bauxite contains high iron oxide (Fe_2O_3 17.5 %) and alumina (Al_2O_3 49–6 %). Mineralogical analysis shows that bauxite is gibbsitic in nature and iron oxide is in the form of hematite and alumo-goethite.

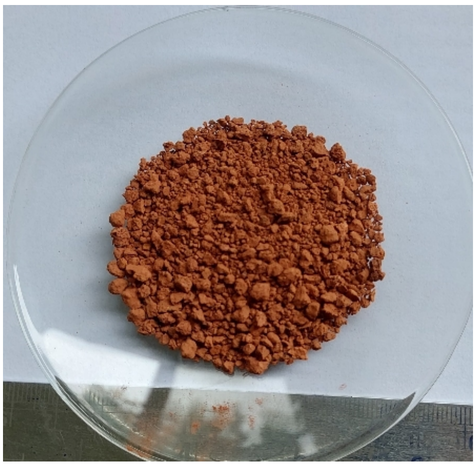
3.1.1 Beneficiation

The beneficiation studies have been done to remove the impurities (mainly iron oxide) and enrichment of alumina content. The physical beneficiation techniques such as screening-sieving, hydrocyclone and wet high intensity magnetic separation (WHIMS) applied. It is observed that reduction of iron content up to certain extent (Fe_2O_3 12 %) achieved by using physical separation [8, 11, 19]. As per the specifications, the iron oxide content in the raw bauxite should be below 4%. Keeping these in view, acid leaching tests has been done on various parameters such as acid concentration, temperature, grain size and solid liquid ratio. The test has been done by using various size of bauxite fraction such as -8+4, -4+0.5 and -0.5 mm. Our study on Indian deposits showed encouraging results in -4+0.5 mm fraction in context with reduction in iron oxide and enrichment of Al_2O_3 percentage [3, 8]. By using acid leaching (HCl), reduction of iron less than 1.5% Fe_2O_3 is achieved with Al_2O_3 60 %. The details are given below.

Leaching Tests

Raw bauxite size: -4+0.5 mm
Solid liquid ratio: 1:10
Acid concentration (HCl): 8–15 wt%
Time: 60–180 minutes
Temperature: 90–100°C

The weight recovery of beneficiated fraction (residue) is in the range of 65-70 %. The residue contains 61.35 % Al_2O_3, 1.6 % Fe_2O_3, 2.6 % TiO_2 and 2.50 % SiO_2.


(a)

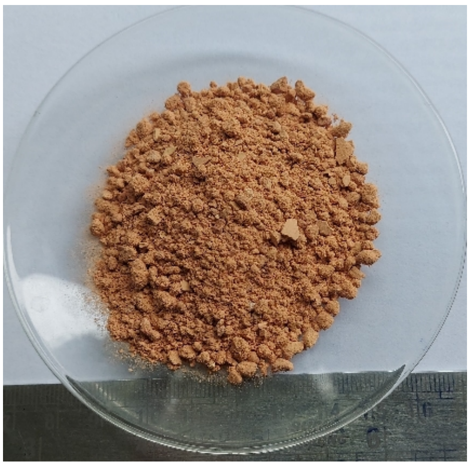

(b)

Figure 1. (a) Raw ferruginous bauxite. (b) Leached bauxite (residue)

3.2 Calcination Studies

After removal of iron oxide, pellets of beneficiated low iron bauxite have been prepared. The calcination tests have been done on the following parameters:

- Temperature (1300-1600 °C),
- Residence time (2-5 hours)
- Heating-cooling rate (10 °C per minute).

The calcined granules (calcined bauxite) contain moderate alumina (Al_2O_3 78 %) and iron oxide (Fe_2O_3 2.5 %) with the bulk density 1.54 g/cm^3. It is observed that due to acid leaching, the raw material loses the original properties such as crystallinity, texture, etc.

3.2.1 Calcination test with additive

The tests have been done by using an additive (sillimanite). The sillimanite contains 54 % Al_2O_3 and low iron oxide (Fe_2O_3 1 %). The pellets (4 mm) have been prepared by using beneficiated bauxite and sillimanite (80:20 %). The calcination tests have done on a temperature 1600 °C with residence time 3 hours. The pellets exhibit grey colour, hard in nature after calcination. The calcined pellets (calcined bauxite) have been characterized. The chemical analysis shows that it contains Al_2O_3 82.33 %, SiO_2 8.36 %, Fe_2O_3 1.9 % and TiO_2 2.01 %. The bulk density is in the order of 3.01 g/cm^3. The mineralogy study by XRD shows that the developed calcined bauxite comprises corundum, mullite as major minerals (figure 2). It is observed that additive plays a vital role in the process of development of calcined bauxite. It is proposed to carry out tests with other additives (Kyanite, Pyrophyllite, etc.). The studies are in progress at JNARDDC to work out the process parameters.

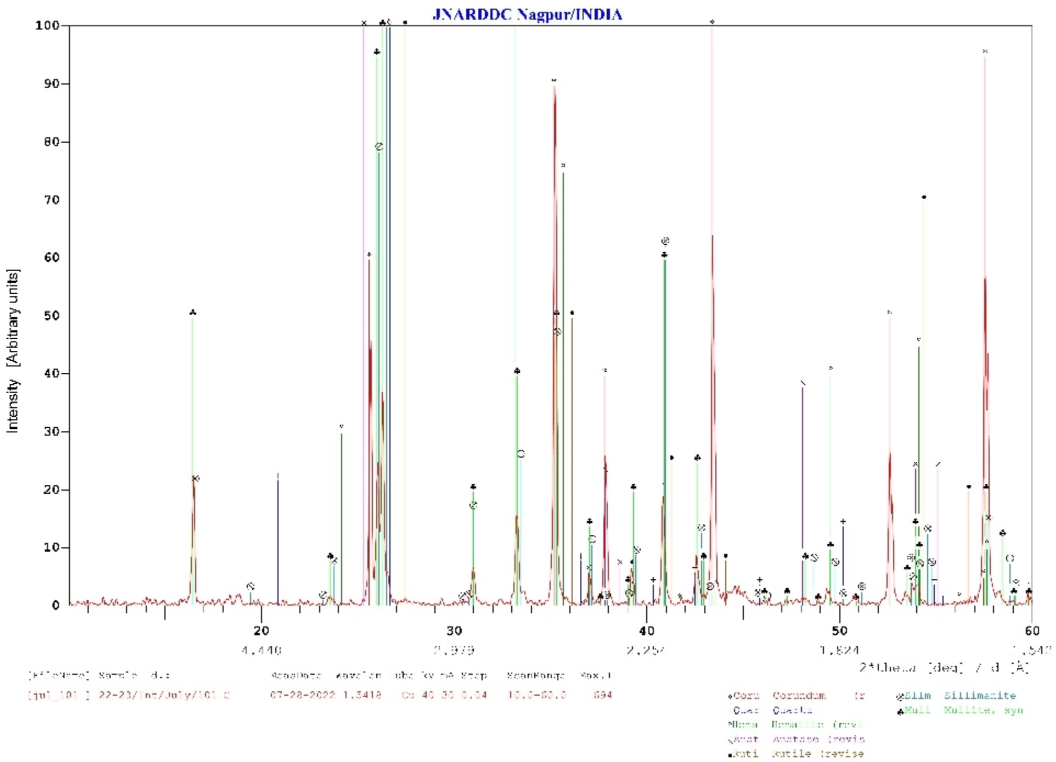


Figure 2. XRD Diffractogram of calcined bauxite.

4. Conclusions

- In India, the high-grade bauxite deposits are small and scattered. The group of small deposits comprising of favorable Chemico -mineralogical, physical characteristics may be viable for utilization. The technological evaluation of the deposits are necessary to identify resources of high alumina low iron bauxite.
- Bauxite for non-metallurgical industries (calcination, refractory) meets very rigid physicochemical requirements and specifications particularly for constituents like alumina (Al_2O_3 %) and iron oxide (Fe_2O_3 %) compared to ore used for the metallurgical industry. The price of imported calcined bauxite varies depending on the quality and parameters. As far as Indian bauxite is concern, it may be more economical to find an indigenous source/option for complex mining and by using low -medium grade bauxite by adopting suitable beneficiation techniques. It is suggested to properly segregate both grades of bauxites while mining.
- The laboratory test results show that it is possible to produce high alumina low iron bauxite by integrated beneficiation processes. The studies indicate after beneficiation, the processed ferruginous ore could be used in the production of calcined bauxite.

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