WHITEPAPER ON

REFRACTORY MATERIALS

Foreword

Refractories are ceramic materials designed to withstand the very high temperatures (in excess of 1000°F [538°C]) encountered in modern manufacturing. They are used to line the hot surfaces of furnaces but apart from thermal protection, they also provide resistance to abrasion and chemical attack. For this reason, refractories are essential components in manufacture of iron & steel, cement, aluminium, copper, glass etc. The refractory raw materials are both natural and synthetic, usually non-metallic, or combinations of compounds and minerals such as alumina, fireclays, bauxite, chromite, dolomite, magnesite, silicon carbide, and zirconia. New developments having combination of Metals, Oxides, Carbides have led to manufacture of many 'Smart Refractories'.

Like other mineral based sectors, refractories industry too is highly dependent on good quality raw material which spread across the globe especially China. Unfortunately, in spite of huge demand, India lacks good quality refractories minerals for which it is completely dependent on imports. Sometimes this has led to serious disruptions in functioning of steel plants when global supply chain of refractory raw materials is affected. Energy cost in the country is emerging as one of the major challenges in raw materials sector; such as in production of fused minerals. Keeping in view the probable resource crisis which seems imminent in future, this industry needs exhaustive brainstorming to develop innovative ideas and attract the due attention of the top policy makers to fight the crisis. The present white paper on refractory raw materials published jointly by Indian Steel Association-Indian Refractory Makers Association is a precise attempt in that direction.

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Introduction: What are Refractories?

Refractories are ceramic materials designed to withstand very high temperatures (in excess of 1,000°F [538°C]) encountered in modern manufacturing. More heat-resistant than metals, they are used to line the hot surfaces found inside many industrial processes.

In addition to being resistant to thermal stress and other physical phenomena induced by heat, refractories can withstand physical wear and corrosion caused by chemical agents. Thus, they are essential to the manufacture of petrochemical products and the refining of gasoline.

Refractory products generally fall into one of two broad categories: preformed shapes or unformed compositions, often called specialty or monolithic refractories. Then, there are refractory ceramic fibers, which resemble residential insulation, but insulate at much higher temperatures. Bricks and shapes are the more traditional form of refractories and historically have accounted for the majority of refractory production.

Refractories come in all shapes and sizes. They can be pressed or molded for use in floors and walls, produced in interlocking shapes and wedges, or curved to fit the insides of boilers and ladles. Some refractory parts are small and possess a complex and delicate geometry; others, in the form of precast or fusion-cast blocks, are massive and may weigh several tons.

1. Refractory raw materials & their sources

It is a well-known fact that the Indian Refractory Industry is highly dependent on imported raw materials mainly China. It is also well known that China's strict environmental policies are impacting raw material supply chain. There has been drastic fluctuation in Chinese supply of critical raw materials in recent times which has impacted entire supply chain thereby creating shortage of key refractory raw materials especially during winter times.

For India it has now become imperative to enhancing domestic raw material production & use of alternate sources are the key components to remain competitive in the current scenario.

Table 1.1: The global raw material source matrix.

Refractory classification	Industrial mineral (incl. synthetic)	Main chemical component	Primary source country
BASIC	**Dead burned magnesia**	85-99.8% MgO	**China**
	Fused magnesia	97-99.8% MgO	**China**
	Dead burned dolomite	56-62% MgO, 36-40% CaO	USA
	Chromite	>46% Cr2O3	South Africa
	Sintered/fused spinel	66-80% Al2O3, 21-33% MgO	**China**
	Olivine	40-50% MgO, 35-45% SiO2	Norway
ACIDIC High alumina	**Calcined alumina**	>99.5% Al2O3	**China**
	Fused alumina	94-99.5% Al2O3	**China**
	Calcined bauxite	85-88% Al2O3	**China**
	Sintered/fused mullite	40-75% Al2O3	USA
Low alumina	**Andalusite, sillimanite, kyanite**	60-65% Al2O3	South Africa
	Refractory clays	20-45% Al2O3	**China**
	Pyrophyllite	20-30% Al2O3	South Korea
Silica	**Quartzite, silica sand**	>97% SiO2	Regional
	Fused silica	>99.8% SiO2	USA
SPECIALISED	**Zircon**	66% ZrO2+HfO2	Australia
	Zirconia	>99% ZrO2	**China**
	Silicon carbide	>93% SiC	**China**
	Graphite	75-99% C	**China**
INSULATING	**Diatomite**	>75% SiO2	USA
	Perlite	65-80% SiO2	**China**
	Vermiculite	45% SiO2	South Africa

1.1. High Alumina Materials

Table 1.2: The possible sources of high alumina raw materials in India.

Raw materials	Remarks
Fireclay	• Abundant Availability. • Total Reserve 30.1 million MT • Proven Reserve Probable Reserve • 15.7 million MT 14.4 million MT • Total reported fireclay consumption: 713 K MT (Refractory & Agriculture). • Fireclay found above coal bed is being dumped, hence acute shortage of good quality Fireclay.
Beach sand sillimanite	• Highest purity & abundantly available. • Laboratory know-how to convert into 55-80% Al_2O_3. • Also containing mullite/high alumina aggregates available. • Need up scaling with industries.
Kyanite	• Limited applications and limited availability. • Majority resource is low grade. • Telangana (48 million MT) and Andhra Pradesh (32 million MT). • Production is low grade kyanite of around 40% alumina
Andalusite	• Highly acceptable, but not available in India. Inferred resources of low grade are in Jharkhand and UP
Bauxite (boehmite, gibbsite) or Diaspore (oxi-hydroxides)	• Most of the Indian sources are not suitable for refractory applications due to the presence of high level of impurities (Fe_2O_3, TiO_2&CaO). • Need value addition with or without beneficiation. • Fundamental research findings available. • Applied research/upscaling necessary jointly by research organization & industries.
Mixture of bauxite & Kaolin	• A potential source of 60-70% Al_2O_3 containing aggregate (sintered mullite)
Enriched clays by high alumina recycling materials	• Cannot meet the sufficient demand, but it is one of the good possibilities.
Synthetic aluminas (calcined, normal/fast sintered, fused)	• Well known & regularly in use for high value-added refractory products. However, calcination cost is high in India due to high electricity for which it is mostly imported from China.

1.2. Bauxite

India's leading refractory grade bauxite producer is Gujarat Mineral Development Corporation from its main sources of Gadshisha, Kutch and Bhatia, Jamnagar. Other Indian sources are in M.P. & Jharkhand region. Most of these bauxites are not suitable for refractory application due to the presence of high level of impurities (Fe_2O_3, TiO_2&CaO).

Categorisation of Indian Bauxite:

- Metallurgical Grade,
- Refractory Grade (*$A1_2O_3$ 55% (min.), Fe_2O_3 4.5% (max.), CaO 1.5% (max.)*
- Abrasive
- Chemical
- Cement and others

Out of 28000 million MT of World Bauxite reserve, only 5 % is non-metallurgy grade.

Table 1.3: Indian Bauxite resource & reserves

	Resource (mill t)	Reserve (mill t)
Total	3739	830
Refractory Grade	111	17 (~2%)

With approx. 2.5 Mill Tons consumption of above grade, every year, current reserves to last only 3-4 years until fresh reserves are identified and released for mining.

Gujarat is the main source of refractory bauxite in India. However, there is steady deterioration in quality of the mined mineral in the past few years as seen in the table below.

Table 1.4: High Grade Analysis Report

Year	Al_2O_3 (in %)	SiO_2 (in %)	CaO (in %)	TiO_2 (in %)	Fe_2O_3 (in %)	LOI (in %)
2009-10	57.34	4.11	1.64	2.78	2.94	30.76
2010-11	57.02	4.23	1.22	3.01	3.09	30.61
2011-12	56.75	4.46	1.18	2.98	3.17	30.47
2012-13	56.53	4.93	1.42	2.70	3.33	30.39
2013-14	56.24	5.14	1.16	2.99	3.49	30.15
2014-15	56.17	5.24	1.03	3.10	3.62	30.41
2015-16	55.80	5.85	1.09	3.13	3.75	29.89
2016-17	55.63	6.12	1.79	2.78	3.80	29.61
2017-18	55.31	6.38	1.12	2.70	3.95	29.49
2018-19	55.12	6.52	1.08	3.04	4.02	29.34

(Source: GMDC)

Also, in case of captive mines for refractory grade bauxite, only 20% of the output is refractory grade while the balance 80% is non refractory grade (mainly sold to the cement industry). Govt of Gujarat is not issuing mining license of bauxite available in Kutch region. Of the bauxite quality available there, 30% of it is estimated to be refractory grade while the rest is non refractory grade.

At present there is not a single acre of Government open land is available to create blocks for auction process in the same district. Though there are plenty of private land having high grade bauxite in large quantity but they are not applying for getting Mining Lease/Prospective license for their land because of auction policy on private land might prove detrimental to private mine owners as it does not give surety in acquiring his land for his own captive use. The statistics depicts that within last 4-5 years' time hardly very few private land applications have come up for converting their and into Mining Lease/Prospective license. The demand for high grade bauxite is pretty high, there is good reserve in privately owned lands but the system of granting of Mining Lease/Prospective license is not acceptable by the private land owners who have possessed these lands for the past 4-5 decades. If a mutually agreed solution to this crisis can be worked out, it can be beneficial for private land owner, Government and economy as the industry has a high potential to play a vital role in the current economy slowdown.

Indian bauxite contains considerable amount of iron oxide, titania and lime as impurities which restrict the high temperature refractory applications. For the past many years, researchers have been trying to improve the quality of Indian bauxite either by beneficiation or by modifying the high temperature phase assemblage with different additives. However, none of them proved to be commercially viable.

For all these reasons, India is heavily dependent on imports to meet its requirement of Low Iron Bauxite.

1.3. Diaspore

Sizeable Diaspore availability is limited in the states of Madhya Pradesh and Uttar Pradesh. Although Indicated Reserves are high, the production in 2016 was estimated to be 17400 MT. Exploration needs to be done to increase the output.

Table 1.5: Diaspore resource & reserves

S No.	Classification	Qty in MillT
1	Total Resource	10.19
2	Reserves	7.88
3	Refractory Grade Resources (87%)	8.85
4	Refractory Reserves	6.86

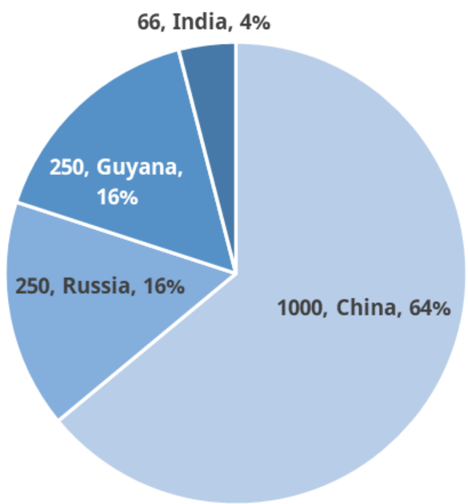
1.4. Brown Fused Alumina/White Fused Alumina and Fused Mullite

There is sufficient domestic production capacity to meet the requirement. Two major players have capacity of around 45000 Mt /annum of BFA and around 13000Mt/Annum of WFA and Mullite. Higher demand from abrasive industry at more remunerative prices leads to shortage for Refractory Industry and is met by imports. Combination of mining restrictions, production shutdowns and increasing costs have put market prices on a decisively upward course. Also due to comparative lower power tariff in China, the cost of fusion of these materials is much less. Hence from the point of view of economics, most of the times it becomes much cheaper to import than to locally produce BFA and WFA.

1.4.1. Bauxite & BFA: The International Scenario

From 2017, the Govt. of China has stopped production of calcined bauxite and BFA from November – March near 28 cities (Beijing, Tianjin, Zhengzhou, Kaifeng, Puyang, Anyang, Hebei, Xinxiang, Jiaozhou etc). This measure will continue for some time till the ambient air quality improves.

Fig 1.1: World Bauxite Capacity ('000 tonnes)



In 2020, global calcined bauxite capacity reached approximately 1.7 million tons. In which, China was the largest production country with capacity of 1 million tons of calcined bauxite, accounted for nearly 64% of total amount. Russia and Guyana were both 275,000 tons respectively, together occupied roughly 35% of world total capacity. both 275,000 tons respectively, together occupied roughly 35% of world total capacity.

Table 1.6: Some important global bauxite and alumina producers

Bauxite producers	Alumina producers	Fused alumina producers
• **Bosai Minerals Group – China** • **CMP Group- China** • **Demireller Mining Turkey** • **Hellenic Mining Enterprises – Greece** • **S&B Industrial Minerals – Greece**	• Alcoa – USA • Almatis – Germany • Aluchem – USA • MAL Magyar Aluminium – Hungary • Martinswerk – Germany • Nabaltec – Germany • Alteo – France • Hindalco - India	• C-E Minerals (part of Imerys) – USA • Elfusa – Brazil • Henan Mianchi Great Wall Corundum – China • Treibacher Schleifmittel – Austria • Washington Mills Electro Minerals – USA

1.5. Kyanite, Sillimanite and Andalusite

All these are structurally different but same chemical formula. These Alumino-Silicates have a very limited availability in natural form except for deposits of sillimanite in sand form. The andalusite market is characterised by tightness in supply and higher prices at the present time. India does not produce Andalusite, hence it is completely dependent upon imports. Because of this aforesaid problem, refractory makers many times seek alternate replacement materials like kyanite or mullite.

Table 1.7: Country-wise Matrix of India's Import of Key Refractory Raw Materials

S No.	Product	Main Sourcing Countries	Others
1.	Calcined Bauxite	China	Netherlands, Turkey
2.	Brown Fused Alumina	China	Brazil
3.	White Fused Alumina	China	Bahrain
4.	Tabular Alumina	EU	China
5.	Calcined/Reactive Alumina	EU	China
6.	Andalusite, Mullite	South Africa, China	N.A.

1.6. Magnesite

India contains large resources of magnesite from the states of Tamil Nadu, Karnataka, Jammu & Kashmir, Uttarakhand. India is a supplier of crude and caustic-calcined grade, but produces mainly dead burned magnesite to meet the demand of Indian refractory industry for application in steel and cement industries. Notable magnesite producers in India are Tamil Nadu Magnesite Ltd (Tamil Nadu Govt owned company), Almora Magnesite Ltd, jointly with TRL Krosaki Refractories Ltd & Steel Authority of India Ltd., Dalmia Magnesite Corporation.

The production figure of the major companies is available in a report where it is indicated that around 80,000 tonnes per annum of dead burnt magnesia is produced in India containing 82-92% MgO. The major impurities present in natural magnesia raw materials are CaO, SiO_2, Fe_2O_3 and Al_2O_3. While Salem variety of magnesite is rich in SiO_2, the Almora variety contains considerable amount of CaO and Fe_2O_3. For improved corrosion resistance & hot strength, the sintered MgO should be free from such impurities and the grain size should be more than 150 μm.

The value of imports of commodity group 251990 "Fused magnesia; dead-burned (sintered) magnesia, etc" to India totaled $95 million in 2020. Sales of commodity group 251990 to India decreased by 32% in value terms compared to 2019. imports of commodity group 251990 "Fused magnesia; dead-burned (sintered) magnesia, etc" decreased by $ 45 million (the value of imports of commodity group 251990 to India was equal to $140 million in 2019).

Some of the key issues to be noted are:

- Magnesite is used in Refractory Industry as Dead Burnt Magnesite & Fused Magnesite forms.
- Indian refractory industry uses 90% Magnesite in Dead Magnesite Form.
- No production of fused Magnesite in India.
- Total reserves of 21 million MT (mostly medium grade) out of 328 million MT of resource.
- North Indian Himalayan deposits are high in Iron content. Not suitable for bricks
- Salem deposits of South India are high in silica and low in Lime & Iron content. Suitable for bricks in certain applications.
- A number of attempts were made to beneficiate the low-grade minerals by R&D institutes like CSIR-CGCRI but none had been commercially successful.
- No Indian Magnesite has been commercially exploited for fusion hence country is fully dependent only imports and that too from China. Hence the price and supply of the material comes under severe stress when China clamps down on polluting industries.

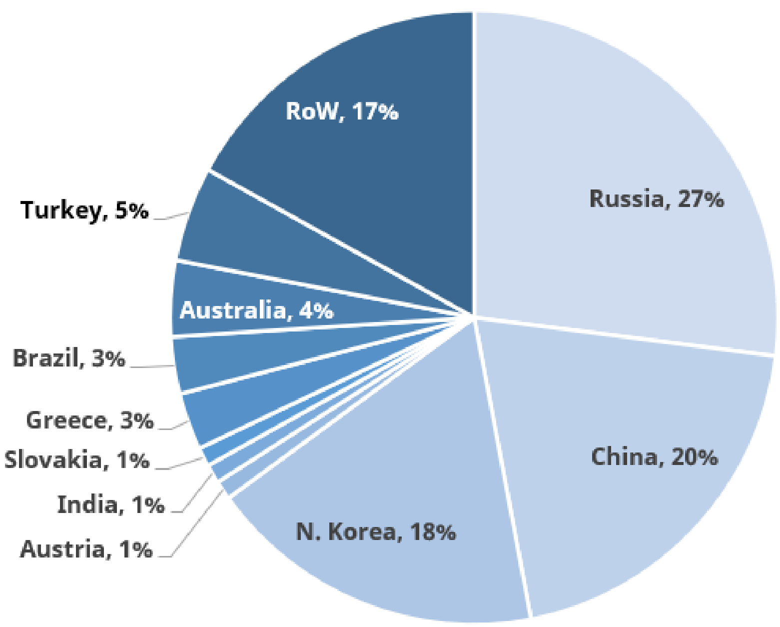
1.6.1. Magnesite: The International Scenario

Magnesite is mined in the following provinces of China:

1. Anshan (having 42 operating mines)
2. Yingkou
3. Liaoyang
4. Dandong

Anshan province has the best quality magnesite mines (having 95-97% MgO content) while others have inferior grade of magnesite (85-87% MgO content). During winter, Chinese authorities take strict steps to reduce pollution level of the region as per its "Blue Sky Policy". This leads to frequent closure of mines or reduced output. This problem is much more acute at Anshan province which is the sole supplier of quality magnesite.

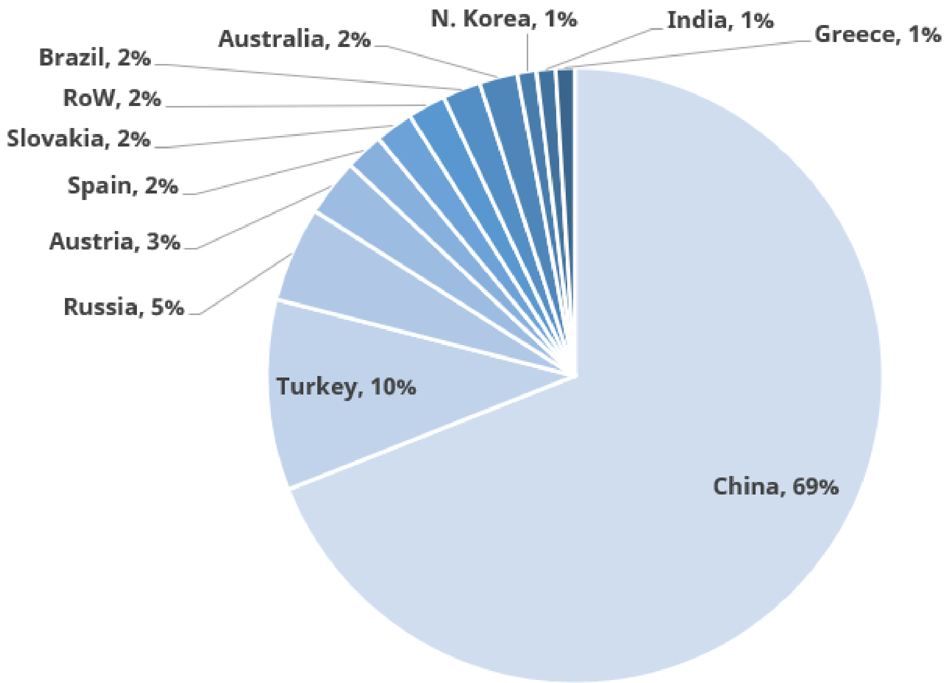
Fig 1.2: World Magnesite Reserves totaling 8.5 bn tonnes



Source: Data from USGS

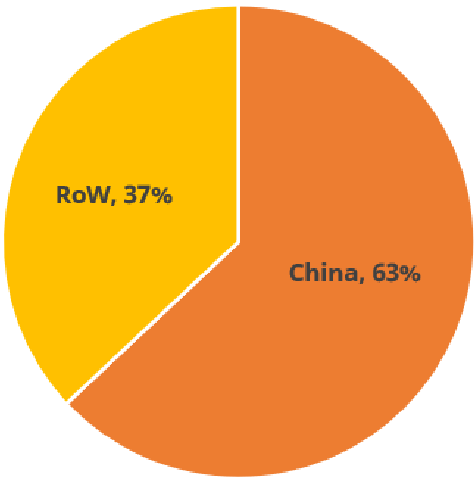
For India, at present China is almost the sole provider of fused grades of magnesite.

Fig 1.3: World Magnesite Production totaling 27.7m tonnes



Source: Data from USGS

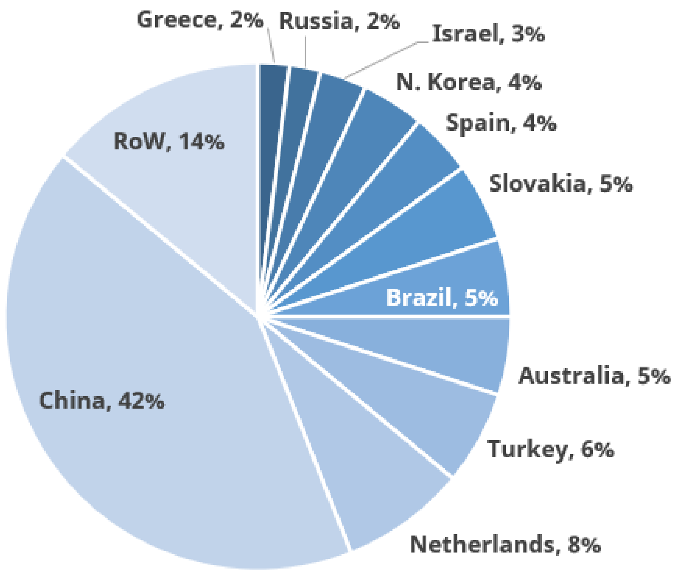
Fig 1.4: World Natural Magnesia Production (2015)



Source: Richard Flook & Ian Wilson (2016)

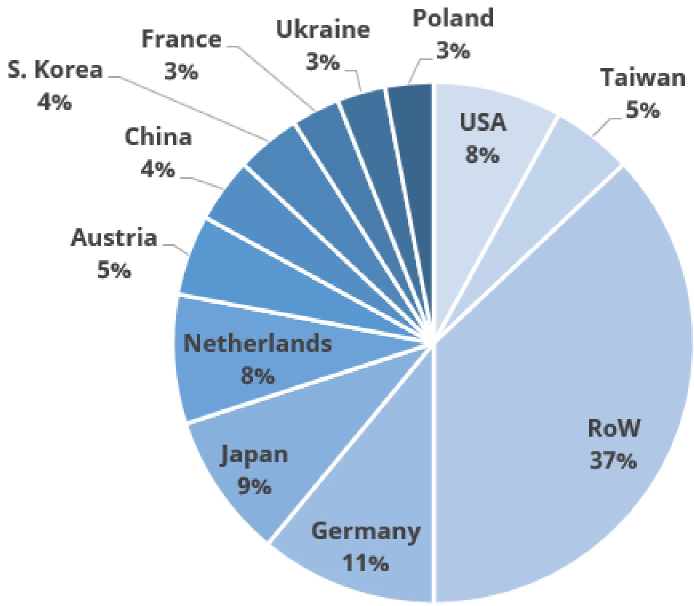
The figures shows that China has 20% of world magnesite reserve but 69% of world magnesite production is attributed to it. In other words, after few decades, when Chinese magnesite sources will be depleted, there will be acute problem of basic materials unless alternative raw materials (mainly synthetic) are not discovered.

Fig 1.5: World Magnesia Exports (2016) totaling 4.5m tonnes with Primary trade > 100,000 tonnes MgO



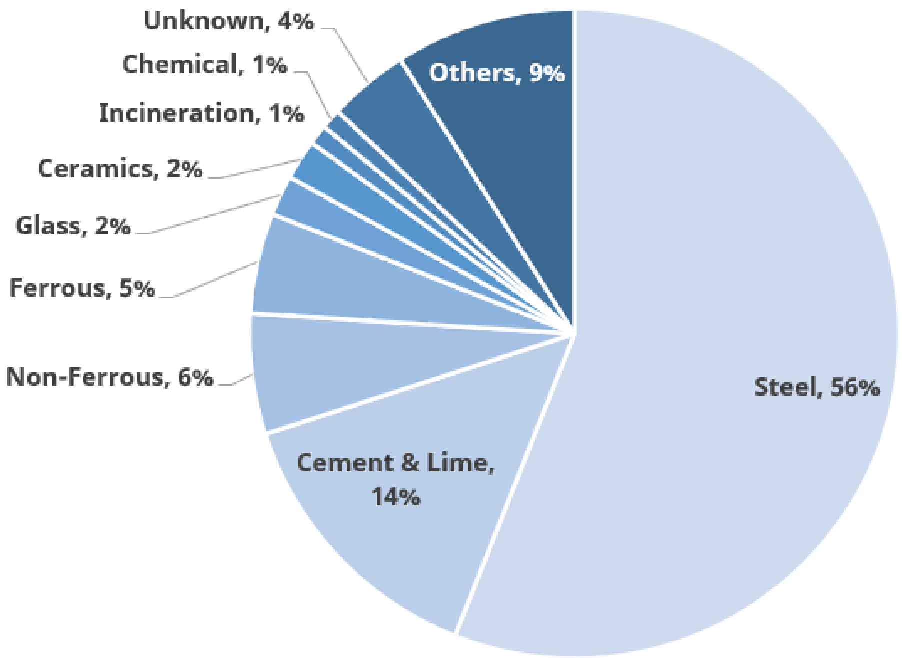
Source: Data from USGS

Fig 1.6: World Magnesia Imports (2016) totaling 4.2m tonnes with Primary trade > 100,000 tonnes MgO



Source: Data from USGS

Fig 1.7: EU Refractories Market (2014) totaling 3.6m tonnes

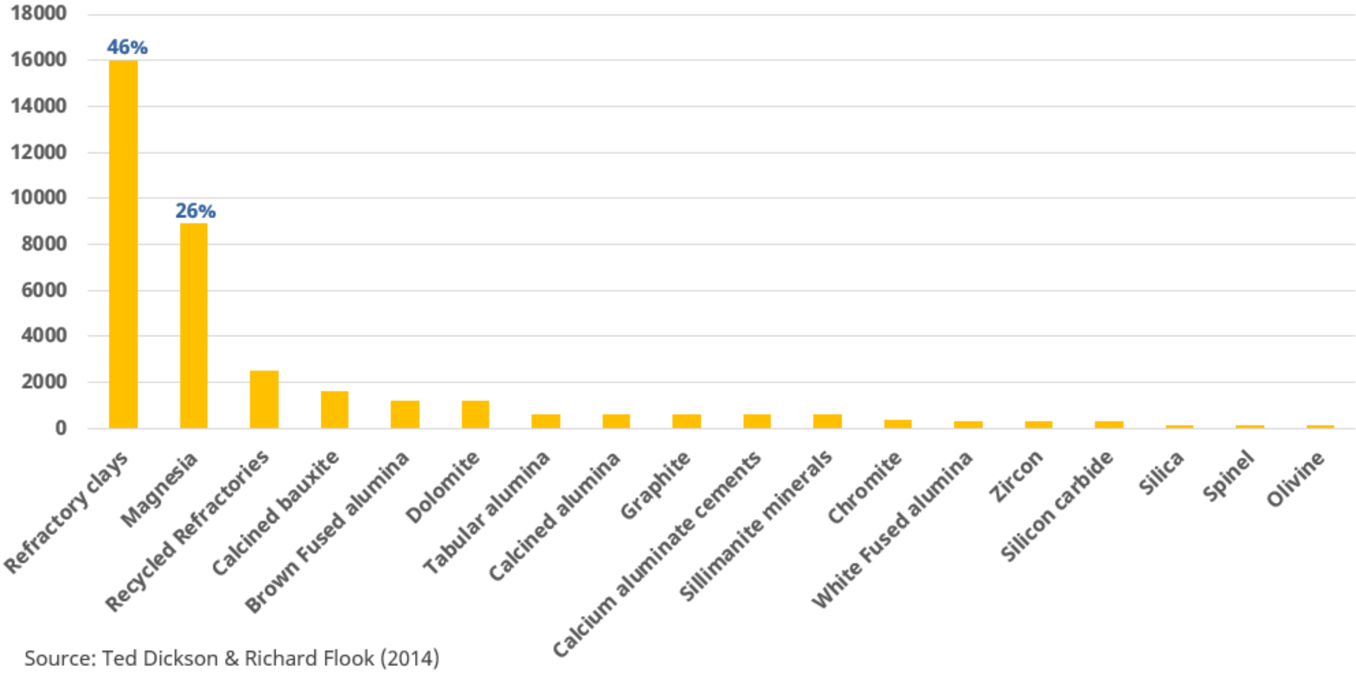


Source: PRE

Table 1.8: Top 11 MgO markets account for 74% crude world steel output.

Primary MgO Market	World Crude Steel Output Ranking (2016)	World Crude Steel Output in 2016 (1,626.6m tonnes)
Germany	7	3.0%
Japan	2	6.0%
USA	4	5.0%
Netherlands	23	0.5%
Taiwan	12	1.0%
Austria	22	0.5%
S. Korea	6	4.0%
China	1	50.0%
Poland	19	1.0%
Ukraine	10	1.5%
France	15	1.0%
Total		73.50%
Russia	5	4%
India	3	6%

Fig 1.8: Refractory Market Context: Estimated World Consumption of Refractory Minerals totaling ~35m tonnes



Source: Ted Dickson & Richard Flook (2014)

Let us bear in mind that improving the environmental conditions in the country is one of the goals of the Beijing government's current Five-Year Plan, so it has a high priority. The country's efforts to improve the conditions of its local environment will continue to hinder mining and mineral processing as shown by routine winter shutdown of heavy industries. The unpredictability has been having clear effects on market sentiment and pricing patterns.

Table 1.9: Country-wise Matrix of India's Import of Key Refractory Raw Materials.

S No.	Product	Main Sourcing Countries	Others
1.	Fused Magnesite	China	Greece, Germany, UK, Australia
2.	Dead Burnt Magnesite	Turkey, China	Australia

1.7. Chrome

Bulk of Chromite used by Alloy Industry e.g., Ferro chrome, Charge Chrome etc. and approx. 2% of total production 2.3 million MT goes in Refractory and Steel industry combined. Chrome is mainly used in Filling Masses & bricks for Copper Industry and heavy chemical Industry.

India hardly has 1% of world chrome deposits but exports around 30-35% of the world chrome demand. Out of Resource of 322 million MT, reserves of only 107 million MT have been identified. Hence more exploration is needed to identify additional reserve. To meet its domestic demand, India has to import Chrome, mostly from South Africa.

Fig 1.9: Refractories Raw Materials Sourcing Map.

Probably other than fused magnesite, there is alternative to China for the available refractory materials. FM is an extremely energy intensive process (FM grains are called crystallized electricity) plus the fusion process and segregation of various grades of fused grains to ensure proper quality is technically challenging. Plus, the global prices are completely dependent on Chinese local price. When the Chinese FM prices are low, no Chinese FM producer has high probability of bleeding because energy cost in China is still relatively cheaper and the whole world is dependent on Chinese FM for which product movement is always there. Hence profit margin might be slender but will still exist. That is not the same case for non-Chinese FM producers. Their profit margin is linked to Chinese prices as no refractory maker will buy their costlier products when cheaper Chinese variants of same quality are readily available. This acts as a detriment to expand their capacity. For other refractory raw materials, the non-Chinese sources are pricier options compared to their Chinese counterparts. Hence when Chinese raw material prices are at competitive level and/or there is no hindrance in supply, it makes no economic sense to make refractories with non-Chinese materials. The resultant products being higher priced will have no taker in the market. *It is not possible for any refractory maker who operates with limited working capital to buy costlier non-Chinese raw materials and compete in the market without any mutual reciprocity from the steel industry.*

Table 1.10: Dependency mapping for all imported raw materials country-wise.

Raw Material	Sources of supply
Fused Magnesite	1. China 2. Australia 3. Turkey
Dead Burnt Magnesite	1. China 2. Turkey 3. Australia 4. Brazil
White Fused Alumina	1. China 2. Bahrain 3. Germany
Brown Fused Alumina	1. China
Calcined Alumina & Tabular Alumina	1. EU 2. China
Calcined Bauxite	1. China 2. Guyana
Graphite	1. China 2. Madagascar 3. Mozambique

2. Refractory Production and Raw Material Requirement

75% of the refractories produced in India goes to feed the steel industry while 15% is consumed by cement and the rest 10% by non-ferrous, glass, petrochemicals etc. Hence it is no gain saying to state that refractories consumption in India is driven basically by steel industry.

Govt of India has taken an ambitious project of reaching 300 million crude steel production capacity for India by 2030. Even if it reaches 250 million tonnes, there will offtake of refractories.

Table 2.1: Refractory Production in India (T)

Item	2015-16	2016-17	2017-18	2018-19	2019-20
Fireclay Bricks & Shapes	235801	229195	224937	216335	197803
High Alumina Bricks & Shapes	216917	224115	215444	195210	230319
Silica Bricks & Shapes	45900	45860	45990	72236	79259
Basic Bricks & Shapes	191875	190020	189689	195214	180299
Monolithics/Castables/ Pre-Cast Blocks	329933	324651	317419	317454	392837
Special Products (incl. CC)	56792	58191	60730	66084	60802
Others	61184	63636	52950	53542	67607
Total Production (mt)	1138401	1135668	1107159	1116074	1208926
Sales Turnover (in INR lakhs)	731291.6	760468	869467	980437	994383

Source: IRMA

Considering the fact that at present on an average the capacity utilization of refractory industry is around 60-70%, (higher for high end products), the present capacity is enough to cater to 150 million tonnes per annum crude steel production. Beyond that, capacity expansion of plants will be needed and many companies have already embarked upon it especially in mag carbon production.

2.1. Alternative Raw Materials

Dolomite bricks can be used in ladles for Silicon killed steel. It is being successfully done at Durgapur Steel Plant. However, dolomite bricks are not suited for normal steel making operations due to hydration and other problems. Ladle lining will be drastically affected if the ladle is taken off temporarily.

Alumina spinel bricks can be a good alternative to Mag carbon or AMC in ladles. However, the problem is that of higher cost, for which it is not a widely acknowledged alternative especially when DBM and FM prices are low.

Alumina spinel lining life some examples:

- Jamshedpur LD2 shop: 165mt steel ladle, life: 150 heats with 1 slagline repair.
- Tata Steel Jamshedpur, LD3 shop: 165mt steel ladle, life: 100 heats with 1 slagline repair.
- Tata Steel Kalinganagar, LD1 shop: 310mt steel ladle, life: 150 heats with 2 slagline repair.
- JSW Bellary, SMS1 shop: 135mt steel ladle, life: 200 heats with 2 slagline repairs.
- JSW Bellary, SMS2 shop: 180mt steel ladle, life: 175 heats with 1 slagline repairs.

However, at present there is no alternative to magcarbon in slagzone lining. Furthermore, sea water magnesite can be considered as a substitute for fused magnesia imports and as an alternate route for production.

As per National Steel Policy, Govt of India has taken an ambitious step to create 300 mil t crude steel production capacity by the year 2030. Needless to say, the need for refractories will get a significant boost with fructification of the plan. Unlike steel, capacity expansion of refractory units is not much capital intensive an exercise, for which Indian refractory units can augment their production capacity in line with increased crude steel production. However, the key challenge will be to secure raw material linkage as raw material consumption will be more than double of the present level even if crude steel production capacity becomes 250 million tonnes by 2030.

2.2. Summary

2.2.1. Indian refractory industry and in turn the steel industry is completely dependent on imported raw materials. Most of the raw materials used like DBM, FM, WFA, BFA, calcined bauxite are imported mostly from China. There will be a severe disruption in steel manufacturing supply chain if import of any of these raw materials is affected. In 2017-18, there was a severe disruption in supply of magnesite for which all the steel makers suffered. We also saw spike in DBM and FM prices in 2020-21 winter as well.

2.2.2. There will be increased demand for kyanite. However, kyanite sources in India is extremely limited and on the verge of being exhausted. It is more likely to be replaced by imported andalusite or synthetic mullite.

2.2.3. With the increasingly higher demand for purer quality of steel, there will be increased demand for steady refractory performance as well as less contamination of refractories. Hence it is high time, the refractory makers, steel industry and Govt take a stock of the situation and develop an action plan accordingly.

2.2.4. Since about 4 decades of continuous mining of refractory grade bauxite from area has affected the yield ratio between Plant Grade Bauxite and Low-Grade bauxite has come down to mere 2 percent. As the yield has become very low, the cost of production of High-Grade bauxite has skyrocketed. Also, note that the capacity at which calcine bauxite plants are running has decreased to 25-30% and binary effect of that leads to import from China. In 2015, after the amendment of MMDR Act, auctioning is the only route for securing mining right of major minerals. While it ensures transparency in mineral allocation process, there is no guarantee that land owner in whose soil the valuable minerals lie will obtain the mining rights. In a recent amendment, the concept of captive mine too has been done away with. Good quality bauxite reserve in Government land is now more or less exhausted and bauxite reserves are now solely in private land. However, the land holders are not applying to get Mining Lease/Prospective license because of auction policy on private land might prove detrimental to private mine owners *as it does not give surety in acquiring their lands for their own captive use*. The statistics depicts that within last 4-5 years' time hardly very few private land applications have come up for converting their and into Mining Lease/Prospective license. The total demand of Refractory's Grade Calcined bauxite is estimated around 3 lakhs M T per annum. At present, in Dwarka, out of 25 calcination plants, only 3-4 plants are in a working condition in absence of feedstock. This has resulted in extreme difficulty for us refractory makers who are compelled to import calcined bauxite from China at a higher price. Under the circumstances the Govt and the bauxite mine owners need to sit together and thrash out a solution as the existing law of the land does not offer any headway.

2.2.5. India has already signed an FTA with Australia and may explore signing one with Turkey. This will boost availability of some key raw materials. However, the concessional import duty on refractory raw materials has been withdrawn as per the announcement of Hon'ble Finance Minister in the last budget. Refractory raw materials will now attract a duty of 7.5% instead of 5%. It will be of great help to the industry if concessional duty on refractory raw materials is continued for few more years. Similarly, waving off duties with countries engaged in manufacturing of refractory products which are not produced in India including raw materials would encourage to foster economies of scale and diversify sources like Australia, Russia and Turkey.

2.2.6. The established refractory makers use produce gas to fire their products. For obtaining higher temperature (1500^{o}C+) furnace oil is normally used as booster. Need of the hour is to make available natural gas for all major industrial units as well as refractory clusters. Already natural gas is available in Wankaner cluster of Gujarat. India needs approximately 200,000 tonnes of basic bricks for its steel industry and only around 66,000 tonnes are produced locally. In recent times, a number of refractory makers are putting up basic bricks manufacturing plants here in India in tune with the ambitious "Atmanirbhar Bharat" proposal floated by Govt of India. Under the circumstance, we firmly believe that a strong case exists to reopen the Panthal magnesite project of NMDC at Jammu that was shelved by NMDC due to environmental concerns. The exact project entailed setting up of Dead Burnt Magnesite Plant (0.03 MTPA with Magnesite Mine (0.124 MTPA) at Chipprain near Katra, Reasi district by M/s J&K Mineral Development Corporation Limited (a subsidiary company of NMDC Limited). In recent years, there has been significant advancement in pollution control technology and we believe careful mining at Panthal adhering to benchmarked global practices will not disturb the pristine Himalayan environment nor cause any disturbance to the assembly of devotees to Shri Mata Vaishno Devi shrine. India needs good quality magnesite to meet the demands of growing steel industry and it is our humble wish that considering all these factors, your good office will suitably advise NMDC to have a relook at the presently stalled project which in our opinion should be treated as a project with national importance.

3. Recommendations

3.1. Bauxite – The Way Ahead

3.1.1. Govt of India should immediately start dialogue process with owners of bauxite mines in private land of Gujarat so that a win-win situation can be arrived and bauxite mining can be initiated.

3.1.2. IBM recommended to properly segregate both grades of bauxites while mining especially in Gujarat and Chhattisgarh.

3.1.3. Govt of Gujarat should allocate captive mines to refractory makers in Kutch region as it is amply clear that present reserve is not adequate to put up a smelter plant.

3.1.4. Beneficiation of available Gujarat bauxite to remove its lime content. There have been sporadic efforts in this regard, but very little success has been achieved. A serious rethink on R&D approaches is needed.

3.1.5. Government has to provide incentives to Private player to set up Beneficiation plants to improve quality of local deposit (Gujarat, Madhya Pradesh) and invite foreign collaboration in this regard.

3.2. Magnesite

3.2.1. The need of the hour is to identify more reserves and manufacture fused magchrome grains by beneficiating both the Magnesite as well as chromite if required.

3.2.2. Economically viable and environmentally responsible magnesite mining at Salem. This has the potential to replace at least a part of Chinese imports.

3.2.3. Almora magnesite (which has high alumina content) can be fused after beneficiation.

3.2.4. Reopen the Panthal magnesite mines of NMDC after taking due environmental precaution.

3.2.5. Sea water magnesite could be an economical solution and a substitute to fused magnesia imports (as mentioned in Para 2.1 as well).

3.3. Suri Clay

The silica of Suri clay of West Bengal can be removed after flotation process. It will be excellent 40% alumina aggregate replacing chamotte.

3.4. Fire Clay

Geologically Fire Clay, an important raw material for making refractory exists with coal deposits. A big anomaly continues in the system which allows Coal Mining Plan approval by Coal Ministry whereas all other Mining Plans for other minerals including fireclay is approved by Indian Bureau of Mines. In the process, the overlapping mineral like fireclay found in coal mining is being wasted and India is now short of fireclay reserves. The refractory makers in the SME sector who are largely dependent on fireclay are facing lots of difficulties. Hence a system needs to be devised where Coal India can sell fireclay to refractory makers and in the process the Govt also receives some revenue in this regard.

3.5. Flake Graphite

The Government must usher in an environmentally viable but cost-effective mining and production of refractory-grade graphite in India.

3.6. Special Raw Materials

3.5.1. Flexible facilities may be created for manufacture small batches of materials mostly through fusion/sintering and grinding e.g. especial Aluminas, Carbides and nitrides etc.

3.5.2. Synthetic aggregates 45-50%, 69%, 72% alumina can be prepared from sillimanite sand of which India has huge reserve.

3.5.3. Possible government incentives and facilitation for indigenous production of BFA.

3.5.4. Sillimanite Sand & Zircon Sand: Both are used in Refractory, Ceramics & Abrasives industries: Govt has to take initiative to enhance production through IREL or allow Private Miners to mine Beach Sand (private mining was stopped in 2018). IREL is not able to augment production of Beach Sand. Sillimanite is a substitute of Imported Andalusite while Zirconia is mostly imported from Australia. Augmenting their production will save foreign currency.

3.5.5. SiC: High energy cost shifted production to China, Vietnam & Bhutan. In India CUMI, Grindwell Norton & Snam Abrasives reduced their furnacing capacity due to high power cost and are importing Crude from China, Vietnam, Bhutan. Grindwell Norton has set up a plant in Bhutan, Snam Abrasive in Vietnam. Govt needs to work out a comprehensive power package for production of these critical raw materials in India.

3.5.6. High power tariff is also hampering the growth of WFA, BFA and mullite industries in India.

Most of these activities need intense R&D efforts which refractory industry due to their fragmented nature, low turnover and widely diverse raw material requirement cannot support. Hence active support of Govt of India is needed along with knowledge partnership with overseas R&D bodies of repute to address the raw material challenges concerning the refractory industry.

Lastly there has to be a duty differential of at least 5-8% between imported raw materials and imported finished products. (At present it is around 2.5% only). This will encourage more value creation in Indian soil and boost domestic manufacturing.

3.7. Opportunity knocks outside China

There is new lease of new life for existing ex-China sources to supply world *and* China market (andalusite, graphite, and DBM now being *exported to* China!). Established ex-China producers evaluating/conducting capacity expansions. Some of the examples are

- Exploring Russia as an alternative to China for many of the refractory minerals (especially magnesite & fused alumina). This will need the Indian government to open discussions with Russia at a politically suitable moment of time;
- Magnesia – Saudi Arabia, Serbia, Greece, Turkey, Jordan, Australia, Brazil;
- Bauxite – Guyana, Australia, Guinea, Surinam;
- Graphite – Africa

Also, it is time to reassess refractory formulations to accommodate alternate materials and more recycled materials. The future is going to witness efforts for increasing the "recyclability" of refractories.

Most of the major refractory makers have their own technology on recycled raw materials. Problem is extraction of the used bricks as per grades which presently is manned mostly by unorganized sector. Need of the hour is to do organize sorting of the used bricks (because grain quality of a brick varies as per the application area). In this context the steel plants may think of working on an end-end solution for the refractories i.e. the refractory maker who has installed the lining be allowed to dismantle the lining, sort the bricks as per grades and take them away to be reprocessed in their own plants. This will ensure increased supply of recycled raw materials to the established refractory makers as well as improve the quality of the recycled raw materials.

3.7.1. Recycling and Recovery Units

Government intervention especially in the form of incentive scheme to processors is necessary in establishing supporting units (of industrial scale) for recycling and recovery setups. Recycling is not just an environment friendly measure but can also reduce import dependency. For example, in Europe, 40% recycled content is now used in prime products. In India, TRL Krosaki Refractories Limited and RHI Magnesita India Limited are already in this space, but India needs large processing units to handle the amount of waste generated (mix of slag, muck, used bricks, leftover lining material, etc.) to substantiate the economic benefits. Recycling could reduce import dependency to the tune of 100% for foundries, small furnaces and monolithics, while partial replacement of prime raw materials in premium grades required to meet the performance demands of integrated steel plants.

The Government can encourage environment friendly recycling with export-oriented incentive schemes. Export incentives to Indian Units could expedite technology transfer and encourage mass manufacturing in India, further driving investments and R&D, possibly making India the next destination for refractory solutions.

Annexure

Table A.1: Import of Refractory Items

Items	2015-16		2016-17		2017-18		2018-19		2019-20	
	mt	Rs. Lakhs	mt	Rs. Lakhs	mt	Rs. Lakhs	mt	Rs. Lakhs	mt	Rs. Lakhs
Fire Clay Bricks & Shapes	3190	1036	610	131	1610	556	2510	286	21210	4641
High Alumina Bricks & Shapes	7550	10315	1590	730	2720	2244	5030	2469	11230	4144
Silica Bricks & Shapes	8850	6892	790	1569	4670	4676	15210	6249	40170	11866
Basic Bricks & Shapes	120260	51070	68256	24086	61319	36162	148093	127926	100406	74852
Monolithics/Castables	149019	65956	172015	72910	192526	82547	198373	94998	176150	85409
Special Products	3200	3900	2700	3058	2420	3051	1800	3011	12090	3794
Others	132250	105380	88820	78002	299560	127268	127800	141485	328460	149510
Total	**424318**	**244550**	**334781**	**180485**	**564824**	**256503**	**498815**	**376424**	**689716**	**334216**

Table A.2: Export of Refractory Items

Items	2015-16		2016-17		2017-18		2018-19		2019-20	
	mt	Rs. Lakhs	mt	Rs. Lakhs	mt	Rs. Lakhs	mt	Rs. Lakhs	mt	Rs. Lakhs
Fire Clay Bricks & Shapes	35450	6003	26950	4979	36850	5884	54090	7733	38320	8292
High Alumina Bricks & Shapes	57280	39408	60930	51176	80690	61409	83420	74972	81740	81007
Silica Bricks & Shapes	19320	5326	18090	4344	8070	1450	11090	2497	21090	7943
Basic Bricks & Shapes	7719	3817	7068	4584	7634	5397	36603	14661	15425	14576
Monolithics/Castables	75300	23399	17182	28480	128257	35101	151666	37242	170416	40810
Special Products	18550	21619	20930	21873	20770	25319	23580	29719	15290	26810
Others	80410	45939	101080	58289	81920	63355	87730	66442	80080	63377
Total	**294029**	**145511**	**252230**	**173726**	**364190**	**197914**	**448179**	**233266**	**422362**	**242815**

NOTES

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