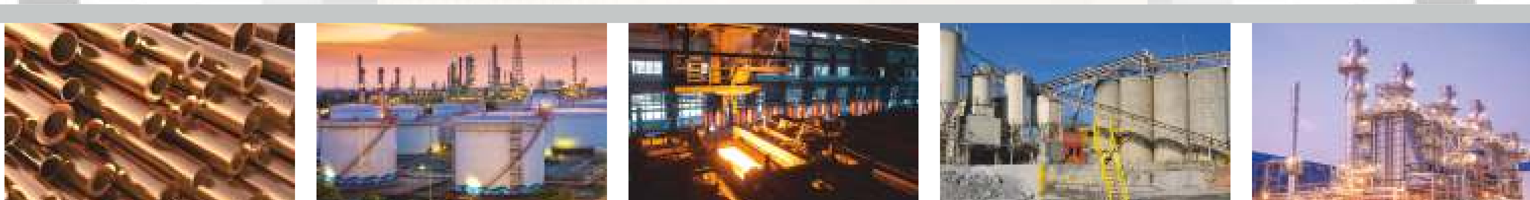
ISSN 0250- 5304

IRMA JOURNAL

(for Private Circulation Only)
Volume LVIII, No.2, June 2025

Quarterly Journal Of Indian Refractory Makers Association

CHAIRMAN'S ADDRESS | ASSOCIATION ACTIVITIES | IN THE NEWS | MEMBER SCAN
OVERSEAS NEWS | BUSINESS SECTION | TECHNICAL SECTION | INTERVIEW | STATISTICS



IRMA
PARTNERING HEATING SOLUTIONS
INDIAN REFRACTORY MAKERS ASSOCIATION

Address : Indian Refractory Makers Association, Duckback House, Flat No. - 2B, 2nd Floor, 41, Shakespeare Sarani, Kolkata 700017
Contact : 0914003-2748
Email : support@irmaindia.org
Web : www.irmaindia.org

Vol. LVIII, No.2, June 2025

IRMA JOURNAL **-** A Publication of:
INDIAN REFRACTORY MAKERS ASSOCIATION
41, Shakespeare Sarani, Duckback House,
Unit-2B, 2nd Floor, Kolkata 700017
Phone: 033 4003-2748
Mobile: 98304 24582
E-mail: secretary@irmaindia.org
Website: www.irmaindia.org

CONTENTS


HINDALCO
SPECIALTY ALUMINA
POWERING THE
UNSUNG HEROES..
REFRACTORIES
ENGINEERED TO ENDURE
1600°C+ HEAT ENDURANCE
REDUCES THERMAL LOSS & EMISSIONS
LONGER LINING LIFE
CRITICAL ZONE RELIABILITY
SUPERIOR CORROSION RESISTANCE
ENERGY-SAVING
SCAN QR TO KNOW MORE OR LOGIN TO
hil.refractory@adityabirla.com
ADITYA BIRLA
HINDALCO

MESSAGE FROM THE CHAIRMAN

Dear Colleagues,

A key challenge being faced by our industry is lack of qualified and skilled man-power. Every year a good number of ceramic graduates who pass out from leading engineering colleges of the country opt for jobs in information technology, finance, start ups etc rather than the core sector. Yet our sector is not a mere amalgamation of brick and mortar, heat and dust. Our job demands in-depth analytical skills in understanding material behaviour, have insights on big data analysis as we talk about preventive maintenance of vessels and over all great managerial skills to negotiate with other stakeholders some of whom are true Goliaths in terms of their technological, financial and managerial strengths. In other words, every day is a learning day for us, and the fact of the matter remains a true learner never has a dull moment.

For long, a need was felt to highlight the challenges and opportunities that beckon our industry before the young talents who aspire to entire our realm and scale new heights on their career path. In this regard, I am happy to announce the first edition of Student IREFCON which will be held on 5-6 November 2025 at Kolkata. The programme will have components where the students can listen to CEOs/CXOs, professionally qualified ceramic graduates who have earned laurels in their career journey, technical presentations by the students themselves and a day long intensive training programme on modern refractories engineering. We already have confirmed participation from five reputed ceramic institutes of the country.

We live in a business climate that is being re-ordered in every aspect–economically, strategically, socially, technologically, ecologically. It is a world of complexities and extreme competition, where there will be battles for dominance and survival. Student IREFCON is the first step for our future leaders to transform every tomorrow to a better tomorrow.

Sunanda Sengupta
Chairman

ASSOCIATION ACTIVITIES

IRMA Board of Directors Meeting

IRMA Board of Directors meeting was held on 10th May 2025 vide Zoom platform under the chairmanship of IRMA Chairman Mr. Sunanda Sengupta. Issues discussed were collection of formation of sub committees, PR and communication activities, student IREFCON and IREFCON 2026.

Student IREFCON 2025

The first edition of Student IREFCON 2025 will be held at Hotel Pride Plaza, Kolkata from 5th-6th November, 2025. The participating educational institutes are:

- Dept. of Ceramics, Anna University
- Dept. of Ceramic Engineering, University of Calcutta
- Dept. of Ceramics, NIT Rourkela
- Govt. College of Engineering & Ceramic Technology, Kolkata
- Dept. of Ceramics, Utkalmani Gopabandhu Institute of Engineering, Rourkela

The programme will comprise interaction with CEOs/CXOs who are ceramic graduates, lectures by experts, technical presentations by students as well as technical training programme. More details can be found at https://studentirefcon.com/.

MoU with UGIE, Rourkela

IRMA has recently signed a MoU with Utkalmani Gopabandhu Institute of Engineering, Rourkela to provide technical training to the students of Diploma in Ceramic Engineering. The objective of the programme is to skill the students with the recent advancements in refractories engineering and to make them industry ready.

IN THE NEWS

Stainless Steel Consumption

Domestic stainless steel consumption has registered a growth of 84 per cent over the last five years to reach 4.80 million tonnes in FY 2024-25, industry body Indian Stainless Steel Development Association (ISSDA) has said. The demand has been driven by sectors like infrastructure, railways, airports, metros among others, ISSDA President Rajamani Krishnamurti said in a presentation at the ongoing Global Stainless Steel Expo (GSSE) 2025.

Tata Steel

Tata Steel has allocated Rs 15,000 crore for capital expenditure across its India, UK, and Netherlands operations in FY26, with 80% dedicated to ongoing Indian projects. The company is expanding capacity in India, transitioning to electric arc furnaces in the UK, and focusing on decarbonization and efficiency improvements in the Netherlands. While Rs 11,000 crore is planned for domestic operations, around Rs 1,900 crore is planned for the UK, and the remaining is in the Netherlands.

Rio Tinto

Rio Tinto, the world's second-largest mining company, has confirmed plans to re-enter India after nearly a decade, setting up an integrated clean energy-powered aluminium project in partnership with AMG Metals and Materials, backed by Greenko Group founders. Once fully commissioned, the facility is expected to be the world's largest green aluminium plant, the companies said in a joint statement.

The firms have signed a memorandum of

understanding to conduct a feasibility study for setting up a primary aluminium smelter with a capacity of 1 million tonne per annum. They will also assess the feasibility of a 2 mtpa alumina production plant.

Demand for Cement

The robust demand for real estate, which gains support from the government's major housing initiatives such as the Pradhan Mantri Awas Yojana (PMAY), will sustain the momentum in cement demand, said a report by Axis Securities. According to the report, the cement demand is expected to grow in the range of 7 per cent-8 per cent in FY26, supported by the government's emphasis on infrastructure development and sustained real estate activity. The Cement sector witnessed a subdued performance in the first half of the financial year 2025 (Q1FY25), with year-on-year (YoY) growth of only 2-3 per cent.

Cement demand witnessed a notable recovery in Q3 and Q4FY25, expanding at a high single-digit pace.

Veddanta Group

Vedanta Ltd delivered a mixed operational performance in the first quarter of FY26, with some segments reaching new highs while others registered noticeable declines. Vedanta set a new production milestone at its Lanjigarh Refinery, turning out 587 kilotonnes of alumina in the June quarter the highest ever for the plant. The output rose 9% from a year ago and surged 36% over the previous quarter. Zinc India reported a record Q1 mined metal production of 265 kilotonnes, up slightly from the same period last year.

Zinc International output rose to 57 kilotonnes, marking a 50% year-on-year and 12% quarter-on-quarter growth. In contrast, aluminium production held steady at 605 kilotonnes, showing little change both year-on-year and quarter-on-quarter. However, refined metal output dropped to 250 kilotonnes, down 5% from last year and 7% sequentially, mainly due to planned maintenance and temporary plant constraints.

IISCO Steel Plant

Steel Authority of India Limited (SAIL) has kicked off the expansion and modernisation of its IISCO Steel Plant at Burnpur, after receiving environmental clearance from the Union ministry of environment, forest and climate change on June 4.

The project, estimated to cost ₹45,810.92 crore, will have an installed capacity of 7.1mt after the project's targeted completion by 2029. However, unlike the existing mill that produces bars and rods used in construction, the new facility will manufacture advanced steel grades used in the automobile and consumer durables sectors, among others.

OVERSEAS NEWS

Ma'aden

Ma'aden, Saudi Arabian Mining Company, has finalised its acquisition of almost 25.1% stakes in MBAC (Ma'aden Bauxite and Alumina Company) and MAC (Ma'aden Aluminum Company), two critical pieces of Saudi Arabia's aluminum value chain. Previously, Alcoa held a 25.1% ownership stake in the company, whereas Ma'aden held a stake of about 74.9%.

Almatis Alumina

Almatis and Çimsa have announced their intention form a strategic collaboration for Calcium Aluminate Cement (CAC) products. The Parties intend to explore a strategic collaboration to leverage their combined expertise, market presence and resources to offer a wide product portfolio and support sustainable growth in the CAC market. Both organizations have agreed in principle to cross-sell their respective CAC products in the market, utilize their respective supply chain & warehouse networks, investigate production capability & capacity expansion possibilities and collaborate for new product development. The strategic cooperation is intended to be finalized within the coming quarter and both organizations expect to begin joint commercial activities before years' end.

Rusal

Rusal has agreed to buy a 26% stake in Pioneer Aluminium Industries Limited, an Indian alumina refinery owner, for $243.75 million, with plans to increase its stake to 50% in stages. This move aims to reduce Rusal's reliance on third-party raw materials. The world's largest aluminum producer outside China, Rusal lost about 40% of its alumina supply after Australia halted exports to Russia and the company shut down its Ukrainian refinery.

RHI Magnesita

RHI Magnesita and BPI, Inc. have announced a transformative joint venture to expand circular economy initiatives and accelerate sustainability across North America. The strategic partnership combines RHI Magnesita's (RHIM) global refractory expertise with BPI, Inc.'s (BPI) robust US infrastructure, local sourcing, and technical processing capabilities. This collaboration is set to create a powerful platform for innovation in circular raw material processing and recycling.

Syrah

Australia-based Syrah Resources has restarted natural graphite production at its Balama operation in Mozambique, following the restoration of site access in May and the completion of preparatory work including inspection and maintenance. The company said that it would progressively increase plant utilisation and production volumes as part of an operating campaign aimed at restocking finished product inventory. Shipments to ex-China markets were expected to resume in the September quarter.

Tata Steel

Tata Steel Limited is planning to begin construction of its low-carbon electric arc furnace (EAF) at its Port Talbot mill in UK in July 2025 and operations scheduled to start in 2027, the company said in its annual report for the fiscal 2024-25. "Using recycled scrap, the new Port Talbot steelmaking facility will reduce the on-site carbon emissions by up to 90 percent," the company said.

The EAF is scheduled to become fully operational by 2027, with an annual production capacity of 3.2 million mt of low-emission steel.

Onur Group

The Turkish company Onur Group plans to begin mining at the Burtyn graphite deposit in Khmelnytskyi Oblast, Ukraine in 2026. Experts previously said that the Burtyn graphite deposit could become the largest in Ukraine. The Horodnyavska site alone holds approved reserves of nearly 130 million tons of graphite ore, with an average carbon content of 5.14%. These reserves are expected to last for 130 years, according to the State Service for Geology and Mineral Resources. In June, the European Union included the Ukrainian deposit on its list of strategic projects.

MEMBERSCAN

Calderys India Refractories Ltd.

Calderys has reached a first crucial milestone at CAPES (Calderys Plant in East & South India) with the successful trial of the acidic monolithic refractories line—exactly one year after the project's groundbreaking—marking a significant step toward the overall facility's commissioning. The investment comprises five state-of-the-art production lines to deliver high-quality refractory solutions and steel casting fluxes. Construction at the plant is progressing well, with production expected to begin by the second half of 2025.

Carborundum Universal Ltd.

Carborundum Universal Limited has reported a sharp decline in its net profit for the January-March quarter (Q4) of FY25. The company's consolidated net profit dropped by nearly 79 per cent year-on-year (YoY) to Rs 30.10 crore, compared to ₹142.56 crore in the same quarter of the previous financial year. For the full financial year ending March 31, the company's net profit stood at ₹298.71 crore, marking a 37.27 per cent decline from ₹476.18 crore recorded in the previous year.

RHI Magnesita India Ltd.

RHI Magnesita India Limited has reported its audited consolidated financial results for the fourth quarter and full year ended March 31, 2025 (Q4 & FY 2025).

Key Performance Highlights:

- Revenue from operations for FY25 was Rs. 3,675 crore
- EBITDA for FY25 was Rs. 505 crore
- PAT for FY25 was Rs. 203 crore
- Net Debt/EBITDA ratio at 0.3x.

IFGL Refractories Ltd

IFGL announced the inauguration of its 60TPD fully automatic continuous tempering kiln for the magnesia carbon production line in its Vizag Unit. Inaugurated by Arasu Shanmugam, Director and CEO – India, this milestone enhances IFGL's ability to produce high-performance magnesia carbon bricks for steelmaking, ensuring superior performance, longevity, and reliability in high-temperature applications.

The revenue of the company for the FY 2025 was ₹16.7b in FY 2025, up 1.9% from FY 2024, in line with analyst estimates. Net income in the reported period was ₹429.8m, down 47% from FY 2024, and profit margin was 2.6%, down from 5.0% in FY 2024, with the decrease in margin being driven by higher expenses.

Hindalco

Hindalco Industries Limited has announced the acquisition of a 100% equity stake in US-based AluChem Companies, Inc., a prominent manufacturer of Specialty Alumina, for an enterprise value of USD 125 million. The acquisition will be carried out through Aditya Holdings LLC, a step-down wholly owned subsidiary of Hindalco. This strategic acquisition marks a significant investment in specialty alumina, a key step in scaling its high-value, technology-led materials portfolio.

ECONOMY AT A GLANCE

- As per NITI Ayog, India has surpassed Japan to become the world's fourth-largest economy. India is now poised to displace Germany from the third rank in the next 2.5 to 3 years. The International Monetary Fund (IMF), in its World Economic Outlook report released in May, stated that India is set to become the fourth-largest economy in 2025. India's nominal GDP is projected to rise to $4,187.017 billion, surpassing Japan's estimated $4,186.431 billion.

- Retail inflation, based on Consumer Price Index (CPI), has dipped further below to 2.10% in June 2025. It is the second consecutive month of the rate recording below 3 per cent. It is also the fifth successive month of retail inflation below the median rate of 4%. The retail inflation rate was 2.82% in May, which was a 75-month low. Earlier, inflation was expected to dip further, mainly on account of ease in food prices as supplies from a robust spring harvest reached markets.

- As per Goldman Sachs, India set to hit $10 trillion GDP by 2035, with GCCs adding $0.5 trillion. The Global Capability Centers (GCC) sector, which has evolved from traditional cost-saving back offices to innovation hubs driving AI, automation, and digital transformation, stands to benefit significantly from these global trends.

- Large-scale electronics manufacturing and pharmaceuticals cornered about 70 per cent of the total fiscal incentive disbursements in 2024-25 under the production-linked incentive (PLI) schemes, according to government data. The scheme was introduced in 2021 to support domestic manufacturing across 14 sectors with an outlay of ₹1.97 lakh crore. In 2024-25, the government has disbursed a total of ₹10,114 crore. PLI firms in the electronics sector received ₹5,732 crore, while pharmaceutical drugs received ₹2,328 crore, the data showed..

- India launches its first incentive scheme for electric trucks under PM E-DRIVE, targeting 5,600 e-truck deployments to cut freight emissions and boost clean mobility across key sectors.

- India's data centre capacity is set to nearly triple to three GW by 2030, driven by artificial intelligence (AI), cloud growth, and data localisation, supported by rising investments and government incentives.

- India's Labour Secretary Vandana Gurnani has urged Global Capability Centres (GCCs) to actively engage with the government's Employment Linked Incentive (ELI) scheme, warning that it could face the same lack of traction as the earlier PM internship programme.

BUSINESS SECTION:

COLLABORATIVE ROLE OF REFRACTORIES IN SUSTAINABLE CEMENT PRODUCTION

Anjan K Chatterjee

In the entire history of Portland cement production, refractories have always played a crucial and enabling role, changing and adapting to the technological and pollution prevention demands in clinker making through the rotary kiln system, the only system of manufacture that has stood the test of time. The system from the very beginning needed refractories to protect the steel shell from heat and abrasion, to minimize the heat losses through the shell, to ensure unhindered flow of hot material without flushing, and to promote heat transfer to the kiln load. Further, technologically, the kiln system changed from a capacity level of 300-600 t/d to 8000-12,500 t/d with the tentative change in kiln volume loading from a level of $0.5t/m^2.d$ to$5.0t/m^2.d$ approximately. The fuel use pattern changed, not only from fuel oil to coal, but also to natural gas, petroleum coke and a large variety of alternative fuels. At a particular stage, the elimination of chromium from the materials in use was an unavoidable environmental demand. In addition to all these demands, the sustenance of rotary kiln technology could not have been possible, if the burning zone refractories led to frequent failures, resulting in huge losses in production. The refractory industry adapted itself to all the above challenges and, by and large, the product portfolio and application technologies have been in sync so far with the technological and environmental necessities of the cement industry.

Globally, at present, the cement industry is poised to grow further in production volume from about 4.0 billion tons per year to over 5.0 billion tons per year in the next three decades and at the same time it is at the threshold of being totally digitalized, more resource-efficient, and a production system with low-carbon footprint. In this transformation, the refractory sector has to be confronted with and prepared for the following technological demands:

- Data analytics, ML (machine learning) algorithms and modeling
- Recycling of refractory waste
- Assessing and providing the carbon footprint certificates for products supplied

The plant experience shows that the monitoring of kiln shell temperatures is neither accurate nor predictive of refractory damages and hot spots, essentially due to the fall-and-build cycle of inside coating. On the other hand, any unexpected lining failure and kiln stoppage in a modern plant are too expensive to bear. For example, in a 6000 t/d clinker plant a stoppage of 5-15 days results in production losses of 30,000 to 90.000 tons, which is substantial in financial terms. Hence, there is an imminent need to prepare a database of lining performance including historical data in a given plant, subject it to data analytics, correlate the processed data with coating ability and other properties of refractories, and develop a model with the objective of predicting the occurrence of hot spots, refractory damages and lining failures.

Recycling of refractory waste is an important component of the refractory management. Globally the process has started but the progress is not up to the mark. It is reported that out of 32 million tons of refractory waste generated only 7-30% is recycled and that too in low-value applications, primarily due to the lack of technologies for quality based separation. There is an urgent need to explore the laser separation techniques as being attempted under the EU backed RESource project.

In simple terms, the carbon footprint refers to the total amount of greenhouse gases that is emitted directly and indirectly by an entity, which, in the present context, is a refractory product. Since most of these products have high embodied energy, it is important for the cement producers to know their carbon footprint values in order to arrive at their own product carbon footprints (PCF). This practice is yet to be implemented both in cement and refractory industries but the need cannot be kept aside for long. What is urgent is to initiate measures to calculate and supply PCF certified products at least on cradle-to-customer basis.

Thus, the presentation is intended to start with the volume growth history of the global cement industry, its technological evolution from the scale-and-productivity related growth to the present status of a sustainable resource efficient low-carbon industry. The role played by the refractories in this journey has been discussed along with the shift of its product portfolio of shaped and unshaped categories. Finally, the road ahead for both the industry sectors to gear up for digitalization, waste recycling and PCF certification has been highlighted.

(Source: IREFCON24 proceedings)

TECHNICAL SECTION

A NOVEL REFRACTORY SOLUTION FOR REHEATING FURNACE SKID AND POST BEAMS: CALDESEAL REFRACTORY

CALDERYS Team - Aditya Soni, Suparna Basu, Irfan Khan, Bhushan Bobde, Basavaraj,
JSW Team Prakash Patil, JSN Raju, Ganapathi Prasad, V R Sekhar, Avinash Nigam

Abstract - The skid and post beam configuration in Reheating Furnaces plays a crucial role in maintaining operational efficiency and longevity. Traditionally, a steel pipe circulates cooling water while refractory materialis applied to the outer surface to prevent steel deterioration. However, challenges arise from mechanical impacts, thermal shocks, and erosive damage, leading to frequent fumace stoppages and water leakages. This necessitates a refractory solution capable of withstanding thermo-mechanical loads, and temperature fluctuations while facilitating faster repairs to avoid prolonged downtime and furnace damage. In response, a joint solution with the newly developed Calde Seal Refractory was devised. This innovative material offers enhanced mechanical strength, corrosion resistance, Thermal spalling resistance and thermal properties compared to traditional alternatives. The Calde Seal Refractory boasts superior Modulus of Rupture (MPa) and lower bulk density and thermal conductivity, minimizing heat loss from skid pipes. Its application results in significant reductions in installation time, downtime during maintenance, and energy consumption. Trial applications of the Calde Sealrefractory, in walking beams, demonstrate an energy saving of over 25%, compared to the dense materials used earlier resulting in a payback period of less than one year. Compared to on-site castable installations and prefabricated shapes, the CaldeSeal solution reduces installation time by approximately 75% and 30%, respectively, which greatly enhances productivity and operational efficiency. This paper discusses the development, properties, and application of the Cakle Seal Refractory in Reheating Furnace skid and post beams.

1. Introduction

Reheating furnaces are vital components in steel production, where they heat steel Slab/Bloom/Billets to a specific temperature for subsequent hot rolling to thin steel sheet products, bar steel products with round or square sections. A schematic diagram of a Reheating furnace is shown in Fig. 1. A walking beam system is usually applied for transferring semi-finished steel products in a reheating fumace. In the walking beam system, slabs are alternately held by a fixing beam and walking beam. The horizontal section of these beams is called SKID and vertical portion is called POST. The system repeats sequential cycle of ascending (lifting up of the slab), advancing horizontal movement, descending (putting down slab) and regressing horizontal movement for returning to the initial position. This way slabs are moved forward to the discharge side. Thus, the skid and post beam configuration within these furnaces plays a crucial role in supporting the Slabs and ensuring efficient heat transfer.

The operation temperature of the reheating furnaces ranges between 1100 to 1300°C. The refractory lined here are subjected to harsh operating environment owing to the following aspects.

A) Elevated temperature fluctuation due to different charge load.

B) Mechanical stresses due to movement of Slab over the skids.

C) Corrosive atmospheres due to chemical reactions between refractories and iron oxide components, which are generated as mill scale by virtue of surface oxidation of slabs.

Fig 1. Reheating Furnace (1. Bull Nose, 2. Wall, 3. Roof, 4. Skid and Post, 5. Hearth)

The refractory lining is also required to help achieve carbon-neutrality. It is, thus, important to minimize heat loss. Also, refractory lining and/or maintenance work are usually manpower intensive. Thus, labor saving activities or reducing labor workload is the need of the hour. This paper explores a novel refractory solution, CaldeSeal Refractory, that offers superior performance and addresses the limitations of conventional materials. By leveraging its enhanced properties of Thermal Spalling Resistance, Lower Thermal conductivity and ready to use naturehelped, Calde Seal helped reheating furnace with the reliability and efficiency of reheating furnace operations.

2. Root Cause Analysis of Failure in Skid Pipes

Walking beam reheating furnaces in hot strip mills use water-cooled skid beams for moving the slabs inside the furnace. These skids were found to fail frequently owing to water leaks. Failure of these skids results in process interruption and production loss. A detailed failure analysis was carried out to investigate the mechanism and reasons for such failure. The skid beam samples were collected from the affected and unaffected regions as shown in Fig.2 wherein Hardness and Section thickness was measured. They were also analyzed using optical microscopy and their hardness was evaluated. The microstructures (Fig 3a) of the unaffected skid samples revealed a ferritic-lamellar pearlitic structure, whereas at the affected region the microstructure (Fig 3b) showed spheroidization of carbide particles and degenerated pearlite. This change in microstructure indicated that failure resulted from prolonged high-temperature exposure of the skid beams. Following are the list of root cause analysis.

1) Thick Lip Rupture of failed skid is characteristic of failure due to stress rupture because of prolonged overheating.

2) The microstructure exhibits evidence of spheroidization of carbide particle, intergranulation oxide penetration and cavitation.

Thus, Skid has failed due to prolong exposure to heat which can only be possible because of Refractory Failure over the skids.

Fig 2-Cross Section of Good and Failed Skid (Hardness and Thickness measurement)

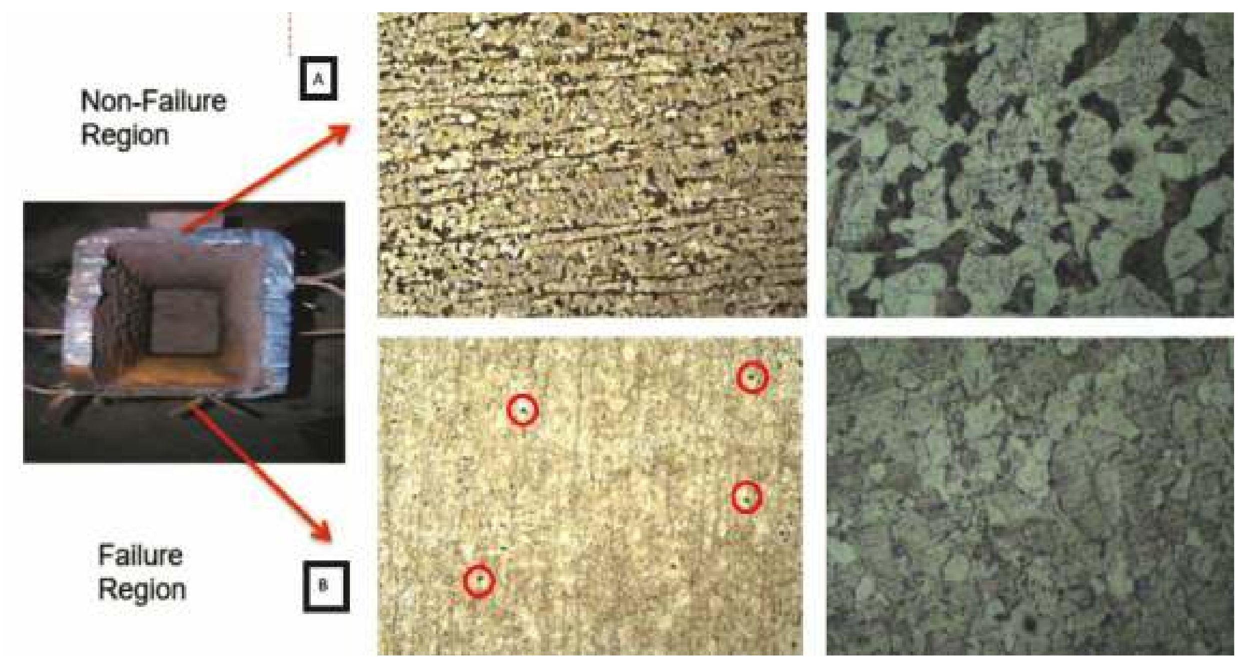


Fig -3 A) Ferritie-Lamellar Pearlite Structure of Unaffected/Non-Failure Skid B) Spheroidization of carbide particles and degenerated pearlite of Failure Region

3) Reason for Refractory Failure

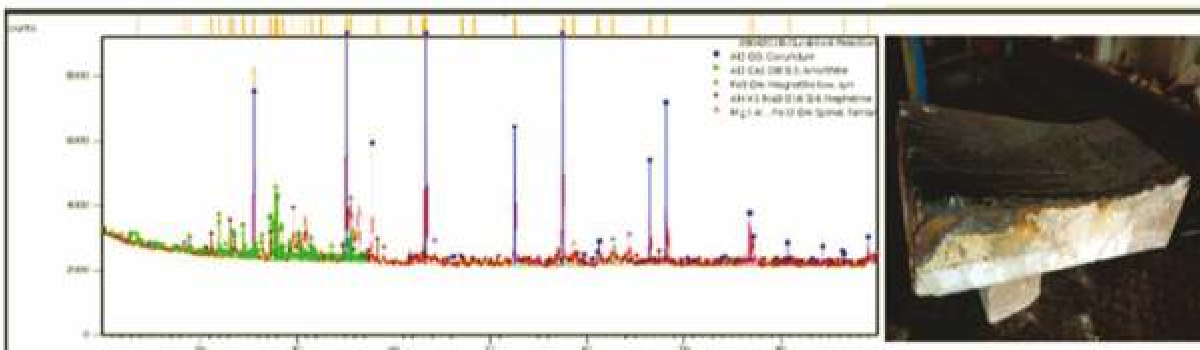
Traditional refractory materials used in skid and post beams face the following challenges:

Mechanical Impacts: The constant movement of steel slabs leads to mechanical damage and cracking of the refractory.

Thermal Shocks: Rapid temperature fluctuations, especially during furnace startup and shutdown, can cause thermal spalling and cracking due to repeated heating and cooling

Corrosion Damage: The XRF analysis revealed presence of FeO, N*a_{1}*O K_{2}*O in the mill scale as shown in Fig 4 and Table 1. FeO originated from the oxidation of slab, whereas N*a_{2}*O and K_{2}*O were from Mould flux. These oxides corrode the refractories. In the process, refractory thickness is reduced, and its integrity is compromised.

Water Leakages: Water leaks from cooling pipes can lead to premature refractory failure and increased maintenance costs.



XRD results

Sample details	Major phases	Minor phases	Remark
Used Durablock RFA from Chandi Steels, Reaction layer	Corundum and Anorthite	Nepheline, Magnetite, Mg Fe Spinel and unidentified phase	Presence of alkali bearing phase has been confirmed by chemical analysis. Formation of Nepheline indicates presence of Alkali in the furnace atmosphere.

Content of Impurities in the reaction Layer

Fe_2O_3 %	Na_2O %	K_2O %
17.44	~1.52	~0.41

Fig – 4 XRD Study of Refractory Sample

Table –1 Showing Major Phases of XRD Study

4) Innovative CaldeSeal Refractory: A Promising Solution

Calde Seal Refractory is a new generation of refractory material that offers several advantages over traditional options:

Enhanced Mechanical Strength: CaldeSeal Refractory exhibits superior mechanical properties, making it more resistant to cracking and damage from mechanical impacts.

Improved Corrosion Resistance: Its dense structure and high-temperature resistance provide excellent protection against corrosion from Mill Scale. We carried out crucible test of traditional refractory as well as innovative Calde Seal. The cup test results are shown in Figure 5 and Table 1.

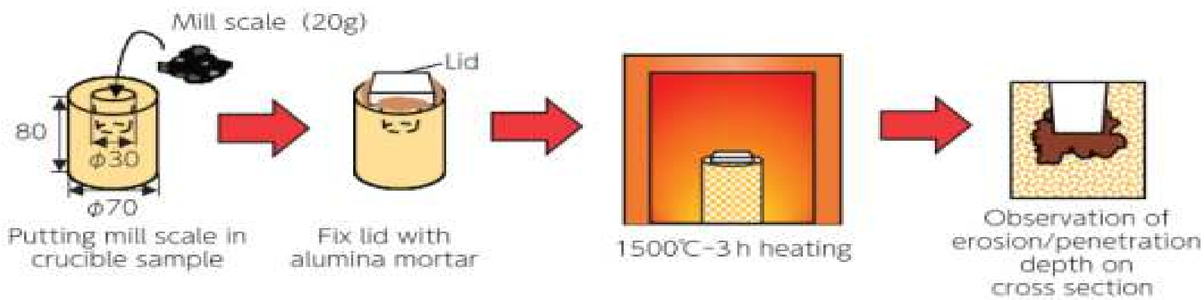


Figure 4 – Crucible test

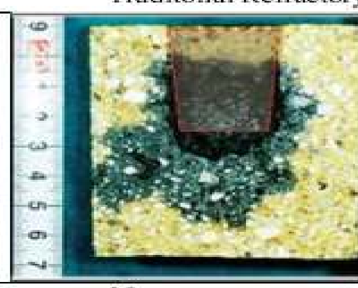
Sample	Traditonal Refractory	Calde-Seal
Cross Section of crucible sample after test		
Penetration depth / mm	20 mm	0.5 mm

Table-2 Cross Section of Tested Refractory Specimens

Excellent Thermal Spalling Resistance: CaldeSeal Refractory can withstand rapid temperature changes without suffering from thermal spalling.

Superior Thermal Properties: Its low thermal conductivity helps minimize heat loss from the skid pipes, leading to energy savings.

Faster Installation: CaldeSeal Refractory can be applied more quickly by wooden hammer ramming, reducing downtime and improving productivity. A comparative timeline study was done between installation practice of Traditional Refractory and innovative CaldeSeal solution for per meter skid pipe lining.

Description of Job	Traditional Refractory	Innovative CaldeSeal
Installation Practice	Casting	Ready to tise - Like M - Seal
Anchoring	60 Mins	60 Mins
Blanket Wrapping	30 Mins	30 Mins
Waterproof Coating on Blanket	30 Mins	Not Reqtiired
Forma Fixing	120 Mins	Not Reqtiired
Installation Time	180 Mins	10 Mins
Nattiral Ctiring	120 Mins	Not Reqtiired
Forma Removal	60 Mins	Not Reqtiired
Total Time	**600 Mins (10 Hr)**	**100 Mins (<2 Hr)**

Table 3 - Comparative Timeline study between traditional Refractory by Casting Versus New Innovative Ready to use material.

Description of Job	Traditional Refractory	Innovative CaldeSeal
Installation	PCPF	Ready to tise - Like M - Seal
Anchoring / Plate Welding	60 Mins	60 Mins
Blanket Wrapping	Not Reqtiired	30 Mins
Block Fixing and Application	150 Mins	10 Mins
Block Tieing	30 Mins	Not Reqtiired
Total Time	240 Mins (4 Hrs)	100 Mins (<2 Hr)

Table 4- Comparative Timeline study between traditional Refractory by PCPF Versus New Innovative Ready to use material.

5) Application of CaldeSeal and its Results

Trial applications of CaldeScal Refractory in reheating ftirnace skid and post beams have demonstmted significant benefits:

Energy Savings: CaldeScal Refractory's low thermal condrictivity has restilted in energy savings of over 25% compared to traditional refractory materials. Heat loss taken away by skid post cooling water contribtites large portion of the entire heat loss from the reheating ftirnace. Heat Fltix was calibrated between Traditional and CaldeScal Refmetory tising software. It is evident that drie to lower Thermal Condrictivity of CaldeScal, less heat get transmitted to the water as a restilt heat fltix is redticed leading todirect energy savings. We have done heat fltix analysis of Traditional 60% Altimina Refractory with Caldescal as shown in Figtire 5 showingheatfltix has been from 19000 W/m to 13000 W/m leading to stibstantial heat loss thereby leading to direct energy savings by lesser heat losses from Skid Refractory.

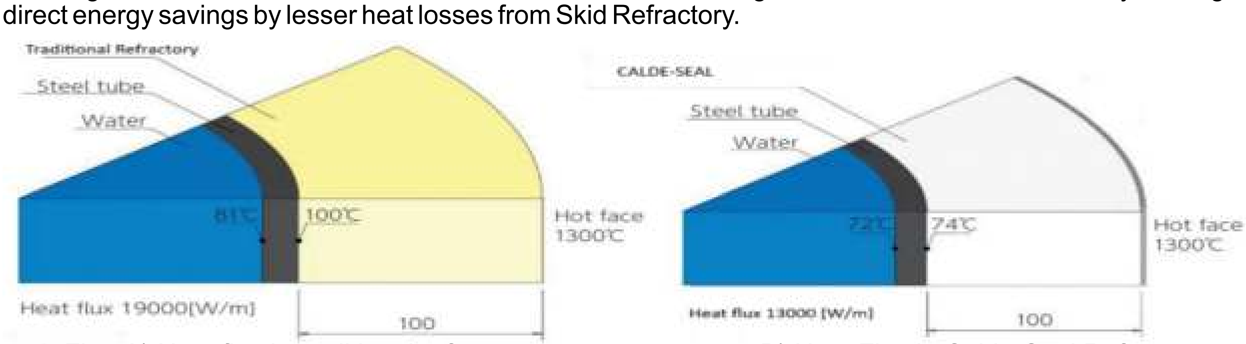


Fig 5A) Heat flux in traditional refractory B) Heat Flux in Calde-Seal Refractory

Reduced Installation Time: The CaldeSeal nature of the material allows for faster installation, reducing downtime and improving productivity.

Enhanced Durability: CaldeSeal Refractory has shown excellent resistance to mechanical impacts, thermal shocks, and corrosion, leading to longer service life.

Lower Maintenance Costs: By reducing the frequency of repairs and replacements, Calde Seal Refractory can help lower overall maintenance costs.

6) Conclusion

Calde Seal Refractory represents a significant advancement in refractory technology for reheating furnace skid and post beams. Its superior properties, including enhanced mechanical strength, corrosion resistance, thermal spalling resistance, and thermal performance, make it a highly promising solution for improving furnace efficiency, reliability, and energy consumption. By adopting Calde Seal Refractory, steel producers can realize significant benefits in terms of reduced operational costs, increased productivity, and improved furnace longevity.

TECHNICAL SECTION

SUPERIOR PERFORMANCE WITH FIRED ALUMINA-SPINEL BRICK FOR STEEL LADLE LINING

J N Chakraborty[1], Shankha Chatterjee[2] [1]Maithan Ceramic Ltd., Kolkata/ Dhanbad, [2]Almatis Alumina Pvt. Ltd., Kolkata,
Correspondingauthor e-mail: jn.chakraborty@maithangroup.com

ABSTRACT

Steel ladle is one of the major area of total refractories consumption and cost in steel production. Steel ladle working lining is the prime consumable refractories here consisting slaglines, metal zone and bottom refractories. Over last 2 decades, chemically bonded magnesia carbon and/ or alumina magnesia carbon bricks are used in the working lining of steel ladle metal zone and bottom areas. Current decade is undergoing specific requirements from end users and thus steel manufacturing technology is also evolving towards new direction where minimum inclusions (carbon or any oxides or other impurities) are permitted in steel. To cope up with such demands, newer refractories are necessary. To meet the refractory demand, fired alumina-spinel refractory brick is developed using high purity sintered alumina aggregate and high purity spinel and other components. The present case study describes the effect of raw materials on refractory product properties (such as density, porosity, shrinkage, strengths and application properties) and finally how the developed alumina spinel fired brick contributed towards achieving better performances in terms of different TCO parameters (like performance, consumption, cost etc) in comparison traditional magnesia carbon lining as well as similar other alumina spinel alternatives. Refractory end user's reference is sighted to prove superior product development and manufacturing based on appropriate raw materials.

Keywords: Steel ladle refractory lining, Alumina-Spinel fired brick, Tabular alumina, Sintered spinel, TCO (total cost of ownership)

INTRODUCTION

Working lining refractories in steel ladle has evolved many changes over last few decades. Till early 1990s, andalusite or bauxite based fired high alumina refractories were used in the metal zone and bottom of steel ladle lining. Such lining could not perform well in contact with corrosive calcium aluminate slag because of chemical compatibility. Next came the developments of magnesia-carbon and alumina-magnesia-carbon. The non-wettability of graphite was the primary focus to incorporate in such refractories. Over about last 2 decades, the demand of high quality steel has evolved. Steel grades such as ultra-low carbon and alloy grades require stringent reduction of carbon and other elements so as to cope up with the requirements of automobile and other industries where low concentration targets of S, P, O, N, H, C etc in steel [1] are essential. So, the demand of working lining ladle refractory without carbon came up. In parallel, process changes were also made in steel metallurgy to produce such special grades of steels. RH degasser and other advanced vacuum steel processing steps are incorporated in various secondary treatments [2,3]. In connection to that, the steel processing operating parameters also became severe, such as increased residence time, higher tapping temperature, very corrosive slag etc. In 1990s, alumina-spinel castable lining [4] has evolved in steel ladle for clean steel production. This monolithic concept was supported by endless lining idea and implemented in some part of the World. However, countries such as in India, having >125 million tonnes per annum and continuously growing steel production with around 50 % flat steel and about 10 % automotive grade high quality steel production in absence of castable/ monolithic ladle lining in place, needed a compatible newer refractory lining. Fired alumina spinel development has filled up this requirement where metal zone and bottom refractory lining will contribute to achieving the desired steel quality [5].

A high purity alpha-alumina dense aggregatebecame the skeleton for designing fired alumina-spinel refractory. Tabular alumina having low impurities in all fractions supported by small sized closed micropores became the choice for improving hot properties and resistances to spalling and corrosion. Consistency and homogeneity in of parameters for continuous process of sintered alumina aggregate production became a major choice for aggregate alumina selection because the target development has to outperform with better predictability during usage. Local abundant availability is also an added advantage for commercial refractory production planning.

Alumina-rich pre-formed Mag-Al spinel is of significant advantages to impart slag penetration and corrosion resistance as well as spalling resistance. Alumina-rich Mag-Al spinel has the capability to absorb FeO or MnO from corrosive calcium aluminate slag within the free vacancies in its crystal structure. Thus slag becomes more viscous and this retards slag infiltration in refractories. Additionally, excess CaO available in slag reacts with Al_2O_3 in refractories to make thin layer of CA_6 in the interface of slag and refractories. This works as protective layer over refractories and helps in slag penetration resistance. It is also well established that purity of such alumina-spinel refractory plays vital role in the performance [6] and suitable quantity of spinel improve the wear mechanism by improving corrosion and spalling resistances [7,8,9,]. Certainly to achieve this, proper quality of spinel addition in terms of size grading is also an essential aspect [10,11].

CASE STUDY

Fired alumina-spinel brick is manufactured by using required granulometry of high purity synthetic sintered alumina aggregate (Tabular alumina) and Mag-Al spinel in combination of different fractions and suitable calcined alumina. The present work describes the effect of raw materials on product properties such as density, porosity, shrinkage, cold and hot strengths as well as on the application properties such as slag corrosion, thermal spalling which are of prime focus of end users for evaluating refractories for predicting higher performances. SEM studies and pore size distribution are analyzed to understand the roles of raw materials on properties. The selected raw materials are different commercially available size fractions of tabular alumina and mag-al spinel as mentioned in Table 1 with the chemical properties and in Table 2 with physical properties. Table 3 indicates distribution of chemical impurities in different Tabular alumina fractions. The fine fractions of Tabular alumina which is produced in continuous sintering process are also very consistent in chemistry. Fig1 shows SEM microscopy of Tabular alumina having distributed closed micropores which is expected to help in resistances to thermal spalling and slag corrosion. Calcined alumina in the matrix portion of such refractory is a pure alpha-alumina of mono-modal PSD with specific surface area (BET) of about 1.0 m2/g and d50 of about 3.5 µm is selected. Some part of spinel is also distributed in fine fractions so as to impart improved corrosion resistance. Commercially available organic binder is used for the green shaping and providing drying strength.The green mix of all components are mixed as per recipe in industrial mixture and then pressed at high capacity automatic press. Green bricks were dried at over 110 °C/24 hrs in tunnel dryer and then fired in tunnel kiln at significantly high temperature with specific profile.

Tab.1: Chemical analysis of raw materials used

	Na_2O %	Fe_2O_3 %	SiO_2 %	MgO %	CaO %	Al_2O_3 %
Tabularal umina	0.28	0.02	0.02	<0.01	0.02	99.7
Mag-Al spinel	0.09	0.15	0.04	21.7	0.20	77.7
Cal. Al_2O_3	0.10	0.02	0.02	<0.01	0.02	99.8

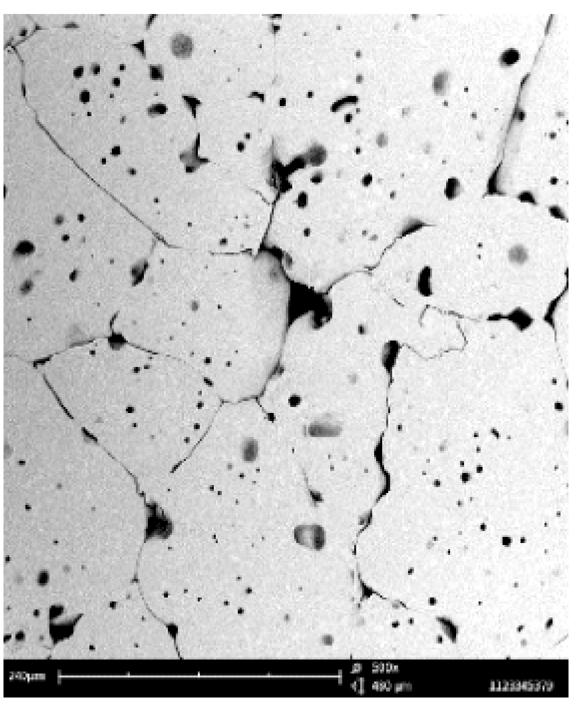
Tab.2: Physical properties of raw materials used

	Water Absorption%	Openporosity %	BSG g/cc
Tabular alumina	0.8	1.5	3.60
Mag-Al spinel	0.5	1.5	3.26

Tab.3 Consistency of impurities in different Tabular alumina fractions.

Tabular alumina fraction	Na_2O %	Fe_2O_3 %	SiO_2 %	MgO %	CaO %
1-3 mm	0.280	0.035	0.022	0.002	0.015
1-2 mm	0.270	0.035	0.014	0.001	0.017
0.5-1 mm	0.300	0.028	0.016	0.003	0.014
0-0.5 mm	0.290	0.035	0.018	0.001	0.009
0.2-0.6 mm	0.300	0.034	0.014	0.001	0.029
0-0.2 mm	0.270	0.040	0.021	0.002	0.016
-325#	0.300	0.052	0.023	0.003	0.037

Fig1. SEM of Tabular alumina



The cut blocks and bars from final brick are checked for density, porosity, compressive and flexural strengths. High temperature flexural strength (HMOR) is checked at 1400°C with 30 minutes soaking time. Thermal shock was evaluated for checking spalling resistance in specific spalling cycle (1350°C water quenching). PLCR is was measured on re-fired samples at 1600°C for 5 hours soaking. Cup slag corrosion test was conducted at 1650 °C/ 2 hrs using synthetic slag as per desired chemistry (CaO 55-60%, Al2O3 25-30%, SiO2 6-8%, MgO 4-5%, FeO 1-2%, MnO 2-3%) of target application. XRD and SEM of selected samples are seen. The results of the conducted tests are mentioned in Table 4 below.

Tab.4: Comparative typical properties of bricks

Properties	Alumina-Spinel	MgO-C	AMC
% Al_2O_3	94.6	0.5	74.5
% MgO	4.6	85.5	8
% C	-	5.5	5.0
A.P (%)	16.5	7.5	8.5
B.D (g/cc)	3.12	3.00	3.08
CCS (kg/cm^2)	820	450	650
Thermal spalling (1350°Cwater quenching, cycles)	7+	6+	7+
HMOR at 1400 °C/ 30 mints (kg/cm^2)	120	95	85
PLCR at 1600 °C/ 5hrs (%)	+0.04	+0.3%	+0.5%
TC at 1000 °C (W/mK)	3.5	8.7	8.5
Cup slag corrosion (1650 °C/ 2 hrs)	Nocorrosion only<10% penetration	Nocorrosion, only <20% penetration	Nocorrosion, only<20 % penetration

Elimination of carbon directly affected thermal conductivity of the refractory. Fired alumina-spinel brick has half the TC compared to that of MgO-C/ AMC bricks. One of the major characteristic of working lining refractory is its porosity. It also indirectly guides the densification and strength as well as resistances to spalling and corrosion. A fired brick having higher apparent porosity has much higher fired density due to absence of carbon. The pore size distribution of fired alumina-spinel brick showed >90% of total pore size ranging from 1-10 µm. High CCS and cold MOR also indicate right selection of granulometry and matrix alumina contribution for better sinterability. Presence of very low amounts of impurities in matrix too, with proper densification and sintering to result high hot MOR. The presence of micropores came from Tabular alumina and is related to better thermal shock and slag corrosion resistance because the micropores act as crack inhibitors. The XRD analysis (Fig.2) of the fired alumina-spinel brick indicates both corundum and spinel as major phases and no evidence of even minor free MgO or other oxides. The SEM (Fig.3) shows well distribution of spinel and good bonding with corundum. Presence of graphite works for improving slag corrosion resistance due to non-wettability and good spalling resistance due to high thermal conductivity. But here, the carbon free fired refractory body has also resulted very comparable slag corrosion resistance and spalling resistance due to optimum pore size distribution and closed micropores (crack inhibitors) and presence of well embedded Tabular alumina grains with equally distributed spinel in matrix as seen in SEM-EDX. Cup slag corrosion is tested (Fig.4) and found slight penetration (<10%0 vol basis) but no corrosion with some build-up and supported for the commercial trial plan.

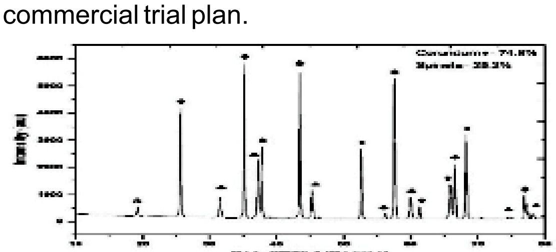


Fig2. XRD of fired alumina-spinel brick

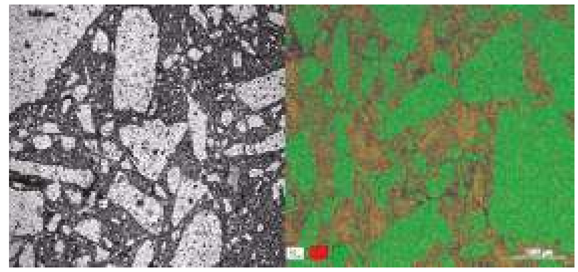


Fig3. Stereo microscopy and SEM-EDX of fired alumina-spinel brick

Fig4. Cup slag corrosion test of fired alumina-spinel brick

INDUSTRIAL APPLICATION BENEFITS

Newly developed fired alumina-spinel refractory is used in steel ladle metal zone successfully in two Indian integrated steel plant having flat steel production as per particulars mentioned in the table 5 below. All the plants have processing route as BF-BOF-LRF -RH.

Tab.5: Performance in steel ladle metal zone

Plant capacity	Ladle capacity	MgO-C, MZ life	Alu-Sp, MZ life	Remarks
5 mtpa	350 ton	90 heats	110-115 heats	
6 mtpa	300 ton	120 heats	145-150 heats	
7 mtpa	180 ton	145 heats	170 heats	Scope of 250 heats (2 SZ repairs)
4 mtpa	135 ton	140 heats	215 heats	2 SZ repairs now
4 mtpa	165 ton	120 heats	150 heats	Scope of 200 heats (2 SZ repairs)

The reasons for ending ladle campaigns are due to life of slaglines MgO-C bricks (different numbers of slaglinesre pairs in different plants). The used metal zone lining showed lesser and uniform erosion pattern resulting better adherence and consistency to target life and confidence of steel operation. Fired alumina-spinel bricks show about 20% service life improvement in these 2 steel plants and improve their productivity and techno-commercial performance parameters.

Fig5. Fresh lining (left), preheated lining (middle), used lining towards end (right)

Total Cost of Ownership benefits

Higher performance with fired alumina-spinel comes at a higher cost of fired alumina-spinel brick compared to chemically bonded MgO-C/ AMC refractories. And as this developed brick for ladle bottom and metal zone is only one component of full set of ladle refractories, the performance or life (heats) is dependent to performance of other refractory components such as slag line bricks and bottom functional refractory parts. Thus cost per ton of steel production is one of the major factor. In this case, although the cost of bottom and metal zone bricks have increased compared to traditional MgO-C/ AMC linings, however the overall cost of refractory per ton of liquid steel for the steel plant has reduced due to higher lining life in metal zone and bottom. Apart from lining life and direct refractory cost, other aspects have gained importance in the "Total cost of ownership" approaches. These factors are listed below. It is obvious that full utilization of TCP benefits is totally dependent on the focus of steel operation on refractory usage.

- Reduction of carbon pick up in steel - Carbon pick up from MgO-C/ AMC lining during secondary metallurgy processing is obvious. Carbon content in modern ULC steels are often specified below 30 ppm and therefore 3-5 ppm difference in carbon pick up can be critical for achieving the target. Alumina-spinel ladle linings are favourable for the production of ULC steel.

- Energy saving - During treatment and transport of steel inside the ladle, it is cooling by typically around 1 K per minute. The working lining contributes to temperature losses in two ways. Firstly, there is heat transfer through the lining to the steel shell, which can be reduced e.g. carbon free lower thermal conductivity materials in the wear lining. Secondly, heat loss comes from the thermal cycling of the ladle during empty ladle time, when the hot face cools down from about 1600 to about 800 °C. This depends on empty period, heat capacity and thermal conductivity of the wear lining. The carbon free lining also helps here.

- Ladle capacity increase – The performance of fired alumina-spinel lining enables the lowest wear lining thickness. This directly increases steel ladle capacity. On overall basis over long time, this allows steel plant to increase steel production capacity without incurring capital expenditure on new ladle shell purchase.

- Raw material/ refractory sourcing, inventory planning and Chinese dependency – China dominates in global market for supply of high quality fused and dead burned magnesia (required for MgO-C production) and refractory grade bauxite or BFA (required for AMC production). However, sintered Tabular alumina production is based on Bayer process based synthetic alumina processing and thus independent on China. Chinese environmental protection policies and global logistic uncertainty also aid concerns for long term smooth planning.

Locally available fully integrated Tabular alumina production facility in India provides better techno-commercial benefits for procurement planning, inventory management for Indian refractory manufacturers and steel plants.

- Others – In addition to the obvious above factors, there are other factors like lower C-footprint and less fume generation during preheating (only slagline bricks generate fume), easier visual inspection for new lining at preheating stage by operators, no crack formation like MgO-C brick during campaign, better recyclability of fired alumina-spinel brick after ladle campaign is over as used graphite containing bricks need experienced inspection to differentiate MgO-C/AMC grade, scope to optimize slightly lesser tap temperature (about 5°C max) due to less heat loss, lesser outer shell temperature (about 20°C typically) and better adherence to planned relining schedule (consistency in performance and less breakdown in new lining).

CONCLUSIONS

- The growing demand for clean steel production in India will further drive the use of fired alumina-spinel lining in steel ladle metal zone and bottom, in absence of monolithic technology.
- Fired alumina-spinel bricks are successfully used in metal zone and bottom of steel ladle as reliable and cost effective linings. Cost has increased by around 10% whereas performance has increased by 20% typically, ultimately reducing overall steel production and maintenance costs.
- Usage of Tabular alumina and proper spinel play crucial roles in achieving superior refractory application parameters and desired refractory performance.
- The value chain benefits can be multiplied further by applying total cost of ownership approaches.

REFERENCES

[1] H.C.Fei; L.F.Zhang; "The 2nd Intl conf on continuous casting of steel in developing country", 77-82, (1997).

[2] N.Moritama, "Recent progress of steel making tech. and expectation for refr."; Taikabutsu Overseas6,18-36, (1986).

[3] V.Kudrin; Steel Making; MIR, Moscow; 1985.

[4] W.E.Lee; R.E.Moore; "Evolution of in situ refractories in 20th century"; J. Am. Ceram. Soc.81, 1385-1410, (1998).

[5] Schnabel M, et al. Spinel: In-situ versus preformed – clearing the myth. RWF 2 (2010) [2], p. 87-93.

[6] Franken,M.C.; Siebring,R.; de Wit, T.W.M.: "New refractory lining for steel ladles BOS no.2 Corus Ijmuiden"; UNITECR 2001, Mexico, Vol I, 128-138

[7] J.Mori, et. Al;"Material design of monolithic refr.for steel ladle"; Am. Ceram. Soc. Bull., 69, 1172-1176, (1990).

[8] K.Fujii, I.Furusato, and I.Takita, "Composition of spinel clinker for teeming ladle casting materials"; Taikabutsu Overseas, 12, 1, 4-9, (1992).

[9] S.Sumimura, T.Yamamura, Y.Cubata, T.Kanashige,, "Study on slag penetration of alumina-spinel castable"; In Proceedings of UNITECR 93, Brazil, 97-101, (1993).

[10] T.Yamamura, et al.,"Alumina-spinel castable refr for steel teeming ladle",Taikabutsu Overseas12,1,21-27, (1992).

[11] P.Korgul, D.R.Wilsod and W.E.Lee, "Microstructural analysis of corroded alumina-spinel castable refractories", Journal of the European Cera. Soci., 17, 77-84, (1997).

TECHNICAL SECTION

THE USE OF SIOXX®-FLOW AS A DISPERSANT FOR LOW-CEMENT CASTABLES IN THE MANUFACTURING OF PRECAST REFRACTORY SHAPES

Arindam Mukherjee[1]*, Riya Ghosh[1], Ankita Mishra[1], Utkarsh Dane[2], Sourabh Singh[2]
1Elkem South Asia Pvt Ltd, Navi Mumbai, INDIA 2Orane Refractory Pvt Ltd, Pune, INDIA *Corresponding author: arindam.mukherjee@elkem.com

Abstract

This paper presents a case study on the use of pre-cast refractory shapes in industrial flooring applications. In recent years, precast shapes have become popular due to their quick and easy installation, shorter dry-out time, and reduced number of joints compared to monolithic and brick alternatives. This case study focuses on the use of a bauxite-based low-cement castable (LCC) with the microsilica-based specialty product, SioxX®-Flow, as a dispersant to produce heavy-duty industrial floor tiles. Over 400 pieces (7 MT) of product were produced and installed, from mould design to installation, within 30 days. The use of SioxX®- Flow resulted in improved flowability of the castables, leading to a better surface finish and increased productivity related to improved consistency of the castable. The increase in green strength also improved handling of the moulded product, resulting in negligible due to chipping. The consistent setting time improved production planning and mould turn-around time, further increasing productivity. This case study showcases the practical benefits and advantages of using SioxX®-Flow as a dispersant for low-cement castables in the manufacturing of pre-cast shapes.

Keywords: Precast shapes, productivity, SioxX®-Flow

1. The Background

Standard industrial flooring made from traditional concrete is not suitable for floors where molten metal is handled. In most cases, the concrete flooring in industrial facilities handling liquid metal becomes an EHS concern due to floor damage. The concept of industrial floor tiles is popular in the western world, however, in India this concept often faces the challenge of high costs.

A working example of successful installation of such industrial flooring tiles is in the Elkem foundry alloy processing site in Nagpur, India, where the small trial installation from 2016 remains in perfect condition. During the commissioning of an induction furnace in 2023, at the same processing site, the industrial flooring was installed as part of an enhanced EHS initiative.

We accepted the challenge of installing industrial floor tiles in the new facility, all while adhering to the project completion deadline. Due to the uneven finish of the flooring tiles, two different thicknesses of the tiles were used. Orane Refractories were approached to assist with improving the consistency and surface finish challenge.

2. The Challenge

To produce and install 540 pieces of floor tiles in 2 different sizes, within a 4-week period.

While the installation and heat-up of pre-cast shapes on-site were highly efficient, the manufacturing of the pre-cast shapes presented challenges similar to the challenges encountered during the installation of castables on-site—curing, drying, and firing. Additionally, the recipe design for the refractory castable, which was to be used for manufacturing of the tiles, required thorough evaluation. Time was considered a critical issue to complete the installation.

3. Elkem Business System (EBS) in-use

The challenges that were identified during the manufacturing and installation of the flooring tiles are shown below – a systematic approach to problem solving called Elkem Business System (EBS, derived from Toyota business system) was employed:

a) Castable recipe design to achieve high compressive strength.

b) Evaluation of properties and finalization of formulation.

c) Design and manufacturing of the moulds.

d) Casting and demoulding of the casted pieces within stipulated time and sufficient green strength for handling.

e) Minimize the drying and firing (up to 1000°C) time.

3.1. Materials and Methods

The first criterion was to determine the compressive strength requirement of this product. The tile should have a high compressive strength (CCS) - minimum 140 MPa at 110°C. The green flexural strength (GMOR) or demoulding strength should be >2 MPa and >4 MPa after 4 hours and 6 hours of casting, respectively. The above properties indicated that the density and particle packing of the mix should be at a maximum whilst the pre-cast body should have capability of short dry-out and heating times.

After a few laboratory-based trials, a low cement castable (Table 1) containing bauxite (Al_2O_3 85%), high alumina cement, calcined alumina, and Elkem Microsilica® 971U along with SioxX® Flow and EMSIL-DRY®, was used. SioxX® Flow functioned as a dispersant, enhancing the rheological properties with controlled setting and demolding time whilst aiding in early strength development of the castable. EMSIL-DRY® fibre was used to facilitate the quick dry-out and heat up of the castable to reduce the risk of spalling and explosion during heat-up. Additional evaluations as shown in Table 2 were conducted.

Table 1: Recipe used for LCC to cast flooring tiles

Raw Material	Quantity (%)
Calcined Bauxite (various sizes)	76
High alumina cement	7
Calcined alumina	10
Elkem Microsilica® 917U	6
SioxX® Flow	1
EMSIL-DRY®	0.1

Table 2: Characterization / properties of floor tile

Properties	Condition	Range of Values
Water demand (%)	-	4.5 – 4.7
Flowability (%)	Immediate flow_F0	130 - 140
	After 30_F30	100 - 110
Hardening time (min)	Ultrasound	200 - 250
Bulk density (gm/cc)	-	2.70 – 2.75
Green flexural strength (MPa)	After 4 hrs of casting	2 - 3
	After 6 hrs of casting	3 - 4
	After 8 hrs of casting	4 - 6
Flexural strength (MPa)	At 110°C	40 - 45
	At 600°C	30 -35
	At 800°C	25 – 30
	At 1000°C	20 - 25
Compressive strength (MPa)	At 110°C	170 - 180
	At 600°C	150 – 160
	At 800°C	120 - 130
	At 1000°C	100 - 120

3.1.1. Design and manufacturing of moulds

Mould design is a critical part of the precast refractory manufacturing process. However, in the present case, the moulds were relatively simple - wooden mould with metal liner were used. Two different mould sizes were prepared to cast two different tile shapes. Tile A (Figure 1) has dimension 320*320*75 mm and Tile B (Figure 2) has dimensions 320*320*60 mm. After receiving the mould, trial casting was performed as quality check to verify the dimensions and tolerance. There were 4 moulds prepared for each tile size. Other detail of the moulds that were prepared are shown in Table 3.

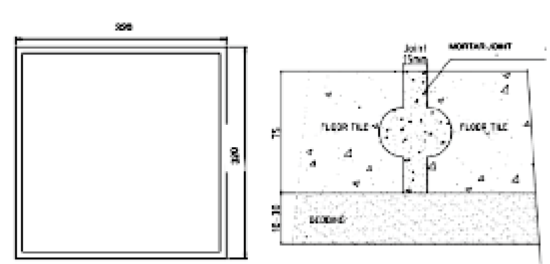


Figure 1: Section drawing of floor Tile-A

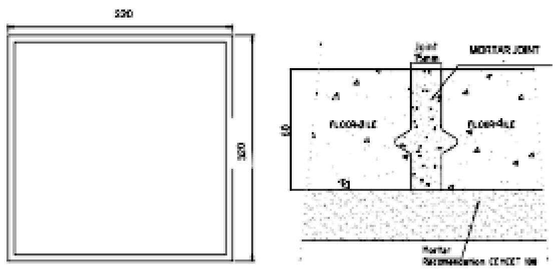


Figure 2: Section drawing of floor Tile-B

Table 3: Dimensions of tile and configuration for floor laying

	Dimension (mm)	Weight (kg)	No. of piece	Number of moulds
Tile -A*	320*320*75	21.5	198	4
Tile-B¤	320*320*60	17	342	4

*Target – 198 pieces; delivery by 25th of Dec 2022. ¤Target – 202 pieces; delivery by 25th of Dec 2022.

3.1.2. Manufacturing process of tiles – Casting, demoulding, Air curing, Air Drying

For casting, 300 kg capacity pan mixer was used. 175 kg of the dry granular castable mix was charged in the mixer; water was added manually using platform weigh scale, and thoroughly mixed until a homogenous castable was obtained. Figure 3 shows the process that was followed to produce the tile samples.

Figure 3: Flow chart for precast manufacturing process

A demoulding target of 4 hours was set to produce 12 pieces per day – in 2 shift operations, and 400 pieces to be delivered by 25th of December 2022. The remaining 140 pieces was planned to be dispatched later. Demoulding time for the castables were set at 4 hours which led to mould rotation of 3 times in 2 shifts.

3.1.3. Dry-out and high temperature firing of tiles

The heating profile that was used for the tiles samples after demoulding is shown in Figure 4 with a total firing time of 120 hour

Figure 4: Firing cycle for casted flooring tiles

The timeline from the start to completion of the project is shown in Table 4. Installation of all the tiles was completed on 20th of January 2023.

Table 4: Project timeline

15th Nov	Idea discussion
18th Nov	Lab work started and finalizing formulation
20th Nov	Mould design finalized
25th Nov	First set of completed moulds received
27th Nov	First casting trial completed
30th Nov	Start large scale casting trial
15th Dec	Completion of casting (first 400 pieces)
18th Dec	Start of firing cycle
23rd Dec	End of firing cycle
27th Dec	Dispatch from Pune
31st Dec	Goods received at Nagpur

4. Results and discussion

Results from the casting and installation practice indicated 4 hours demoulding time. The working time, where flowability was retained, was between 30-45 minutes and completed hardening by 250 minutes. Figure 5 shows an area where the existing flooring in the Nagpur foundry was present prior to installing new flooring.

Figure 5: Image of a pre-casted area in the foundry facility in Nagpur prior to installing new flooring

Manufacturing of the tiles also resulted in a low rejection rate as a result of breakage of the tiles during and after manufacturing. Figure 6 shows the consistency between tiles where thicknesses and shapes (Figure 7) are similar. The use of EMSIL-DRY® fibre in the castable also resulted in quick dry-out and heating. An example of a finished section of the flooring is shown in Figure 8 with no tile breakage.

Figure 6: Floor tile after firing and dimension inspection

Figure 7: Image showing the even shape of tiles produced during manufacturing with SioxX®-Flow

Figure 8: Image of finished section of flooring in Nagpur facility.

5. Conclusions

From the investigation of producing industrial flooring trials using a LCC with SioxX®-Flow and special drying fibre, EMSIL-DRY® the following can be concluded:

a) Planning and execution of the manufacturing process by Orane Refractories resulted in on-time delivery of the tiles.

b) Short demoulding time of 4 hours were obtained through using SioxX® Flow.

c) Retention of flowability up to 30-45 minutes of water addition and hardening time within 250 mins.

d) Low rejection rate of tile due to breakages as a results of high strength development after casting.

e) Quick dry-out and heating time by using EMSILDRY®.

Acknowledgment

The authors would like to thank all partners and stake holders that were involved in the successful execution of this project.

(Source: IREFCON 2024 Technical Proceedings)

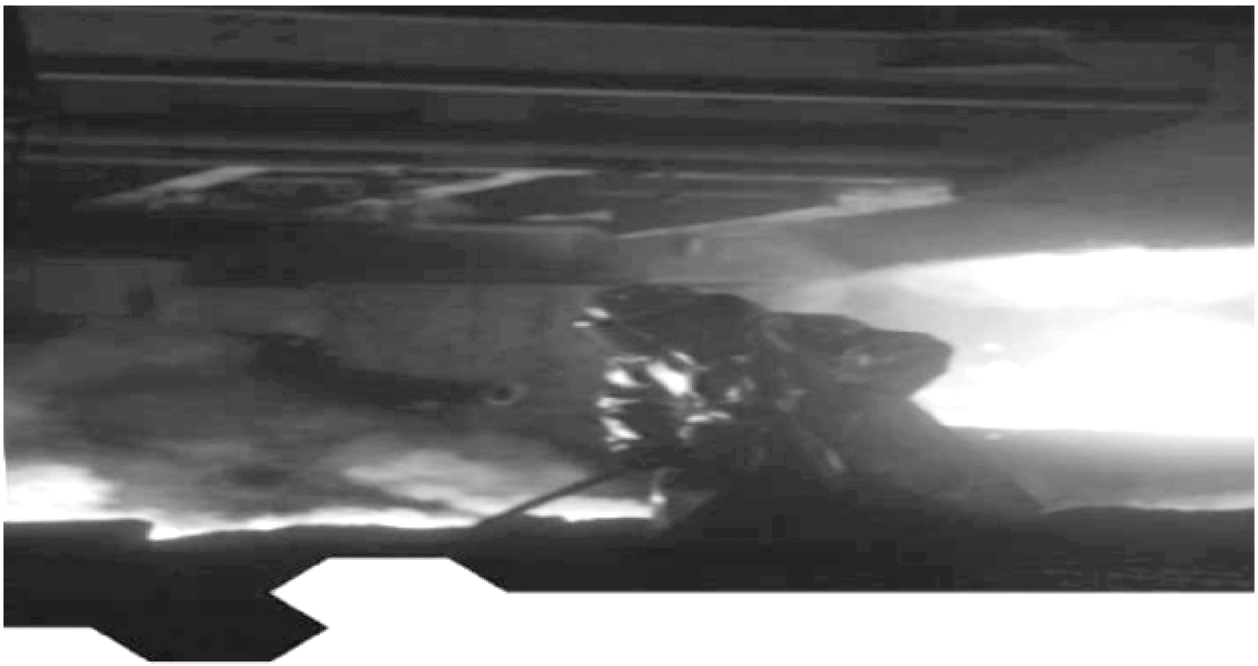
STATISTICS

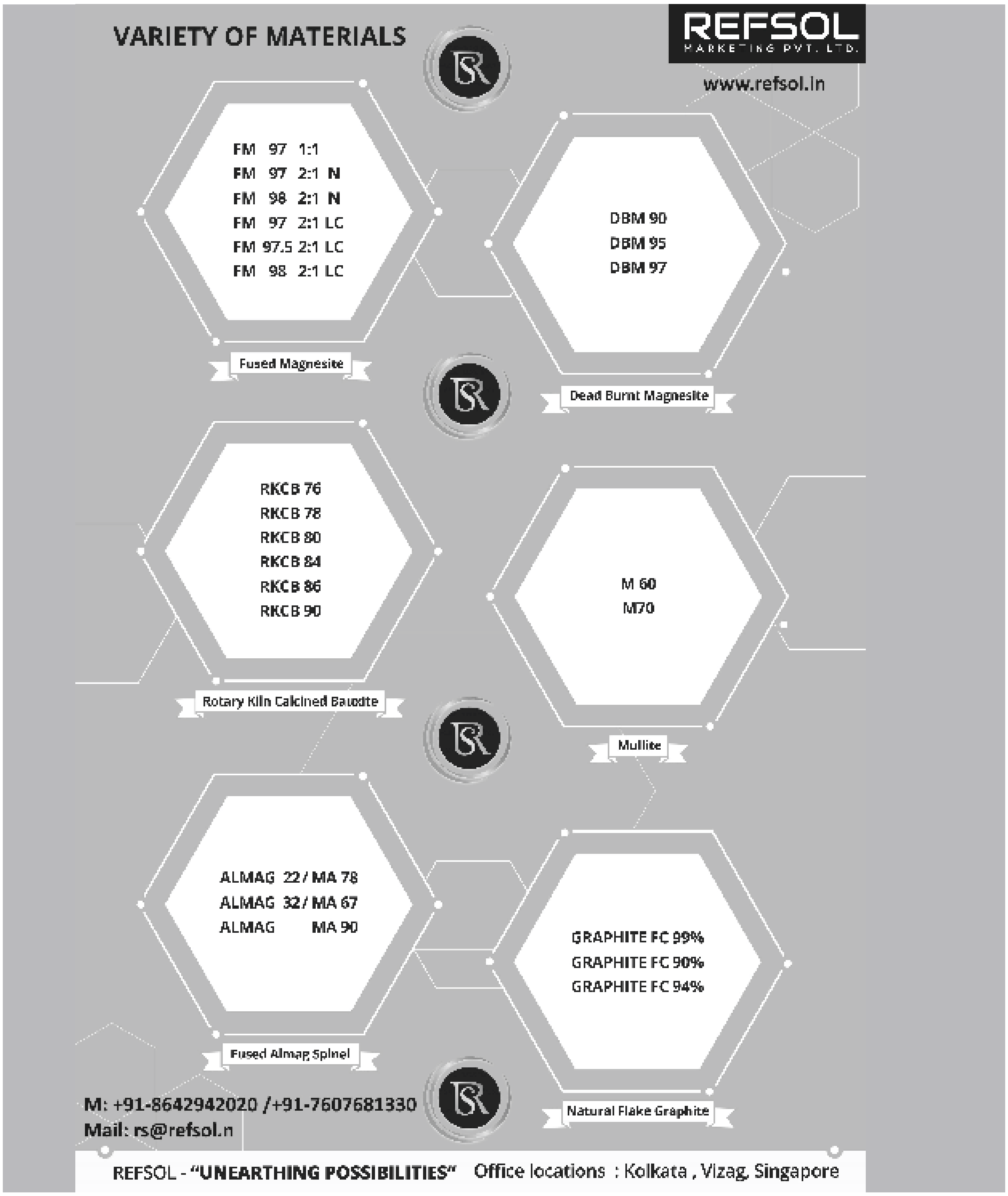
Performance of Eight Core Industries
Yearly Index & Growth Rate
Base Year: 2011-1 =100
Index

Sector	Coal	Crude Oil	Natural Gas	Refinery Products	Fertilizers	Steel	Cement	Electricity	Overall Index
Weight	**10.33**	**8.98**	**6.88**	**28.04**	**2.63**	**17.92**	**5.37**	**19.85**	**100.00**
2012-13	103.2	99.4	85.6	107.2	96.7	107.9	107.5	104.0	103.8
2013-14	104.2	99.2	74.5	108.6	98.1	115.8	111.5	110.3	106.5
2014-15	112.6	98.4	70.5	108.8	99.4	121.7	118.1	126.6	111.7
2015- 16	118.0	97.0	67.2	114.1	106.4	120.2	123.5	13.8	115.1
2016-17	121.8	94.5	66.5	119.7	106.6	133.1	122.0	141.6	120.5
2017-18	124.9	93.7	68.4	125.2	106.6	140.5	129.7	149.2	125.7
2018-19	134.1	89.8	69.0	129.1	107.0	147.7	147.0	156.9	131.2
2019-20	133.6	84.5	65.1	129.4	109.8	152.6	145.7	158.4	131.6
2020-21	131.1	80.1	59.8	114.9	111.6	139.4	130.0	157.6	123.2
2021-22	142.3	77.9	71.3	125.1	112.5	163.0	156.9	170.1	136.1
2022-23	163.5	76.6	72.4	131.2	125.1	178.1	170.6	185.2	146.7
2023-24	182.7	77.1	76.8	135.9	129.8	200.4	185.7	198.3	157.8
2024-25	192.0	75.4	75.9	139.7	133.5	214.1	197.4	208.6	164.9
Apr-May 2024-25	179.0	77.1	76.8	139.9	126.9	209.9	191.5	220.7	164.9
Apr-May 2025-26*	184.6	75.4	75.0	137.5	120.4	221.5	206.4	215.9	166.3

***Provisional**

(Source: PIB, Government of India)




VARIETY OF MATERIALS
REFSOL
MARKETING PVT. LTD.
www.refsol.in
FM 97 1:1
FM 97 2:1 N
FM 98 2:1 N
FM 97 2:1 LC
FM 97.5 2:1 LC
FM 98 2:1 LC
Fused Magnesite
DBM 90
DBM 95
DBM 97
Dead Burnt Magnesite
RKCB 76
RKCB 78
RKCB 80
RKCB 84
RKCB 86
RKCB 90
Rotary Kiln Calcined Bauxite
M 60
M70
Mullite
ALMAG 22 / MA 78
ALMAG 32 / MA 67
ALMAG MA 90
Fused Almag Spinel
GRAPHITE FC 99%
GRAPHITE FC 90%
GRAPHITE FC 94%
Natural Flake Graphite
M: +91-8642942020 /+91-7607681330
Mail: rs@refsol.in
REFSOL - "UNEARTHING POSSIBILITIES" Office locations : Kolkata , Vizag, Singapore

Technical Articles for IRMA Journal

Indian Refractory Makers Association extends an earnest request to all readers of IRMA Journal for their co-operation in providing technical notes and articles concerning raw materials development, introduction of novel inputs, refractory products and their design, selection, application engineering and performance for a better exchange of technical information and experiences amongst producers and user of refractories. The full paper can be mailed to support@irmaindia.org with the title “Technical Article for IRMA Journal”.

The Guidelines for the prospective authors are reproduced below:-

GUIDELINES FOR TECHNICAL ARTICLES FOR THE IRMA JOURNAL

The authors submitting technical articles for publication in the quarterly IRMA Journal (normally published in April, July, October and January each year) are requested to follow the following guidelines:-

1. The technical article should be in camera ready condition on standard A4 size paper and should be sent in soft copy in MS-Word document format by email at support@irmaindia .org
2. The paper should not normally exceed 5 printed pages, including illustration (photos, graphs, figures, table, etc.) in two columns.
3. The print area shall be 16cm width X 24.5 cm height.
4. The title of the paper is to be in 14 point “Arial” Bold and Italics, al Capitals, brief but informative e.g.

MINERALOGICAL STUDIES ON…

5. The authors name and organization shall be printed in 10 point “Arial” Italic, e.g. *A.Dasgupta*
6. The sectional or sub-heading should be 10 point “Arial” Bold, e.g. **Effect of High Temperature**.
7. The body typing should be 10 point “Arial” Normal, e.g. The factor affecting the lining life
8. References are to be numbered in chronological order as cited in the text and should be given in 10 point “Arial” Normal, at the end of the article. The format should be:- surname and name of the author first, followed by the title of the book/article, the title of the paper/ publication, volume number, issue number, page and year of publication.
9. An abstract of the paper containing important feature of the text should be sent in about 100 words, along with the paper.
10. Five reprints of each paper shall be supplied to the author, free of charges.

SHREE SADASHIV REFRACTORIES PVT LTD

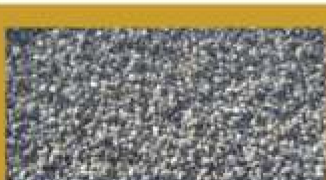
ABOUT US

Shree Sadashiv Refractories Pvt Ltd is an emerging company in the business of Mining and Processing of Refractory Raw Materials in Jamnagar, Gujarat in India. We are engaged in producing Refractory Raw Materials like Calcined Bauxite, Calcined Clay & Chamotte.

MISSION

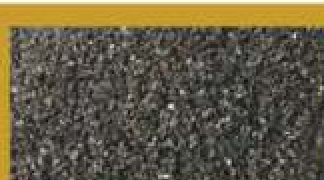
SSRPL's core business mission hinges on its' commitment quality and service and offering raw material products consistent in size, chemistry & physicality. Our Laboratory is equiped with latest equipment for testing as per the industry standard.

KEY PRODUCTS



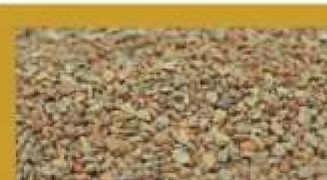
CALCINED BAUXITE

Refractory Bauxite, also known as Calcined Bauxite is produced by sintering high alumina bauxite in rotary kilns at high temperatures.



BROWN FUSED ALUMINA

Calcined Bauxite is heated to Temperatures above 2000°C through smelting process in Arc Furnaces. Then slow solidification process is followed to get blocky crystals, which in other words is known as Brown Fused Alumina.

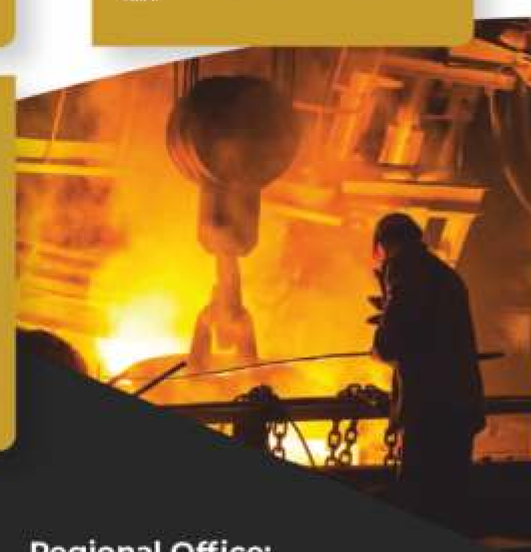


CALCINED CLAY

Calcined clay is obtained by calcining (heating) superior grade clay at high temperature in Rotary Kiln.

WHITE FUSED ALUMINA

White Fused Alumina is manufactured by the Fusion of Pure Quality Calcined Alumina in Arc Furnaces with Temperatures greater than 2000°C. After Slow solidification, a high purity synthetic material is obtained.



Contact

H/O :
F-24, Sej Plaza, Marve Road,
Malad (W), Mumbai- 400 064.

P: +91 90541 16583
P: +91 9558823340
E: marketing@sadashivarefractories.com
W: www.sadashivarefractories.com

Works :
Plot no. 1/2, Survey No. 365,
Village Jogvad, Tal. Lalpur,
Jamnagar,
PIN: 361280, Gujarat.

Regional Office:
(East/Central)
Bhubaneshwar, India.

P: +91 82491 80345
E: abhishek@sadashivarefractories.com

Printed and published by Mr. Anirbandip Dasgupta, on behalf of Indian Refractory Makers Association and printed at **Q**uality **S**upply **S**yndicate, 219C, Old China Bazar Street, 2nd Floor, Room No. C - 10, Kolkata - 700 001 and published at, IRMA, 41, Shakespeare Sarani, Kolkata - 700017, Editor : **Dr. I. N. Chakraborty** • **R.N.I. Regd. Number 34845/79**