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RHI MAGNESITA

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Advancing Sustainable Practices in Refractories for the Cement Industry

The refractory industry plays a pivotal role in various high-temperature industrial processes, such as cement and nonferrous metal production, steelmaking, and glass manufacturing. As environmental concerns intensify, there is a growing imperative to adopt sustainable practices within the refractory industry. For example, in recent years RHI Magnesita started to develop recycling options for magnesia spinel bricks used for lining cement rotary kilns, resulting in a quite extensive low carbon (LC) product portfolio, the ANKRAL LC-Series. The most recently released product, ANKRAL RS-LC, has the highest recycling content implemented so far (i.e., up to 50%), which lowers the carbon footprint by close to 50% compared to the standard product. This paper describes three case studies with products from the LC-Series, highlighting the latest results of ANKRAL RS-LC. The ANKRAL LC-Series contributes to the growing body of knowledge supporting integration of recycled materials in critical industrial processes, promoting a circular economy, and aligning with global efforts to reduce CO_2 emissions.

Introduction

RHI Magnesita set the goal to reduce 15% of its scope 1, 2, and 3 emissions by 2025 [1] and aspires to becoming CO_2 neutral in the future. To achieve this ambitious target, a commitment was made in 2019 to invest €50 million in new and emerging technologies aimed at reducing CO_2 emissions across various processes. In addition to substantial investments, RHI Magnesita was also the first to display the carbon footprint of refractory products on its technical data sheets [2], enabling benchmarking of different concepts according to their carbon footprint. Based on this information, customers can now incorporate sustainable aspects into their product decision-making.

The use of recycled materials to substitute primary raw materials plays a central role in carbon footprint reduction. Furthermore, products that require basic refractory raw materials can benefit significantly in this context because compared to many other refractory materials, basic raw materials have a substantial carbon footprint. This is attributed to the fact that basic raw materials are mostly derived from carbonates and to transform them into refractory oxides they need to be calcined, during which a significant amount of geogenic CO_2 is released. This process occurs at temperatures of up to 1000 °C and requires substantial fuel input, causing further greenhouse gas (GHG) emissions. Additionally, to produce refractory materials with high density and stability at elevated temperatures, an additional step is necessary, which can involve either a sintering or melting process. Sintering requires temperatures of up to 2000 °C, while melting takes place at temperatures above 2800 °C.

Depending on the type of kilns and fuel used, CO_2-specific emissions can range from around 1.4–5.2 tonne of CO_2 equivalent per tonne of raw material (t CO_2e/t) [3]. However, other approaches for producing sintered or fused magnesia do not result in a lower carbon footprint, as the complex production process (e.g., wet route) of seawater or brine-based magnesia types results in the same level of GHG emissions compared to magnesite-based ones [3]. As a vertically integrated company, the production of sintered magnesia and dead burned magnesia, as well as dead burned doloma is responsible for around 85% of RHI Magnesita's scope 1 CO_2 emissions [3]. On the one hand, this is due to the scarcity of alternative primary raw materials available in the market that can serve as substitutes and on the other hand it highlights that using recycled materials within a circular economy is essential.

Refractory products, when in use, are exposed to various wear mechanisms, making the reprocessing process extremely complex in most cases [4]. This complexity is particularly evident in the cement industry, where over the past few decades the use of alternative fuels has significantly increased infiltration of alkali salts into the refractory lining. The concept of fuel switching, which involves transitioning from conventional fossil fuels to alternative fuels with improved CO_2 ratings, varies globally. While Central Europe has made significant progress with substitution rates of up to 100%, other regions like China, Africa, and the Middle East are still relatively early in this transition. Nevertheless, RHI Magnesita has managed to develop a product portfolio with a reduced carbon footprint, the ANKRAL LC-Series, based on recycled bricks from cement rotary kilns.

From Spent Refractories to Circular Raw Materials

At the end of their lifespan, worn out refractory bricks were typically disposed of or landfilled, potentially incurring additional costs for operators. However, these materials are a valuable source of raw materials, which can be repurposed to create new refractory products. Removing used bricks from the kiln involves standard procedures and machinery, without any additional steps. Before debricking, any coatings or build-ups on the lining should be removed. Depending on the type of magnesia (e.g., low or high iron content) and flexibiliser (e.g., spinel or hercynite), the bricks are separated onsite into predefined categories to control the chemical characteristics of the subsequently generated circular raw materials. A well-defined sourcing concept, as well as an adequate reconditioning process, is key to guarantee excellent and stable product properties [5].

Once the material has arrived at a recycling hub, the conversion from spent refractories to circular raw material begins. This process consists of several sorting and classification steps and starts with chemical analysis to verify the nature and type of collected material. After manual sorting (Figure 1), where any foreign objects (e.g., steel anchors and wood) are also removed, the material is subjected to a patented cleaning process in which the largest share of unavoidable alkali salt infiltrations from the cement process are removed. This treatment requires a certain effort in terms of energy and time; however, it is essential to achieve the desired product properties. After crushing the material, the new circular raw material is used to produce ANKRAL LC-Series bricks.

One of RHI Magnesita's priorities is developing fully automated identification and separation of used materials, including sensors specifically designed to meet the challenges of refractory recycling (see page 41). Currently, pilot equipment is being implemented in Austria that will completely change the status quo of spent refractory sorting [4].

Innovative Low-Carbon Series

With the ANKRAL LC-Series, RHI Magnesita has successfully implemented the principles of a circular economy in the production of magnesia spinel bricks for the cement industry. The LC-Series (low carbon) incorporates up to 50% recycled materials. Designed with a significantly reduced carbon footprint, these products aim to assist cement producers in lowering emissions within their supply chain while maintaining technical specifications. To meet the growing demand for sustainable refractories, RHI Magnesita offers a range of LC products, including ANKRAL Q1-LC, ANKRAL R8-LC, ANKRAL Q2-LC, ANKRAL RC-LC, and ANKRAL ZE AF-LC. The different products of the LC-Series have been widely used globally in central burning and transition zones under various operational conditions since their market launch in 2020. During this time, the series has gained recognition as a well-known brand, particularly in Europe.

Figure 1.

Manual sorting at a recycling hub, which will be fully automated in the future.

The primary goal in creating the ANKRAL LC-series was to incorporate circular raw materials, thereby reducing the carbon footprint, while ensuring that product properties remained uncompromised. Although the technical data sheet values for conventional ANKRAL bricks and their corresponding LC-Series counterparts may not be identical, both can be effectively used in the same applications and achieve the same level of performance. Rigorous laboratory tests, combined with meticulous sourcing and raw material processing, guarantee consistent performance even under demanding conditions, which has been proven in numerous applications.

The latest development in the field of sustainable products is ANKRAL RS-LC, where the circular raw material content has been increased up to a remarkable 50%. Despite this high recycling rate, a product with outstanding properties was developed. The brick has an exceptional refractoriness under load (RuL T0,5 > 1700 °C), which is comparable to products based on primary raw materials (Figure 2). Additionally, due to sophisticated processing methods, the brick exhibits a remarkably low content of secondary phases, providing excellent resistance against chemothermal wear. The positive results of this development have already been confirmed in practical applications.

Figure 2.

Technical data sheet of ANKRAL RS-LC.

Technical data sheet

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ANKRAL RS-LC

General information	
Classification	Magnesia-spinel product type MSp80 ISO 10081-2
Main raw material components	Fused spinel, High grade sintered magnesia
Bonding type	Ceramic
Main Application(s)	Sintering and transition zones
Type of brick	Fired
Mortar to use	ANKERFIX CRP

Environmental indicators			
Product Carbon Footprint	1,431	[t CO2e/t prod.]	ISO 14067
The Carbon Footprint of the Product (CFP) has been calculated following the principles of ISO 14067.			

Chemical analysis					
MgO	Al_2O_3	Fe_2O_3	CaO	SiO_2	
85,8%	11,0%	0,5%	1,4%	0,8%	
Determination on fired substance (1025 °C / 1877 °F) acc. to ISO 12677					

Physical properties				
Bulk Density		2,90	[g/cm³]	ISO 5017
Apparent Porosity		18,0	[vol%]	ISO 5017
Cold Crushing Strength		60,0	[N/mm²]	ISO 10059-1
Thermal Expansion	500 °C / 932 °F	0,51	[%]	EN 993-19
	750 °C / 1382 °F	0,84	[%]	EN 993-19
	1000 °C / 1832 °F	1,20	[%]	EN 993-19
Refractoriness under Load $T_{0,5}$		1700	[°C]	ISO 1893
Res. to Thermal Shocks Air		> 100	[cycles]	EN 993-11
Thermal Conductivity	500 °C / 932 °F	4,30	[W/mK]	Dr. Klasse
	750 °C / 1382 °F	3,50	[W/mK]	Dr. Klasse
	1000 °C / 1832 °F	3,00	[W/mK]	Dr. Klasse

The indicated values are standard values, i.e. values taken over a longer representative period of time according to either valid test standards or internal test methods. They may not be regarded as committed specifications and therefore not as guaranteed properties. We reserve the right to further technical developments and new editions of technical product information.
Colour deviations of the product may occur due to the nature of the raw materials used, however they are not an indication of inferior performance or quality.

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ANKRAL RS-LC 1 / 1

Case Study A—ANKRAL ZE AF-LC

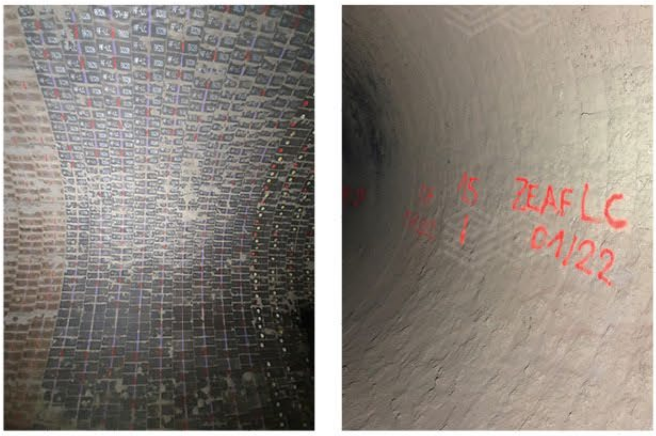
Plant A operates a precalciner kiln (Ø 3.8 m x 59 m long) with a capacity of approximately 1900 tonnes per day (tpd) in Central Europe and an alternative fuel (AF) rate of beyond 90% (including plastics and sewage sludge). ANKRAL ZE AF-LC was installed in January 2022 between 15 m and 17 m in the upper part of the central burning zone (CBZ), where high thermal load in combination with occasional clinker melt infiltration and coating loss are the typical wear mechanisms. After completing a full campaign of one year, the lining was inspected again in January 2023. This revealed a very uniform wear and a residual thickness of 170–180 mm (Figure 3). At the next opportunity to enter the kiln in January 2024, the lining showed a similar appearance, with a residual thickness of 140–160 mm. By mid-2024, at the time of writing this article, the bricks were already in their third campaign, with high expectations for completing a third year. The results of this successful trial confirm ANKRAL ZE AF LC's full equivalency to any other iron-rich CBZ brick on the market.

Case Study B—ANKRAL Q1-LC

The kiln at Plant B (precalciner, Ø 4.0 m x 60 m long with a capacity of 2200 tpd) is another example of a European kiln running with substitution rates close to 100% (e.g., refuse-derived fuels, solvents, and biomass). ANKRAL Q1-LC was installed in the lower transition zone (LTZ) between 6.4 m and 8.4 m, followed by ANKRAL Q1 between 8.4 m and 10 m. In previous campaigns, this area was lined completely with the conventional ANKRAL Q1, achieving lifetimes of one year despite high chemothermal load and proximity to the tyre. After one full year in operation, the Lining Evaluation Scan (LES) showed a residual thickness of 140–170 mm and rather uniform wear in the installation area of the LC-series bricks (Figures 4 and 5). The corresponding standard brick performance was largely the same, confirming that the product development goal of not compromising the product properties by adding circular raw material was fully met. Based on these results, the operator decided to enlarge the installation area of ANKRAL Q1-LC in future campaigns.

Figure 3.

ANKRAL ZE AF-LC in the CBZ between 15 m and 17 m, (a) before and (b) after a one-year campaign.



(a) (b)

Case Study C—ANKRAL RS-LC

The plant for case study C is operating a modern precalciner kiln (Ø 5.2 m x 77 m with a capacity of approximately 6000 tpd) in Southern Europe. It is using a fuel mix consisting of coal/pet coke and residue derived fuel (i.e., sewage sludge and tyre chips), reaching AF rates of more than 60%. The refractory lining of this kiln is exposed to high chemothermal stress and increased mechanical load from the centre tyre and in the outlet area. In addition, the lining is affected by frequent kiln stops.

Figure 4.

ANKRAL Q1-LC in the LTZ, lined between 6.4 m and 8.4 m, after one year in operation.

Figure 5.

Installation of ANKRAL Q1-LC (6.4 m–8.4 m) and ANKRAL Q1 (8.4 m–10 m) after one year in operation.

In March 2023, ANKRAL RS-LC was installed in the remote upper transition zone of this kiln between 40.5 m and 45.5 m (Figure 6). A LES in September of the same year (after approximately 6 months of service) revealed that the brick was in perfect condition, showing no signs of wear and still having the original thickness (Figure 7). Another inspection in January 2024, which again included LES, basically showed the same results (Figure 8). Both lining evaluation scans performed by RHI Magnesita in September 2023 and January 2024 showed that the lining area of ANKRAL RS-LC was in perfect condition, without any spalling and with uniform residual thicknesses beyond 200 mm from the original 220 mm (Figure 9).

Figure 6.

Installation of ANKRAL RS-LC between 40.5 m–45.4 m.

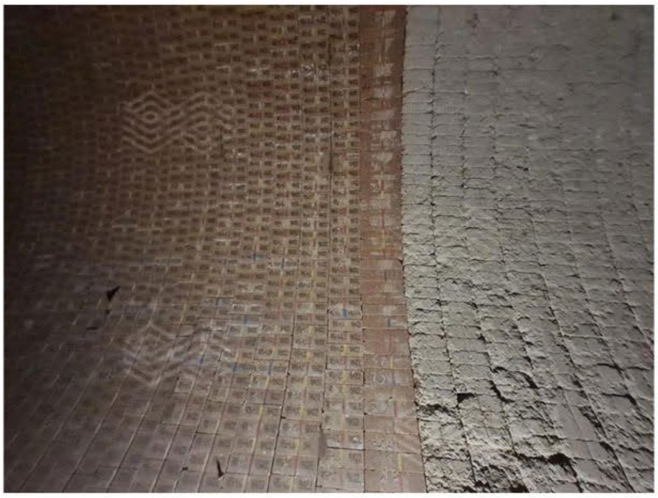


Figure 7.

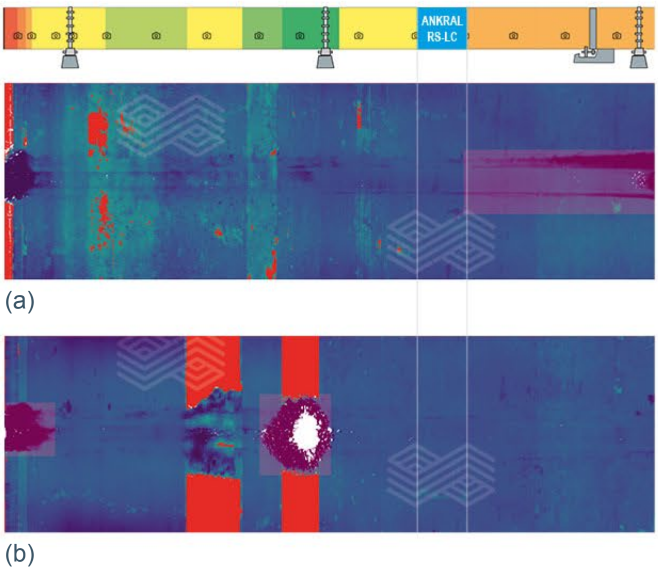
ANKRAL RS-LC in September 2023 after 6 months in operation, showing original residual thicknesses without prewear areas.

Figure 8.

Image taken during a further inspection in January 2024, showing the ANKRAL RS-LC lining area with no significant wear (LES image).

Figure 9.

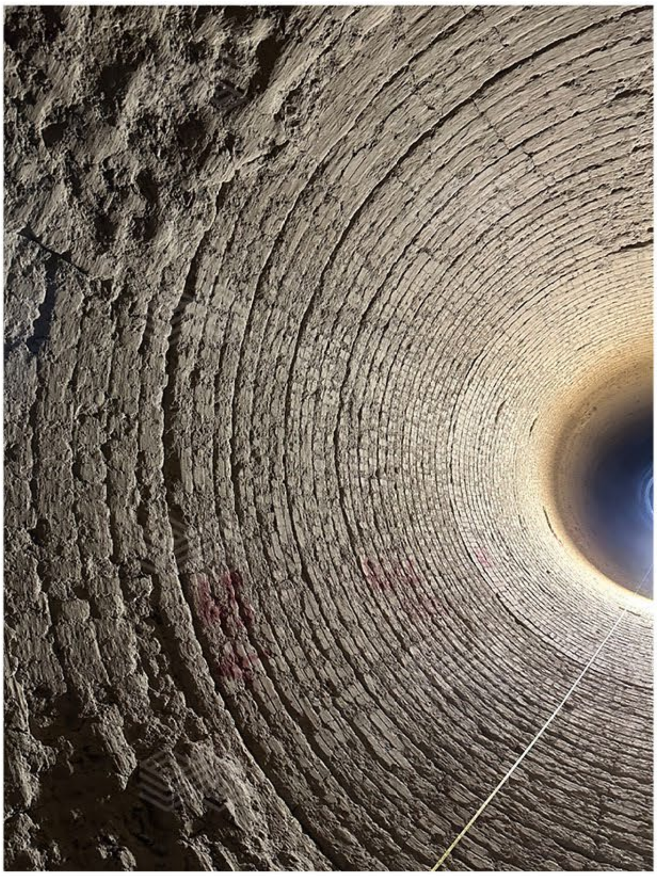
Lining evaluation scans in (a) September 2023 and (b) January 2024.



Another opportunity to inspect the lining arose in April 2024, during a further kiln stoppage. At this time, the ANKRAL RS-LC had been in service for more than 12 months and still did not show signs of massive wear (Figure 10). After the first year of service, the customer confirmed that the bricks were still in satisfactory condition and is very confident that they will remain in operation for at least another year.

Figure 10.

Inspection of the ANKRAL RS-LC lining area in April 2024, showing no significant wear.



Sustainable Refractories

The product portfolio of the ANKRAL LC-Series includes products designed to address the challenges of modern clinker production across all relevant kiln sections that require magnesia spinel bricks. The focus of further developments is to optimise the sourcing, preparation, and production process to incorporate even higher amounts of circular raw materials [4], reduce the carbon footprint, and contribute to a sustainable refractory industry. The priority focus for R&D is on a fully automated identification and separation of recycled materials. Currently, RHI Magnesita is developing pilot equipment that is being implemented in Austria and will completely change the status quo of spent refractory sorting.

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Cover picture: The image depicts the lower section of a RH degasser, a secondary metallurgical unit used in steel plants. In the RH degassing process, snorkels are submerged into liquid steel contained in the casting ladle. Argon gas is purged through the inlet snorkel, creating a suction effect that draws liquid steel into the lower vessel of the RH degasser, where a vacuum is applied. The steel treated in the lower vessel flows back to the ladle through the outlet snorkel, creating a continuous steel circulation between the ladle and the RH degasser. The strong negative pressure (vacuum) within the RH degasser facilitates various metallurgical processes that enhance steel quality, with the key process steps including degassing, decarburisation, deoxidation, and alloying under vacuum. Rail steel, flat steel for the automotive industry, and steel plates for shipbuilding are just a few examples of products that benefit from the RH degasser. Prefabricated snorkels, which RHI MAGNESITA manufactures ready for use and delivers to our globally operating customers, are essential components of the RH degasser.