A masterclass in castables

Herbert Hoenl, REFKO, outlines the benefits of a new castable magnesia spinel solution which promises new opportunities for rotary kiln lining repair.

The development of a magnesia spinel castable is the next step in efforts to help cement plant operators with serious refractory problems in the hot part of the rotary kiln. Together with a state-of-the-art gunning material (REFKO Recovery MG 78), the new magnesia spinel-based castable (Vimag SP 86 B) provides a monolithic solution to manage and resolve critical failures of the standard brick lining.

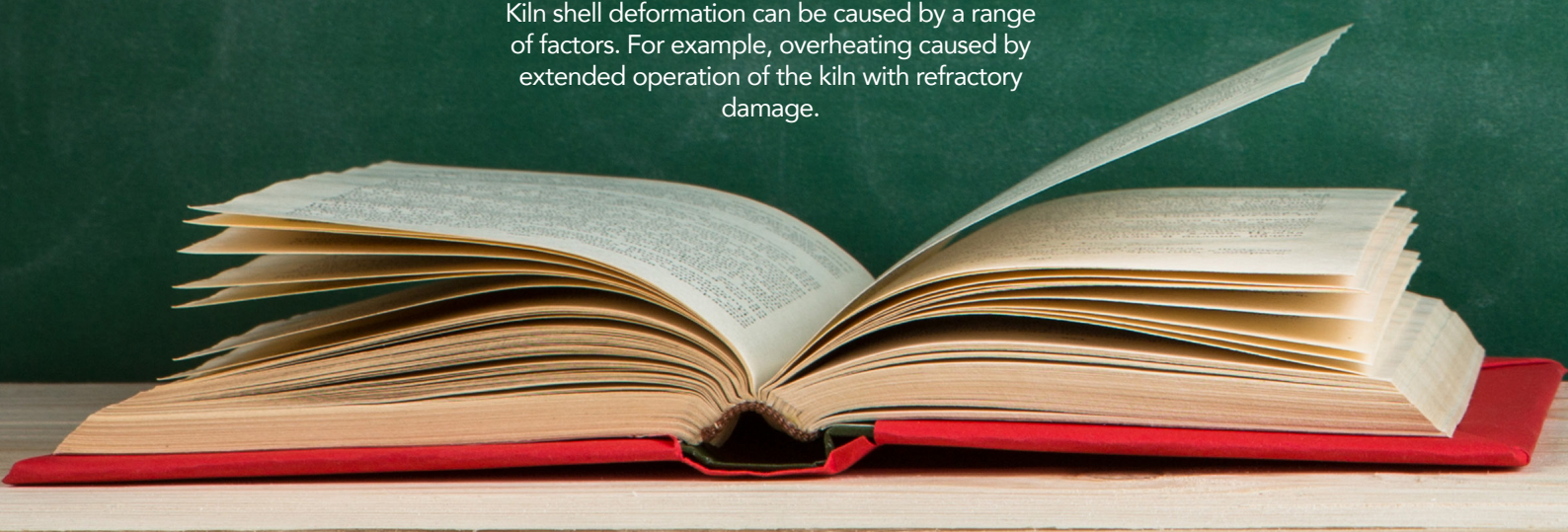
The benefits of the Recovery MG 78 gunning material have been described in detail in previous issues of *World Cement*. This material is already widely used in many cement plants, achieving reliable performance and significantly reducing the shutdown time caused by emergency stops. This article will instead focus on the newest addition to REFKO's portfolio.

Kiln shell deformation

Some rotary kilns face serious kiln shell deformation issues that lead to the collapse of multiple rows of bricks in a short time of service, therefore necessitating a different approach to repair.

Causes and consequences

Kiln shell deformation can be caused by a range of factors. For example, overheating caused by extended operation of the kiln with refractory damage.



Or an overheated shell that becomes choked inside the tyre gear. The cause of deformation could even be as simple as a the steel shell being extremely worn by age.

These kinds of damage are not easy to repair and, in most cases, ultimately require replacement of the deformed steel shell section. As such, repairs are time-consuming and expensive. Also, due to the long delivery time of steel shell segments, the cement plant will usually have no choice other than to operate the kiln with a deformed shell until a proper repair can be undertaken.

With regard to refractories, such defects can also lead to an extremely short brick lining lifetime. Furthermore, with such a deformed steel shell, proper bricklaying is very complicated, or in some cases, close to impossible.

This leads to refractory failures in the brick lining much faster than under good kiln shell conditions. In the worst cases, the brick lining can collapse after three weeks or less of operation. This forces the cement plant into many unplanned, time-consuming, and expensive emergency shutdowns. A further consequence is an increased consumption of refractory material that, in the end, is an environmental issue in terms of the high CO_2 consumption involved in the production of refractory bricks.

Table 1. Chemical composition comparison.

	VIMAG SP 86 B	Magnesia spinel brick
MgO	84 – 88	87 – 89
Al_2O_3	6 – 8	9 – 11
SiO_2	4 – 6	0.8
CaO	<1	0.8

Table 2. Physical and mechanical properties comparison.

	VIMAG SP 86 B			Magnesia Spinel Brick
After heating at:	**120˚C**	**1000˚C**	**1500˚C**	**In state of delivery:**
BD (g/cm³)	2.83	2.79	2.87	3 – 3.05
CCS (MPa)	96	66	85	65

BD= Bulk density

CCS= Cold crushing strength

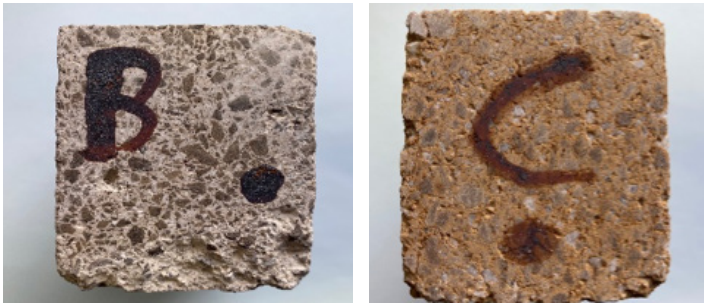


Figure 1. (Left) VIMAG SP 86 B with no cracks. (Right) Magnesia spinel brick with no cracks.

A castable solution

In such cases, a castable would be a perfect solution. The installation can be completed easily, even on a deformed steel shell. A castable can 'follow' the deformed shell structure, making a well-balanced lining possible; all without increasing mechanical stress inside the lining during operation.

Consequently, people within the cement producing community have already been looking for a castable magnesia spinel solution.

The Vimag SP 86 B product offers a castable solution and has similar properties to common magnesia spinel bricks.

These properties were achieved by focusing on chemical composition, mechanical properties, thermoshock resistance, and the flexibility of the microstructure. REFKO also worked to ensure that, after a repair, the kiln can be heated up via the normal heating-up procedure.

Chemical comparison

In Table 1, a comparison between the Vimag SP 86 B and a widely sold magnesia spinel brick is shown. In comparison to the brick, the castable is a little lower in Al_2O_3 content. This could be caused by the slightly different spinel content.

Physical and mechanical properties

The results of a test (Table 2) demonstrate that the ratio of spinel to magnesia is perfect in terms of thermoshock resistance and flexibility of the microstructure.

The slightly higher amount of SiO_2 is a concept from REFKO, designed to produce the necessary properties for this new kind of magnesia spinel castable.

As is typical for castable, the physical properties develop during the heating-up process. This normally achieves additional flexibility inside the lining. On the other hand, a brick is a fired product and is defined by its properties at the state of delivery.

The magnesia spinel castable has a slightly lower bulk density. This is potentially advantageous regarding slightly better insulating properties. However, this will need to be investigated separately, once there has been time to monitor it during test installations.

In terms of cold crushing strength, the castable has the same or higher values than the brick.

Thermal shock resistance (TSR)

REFKO undertook an in-house test for TSR on magnesia-containing materials.

The probes were heated up to 1200˚C and held at this temperature for 4 hours. The probes were then taken out of the furnace and allowed to cool down at normal room temperature for 30 minutes.

After this, the probes were placed back into the furnace, which was still at 1200˚C. After being held at 1200˚C for another four hours, the cool down process started again. This was done 20 times, after which, an optical inspection of the probes was conducted.

Neither the brick sample nor the castable sample showed any cracks after having cooled down 20 times (Figure 1). This is, for both products, a very good result. It can therefore be argued that Vimag SP 86 B is on the same level as common magnesia spinel bricks in terms of TSR.

High temperature flexibility

To find out if a castable has the same flexibility under load and, therefore, the same flexibility of the binding matrix of a brick, the following tests were undertaken:

- Hot temperature modulus of rupture (HMOR).
- Hot temperature Young's modulus/modulus of elasticity (E-Modulus).
- Hot temperature deformation modulus (D-Modulus).

The test temperature for all of the above was 1200˚C. The data from the castable is very similar from the data of the brick (Table 3).

Based on the results of TSR in combination with the data of the E- and D-modulus, it is clear that VIMAG SP 86 B has similar flexibility in the microstructure as a common magnesia spinel brick.

Heating up test

A disadvantage of castable solutions is that sometimes they have to follow a special heating-up pattern. Therefore, the goal was to design a castable that can be heated up with the standard heat-up procedure of a rotary kiln. Accordingly, another REFKO in-house test procedure was developed.

A block, including anchors, with dimensions of 500 mm x 500 mm and a thickness of 250 mm was cast (Figure 2). This block was then used as the door of the test furnace. The furnace was then heated up following a procedure obtained from a cement kiln operator. Once cooled, the block was inspected for cracks. In this instance, no cracks were found after the test (Figure 3).

Evidently, the rotary kiln can be heated up under the same heating-up schema that is valid for the normal start of a kiln after refractory repair.

Summary

Having completed various tests, REFKO has demonstrated that its magnesia spinel castable solution has similar properties to a common magnesia spinel brick. It is clear, therefore, that VIMAG SP 86 B is a suitable alternative to a brick in every situation where bricklaying is difficult to undertake. Or for other installation situations where a monolithic magnesia-spinel lining would be a more adequate solution.

The first installation in a cement plant has just been completed, and updates on its progress will be provided. At the time of writing, the kiln with the test installation has already been up and running for three months without issue. ■

Table 3. High temperature flexibility comparison.

	VIMAG SP 86 B	Magnesia Spinel Brick
HMOR (MPa)	2.64	2.75
E-Modulus (MPa)	990	1007
D-Modulus (MPa)	728	740

Figure 2. A block of the castable solution was cast and then used as the door of the test furnace.

Figure 3. No cracks could be found in the cast block after the kiln heating up procedure.