Meet Magnus

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Alternative fuels can place higher thermo-chemical and thermo-mechanical demands on refractories and this requires an extra-tough refractory brick. Höganäs Bjuf AB has developed the Magnus 87AF brick to accommodate these needs. With a wide global reference list, one of the most successful installations to date is at Hope Construction Materials' cement plant based in the UK.

The substitution of fossil fuels by a wide range of alternative fuels to fire cement kilns is becoming increasingly widespread. These fuels consist of agricultural and non-agricultural biomass, chemical wastes, petroleum-based wastes and several other byproducts of modern-day life. However, their chemical make-up and behaviour in the challenging kiln environment can lead to a more rapid deterioration of the refractory, adding extra costs to the cement plant's annual budget.

Figure 1: Magnus 87AF, the new magnesite brick from Höganäs Bjuf AB is designed to withstand the toughest kiln conditions

Introducing Magnus 87AF

To provide kiln operators with a refractory that can withstand these additional pressures, Höganäs Bjuf AB developed the Magnus 87AF brick (see Figure 1). The Magnus 87AF brick was launched in the market following extensive research carried out in kilns around the world. The brick consists of fired magnesia-spinel with the addition of fused magnesia, high-purity dead-burnt magnesia (DBM) and fused spinel.

Its key physical and chemical properties are shown in Table 1. In addition, Magnus 87AF has a strong matrix structure, optimum thermo-mechanical resistance, high thermal shock resistance, optimum elasticity, high corrosion resistance, small pore size and well distribution to decrease infiltrations as well as low gas permeability.

It is particularly suited to installation in the kiln's upper and lower transition zones, tyre sections and sintering zones subjected to thermo-chemical and thermo-mechanical loads where alternative fuels are used (see Table 1).

Table 1: key physical and chemical properites of Magnus 87AF

Physical properties

- density – 2.92g/cm^3
- apparent porosity – 17 per cent
- cold crushing strength – 70MPa
- permeability – 12cD
- hot modulus of rupture at 1400°C – 3.0MPa
- thermal shock resistance at 950°C/air – >120
- refractoriness under load T_{05} – >1700°C
- thermal conductivity at 500˚C – 3.40W/mK
- thermal conductivity at 1000˚C – 2.80W/mK

Chemical properties

- MgO – 87.9 per cent
- Al_2O_3 – 10.5 per cent
- CaO – 0.8 per cent
- SiO_2 – 0.3 per cent
- Fe_2O_3 – 0.5 per cent

Case study: Hope Cement plant, UK

One of the most successful installations of Magnus 87AF has been carried out at Hope Construction Materials' plant, which is located in Hope Valley close to the three villages of Hope, Bradwell and Castleton, UK. The cement works operates a ϕ4.8m x 70m dry-process kiln with a four-stage Humboldt preheater. At a feed rate of 145tph, it produces around 2000tpd of clinker. Fuels such as pulverised coal, tyre fluff, shredded carpets, meat and bone meal and sewage pellets are fed into the kiln by indirect firing at the main burner. There is also secondary firing of tyre chips (50mm squares) into the riser barrel. Total fuel rate is max 10.1tph with a maximum thermal substitution rate of 54 per cent.

On 2 July 2013, 12m of Magnus 87AF was installed between 21-33m in the upper transition zone of kiln. After nine months, 8m of bricks were removed for

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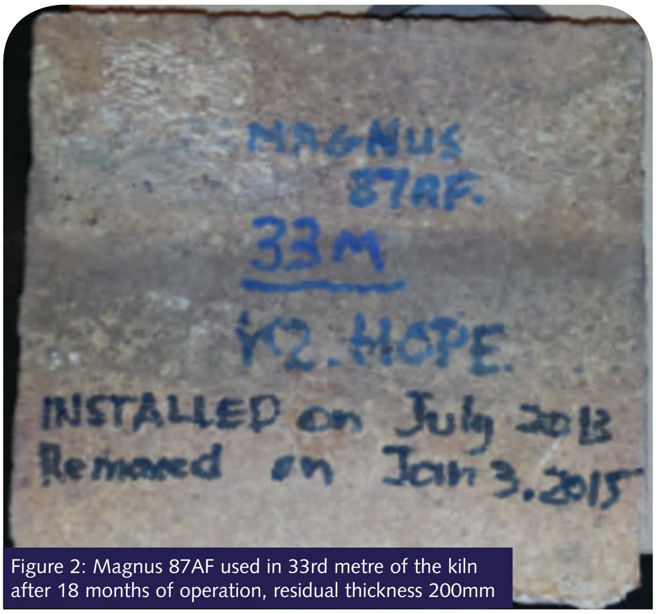

Figure 2: Magnus 87AF used in 33rd metre of the kiln after 18 months of operation, residual thickness 200mm

Figure 3: Magnus 87AF used in 28th metre of the kiln after nine months of operation, original thickness retained (220mm)

mechanical engineering reasons, showing still a full depth and no cracking. While there was heavy metals salts infiltration on the back surface, condensed at the kiln shell, there was no visible damage. The remaining 4m (29-33m) was removed in January 2015 after 18 months of operation. This section has a residual thickness of 200mm, which is 20mm less than the original thickness (see Figure 2).

In addition, several unscheduled kiln stoppages during the year did not affect the Magnus 87AF bricks, reaching the target lifetime of one full campaign. This was not the case for previous installations.

Investigation methods

To record and prove brick performance, the Magnus 87AF brick, used in 28th metre of the kiln, was sent to the laboratory for extended analysis. As shown in Figure 3, it was divided into three segments:

- segment 1 (0-65mm)
- segment 2 (65-130mm)
- segment 3 (130-220mm).

Tests performed on this sample consisted of physical and chemical analysis, and a mineralogical investigation using a scanning electron microscope combined with an energy dispersive X-ray analyser.

Physical & chemical analysis

The physical analysis tests were determined by measuring the bulk density (BD) and apparent porosity (AP) of the three segments, according to ASTM C830 (see Table 2). The chemical (oxide) analysis was carried out using X-ray fluorescence according to EN 15309 standard (see Table 3).

Table 2: physical analysis results on Magnus 87AF

Segments	*Bulk density (g/cm³)*	*Apparent porosity (%)*
1 (0-65mm)	2.99	14.95
2 (65mm-130mm)	3.10	8.14
3 (130mm-220mm)	3.21	3.59

Table 3: chemical analysis results on Magnus 87AF

Element/compound share of total (%)	*Segment 1*	*Segment 2*	*Segment 3*
CaO	0.72	0.83	0.95
SiO_2	0.32	0.34	0.42
MgO	87.73	81.85	79.54
Al_2O_3	7.15	5.79	6.66
Fe_2O_3	0.58	0.50	0.56
NaCl	0.57	1.74	1.48
K_2SO_4	0.51	2.00	3.03
KCl	2.25	6.39	6.69
Br	0.12	0.43	0.54
Rb_2O	0.01	0.04	0.06
ZnO	0.04	0.01	0.01
Pb		0.05	0.04
Cs		0.02	0.02

The porosity value decreased by 77 per cent from 17 to 3.59 per cent due to the infiltration of impurities. These impurities crystallise at the optimum temperature and then create mechanical stresses in the brick structure. Br, Rb, ZnO, Pb, Cs are carried to the cold parts of bricks due to a low melting point. The brick is infiltrated with alkali salts which lead to strong densification of the microstructure. The brick retains its original thickness and, in absence of any mechanical or thermal stresses, no spalling or cracking occurs.

Mineralogical investigation

The mineralogical investigation was carried out by using a scanning electron microscope (SEM). This method is also combined with energy dispersive X-ray spectroscopy used for the elemental analysis or chemical characterisation of a sample.

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Figure 4: $PbSO_4$ crystallisation in Segment 2

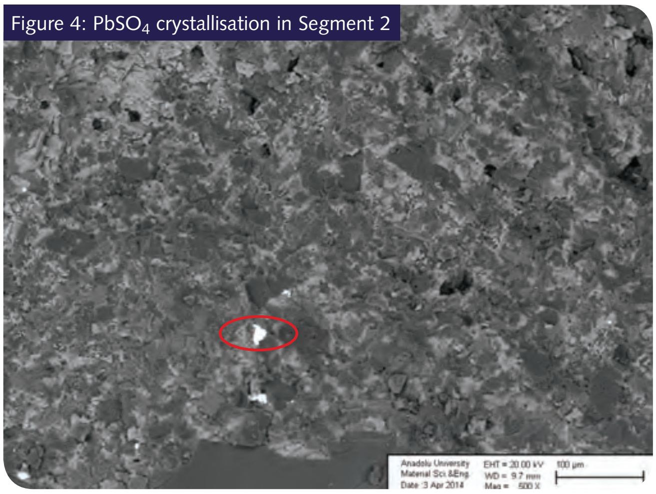

Figure 5: NaCl-KCl infiltration in Segment 3

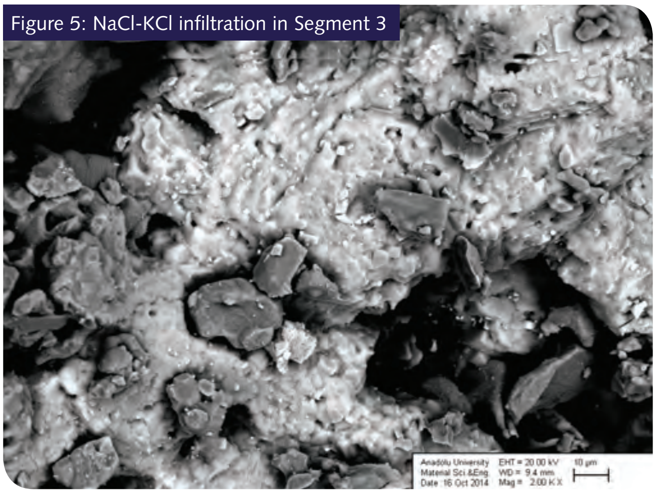

Table 4: Segment 2, scanning electron microscope results

Compound	*By weight (%)*
MgO	8.10
PbO	75.78
SO_3	16.12

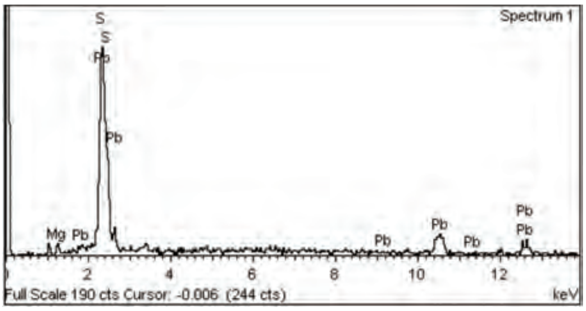

Table 5: Segment 3, scanning electron microscope results

Compound	*By weight (%)*
NaCl	17.41
KCl	52.95
MgO	29.64

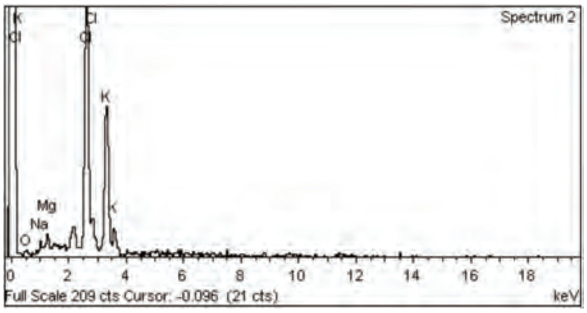

Table 4 shows the SEM results of segment 2 where $PbSO_4$ crystallisation (see Figure 4) has occurred.

Table 5 shows the SEM results of segment 3 where NaCl and KCl have infiltrated (see also Figure 5). KCl infiltration reacts with the fine MgO grain brick matrix and forms $MgCl_2$ which destroys brick bindings. As such KCl causes brick erosion and volume expansion.

$MgO + 2KCl \rightarrow MgCl_2 + K_2O$ (in reducing atmosphere)

$MgCl_2 + ½ O_2 \rightarrow MgO + Cl_2(g)$

$CaO + 2KCl \rightarrow CaCl_2 + K_2O$ (777°C)

As shown by these SEM results, there is a strong infiltration of the microstructure by chloride, sulphate, sodium and lead compounds – all of which have low melting temperatures. If lead reacts with alkali salts, products with a lower melting point will form. Infiltration of molten phases changes the brick pore structure. There are crystallisation reactions of alkalis in brick pores and brick matrix. Moreover, as the liquid phase infiltrates, the bond strength of segments decreases. These changes negatively affect the elastic and thermal properties of the brick. With densification, the thermal conductivity increases. The elasticity and thermal shock resistance decreases and causes mechanical stresses, which can favour crack formation and spalling. These have not been obvious on Magnus 87AF bricks. On the other hand, the brick sample retained original thickness (220mm).

Reference list for Magnus 87AF installations

Lafarge Cement (France)
Holcim (France)
HeidelbergCement (Germany)
Marker Zement GmbH (Germany)
Caspisement LLP (Kazakhstan)
Lafarge Cement (Slovenia)
Hope Construction Materials (UK)
Yanbu Cement Co (Saudi Arabia)

Conclusion

Magnus 87AF is the new magnesite brick from Hoganas Bjuf AB based on fired magnesia-spinel with addition of fused magnesia, high-purity dead burnt magnesia (DBM) and fused spinel. With good physical, chemical, mechanical, thermo-mechanical and thermo-chemical properties, it is suited to upper and lower transition zones, tyre sections of kilns and sintering zones subjected to thermo-chemical and thermo-mechanical loads, especially in the presence of alternative fuels. The brick remains in full thickness after nine months without any spalling or cracks, even if several unexpected kiln stoppages occur. In an 18-month period, thickness loss is limited to 20mm. ■

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