

# INNOVATIVE REFRACTORY PRODUCTS TO LINE AND TO REPAIR HEAVILY LOADED AREAS

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## ABSTRACT:

Increased worldwide globalization in terms of economy and competition imposes innovative measure for the steelmaker and other producers targeting cost reduction in order to have the ability to withstand the pressure of the market.

High reliability and availability of the main vessels used for the process are key factors in the choice of a technology. In the last decades a lot of innovation from the monolithic side has enabled to establish these products worldwide. Some areas still stays as a weak point due to such cumulative stresses during operative conditions such as high temperature, thermal shocks, high abrasion and corrosion.

Our precast technology is giving the answer to these multi-task operations. This new generation of refractory composite material offers a combination of strength, high refractoriness, abrasion resistance and reasonable corrosion resistance. For answering the requirements of the market we have developed a range of refractory self-flowing material allowing working in such different environments as iron and steel making, nonferrous industry, incineration, power plant and cement industry.

Furthermore to new performant lining it is essential to propose some efficient easy hot repair possibility to our customer. This can be achieved with a new spray technology here also constituted by a customized line of products enabling a hot repair by spraying. Applied very successfully in the foundry sector, we can save significant time for the repair of ladles or runners.

## INTRODUCTION:

In the advanced economies, productivity growth is subdued. The contraction in imports by China and other emerging market economies has led to weaker export for advanced economies, reducing economic growth. The global Steel Purchasing Managers' Index (PMI) (figure 1), an indicator of general sentiment, has been trending down since mid-2014<sup>1</sup>.

Growth in world crude steel production has decelerated in the past three years in almost all regions of the world (figure 2). Consequently the profitability of the steel industry has also come under intense pressure.

Steelmakers' answer to this struggling market can just be to optimize the product quality by innovation and optimizing their production cost. Additional pressure is also coming from the environment side. Keeping global CO<sub>2</sub> emissions at current levels or lower will necessitate the development of new, breakthrough steelmaking technologies.

Our contribution as refractory supplier has to concentrate in the performance of the vessel. By optimizing the cost/performance ratio with innovative solutions for the vessels we can propose the best service to the customer. This is the major subject of the next two subjects proposed in this paper:

- Special Precast : a concept proposing the best answer to thermal shock and abrasion.
- New spray technology: a concept for the repair by hot and prolonging the campaign for the foundry and other markets.

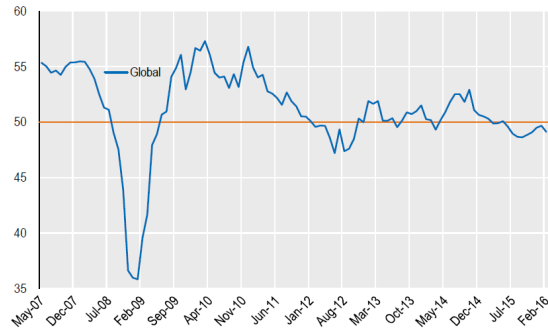


Figure 1 : Global steel PMI <sup>1)</sup>

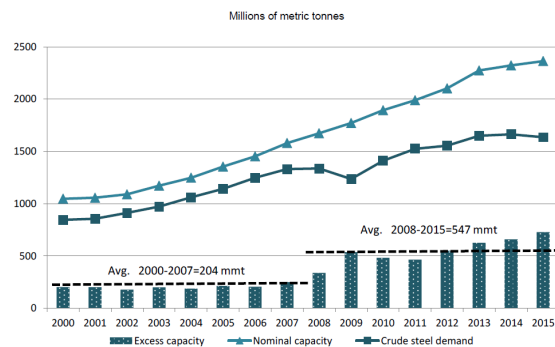


Figure 2: Nominal Steel capacity and demand after OECD <sup>1)</sup>

## PRECAST CONCEPT

### Concept Introduction

This new generation of refractory composite material offers a combination of strength, high refractoriness, abrasion resistance and reasonable corrosion resistance.

For answering the requirements of the market we have developed a range of refractory self-flowing material allowing working in such different environments as iron and steel making, nonferrous industry, incineration, power plant and cement industry.

The origin of the concept <sup>2</sup> started in the nineties in the USA, but at this time the slurry type used for the filling of the frame constituted by the high amount of steel fibres do not present a particularly high refractoriness as major property claim was the high abrasion and impact.

Our contribution was onside in the development of the slurry type introducing the current state of the art of the self-flowing refractory castable. As we are claiming several applications for all type of industries it is essential to have several type of slurries adapted to the local environment (figure 3).

We have developed a range of self-flowing castables starting by the chamotte main grade up to the upper grade of the alumina based aggregates based on tabular alumina and spinel.

For special fields like ironmaking or foundry we have developed SiC-containing material



Figure 3: Cast of the free flow slurry

Similarly for aluminium application we have developed corrosion resistant slurry containing an anti-wetting agent.

Molten salts, mainly chlorides and fluorides are used during processing. These salts are enabling a good protection from oxidation and removing inclusions. Unfortunately they are presenting some collateral damage to the refractories favorizing the corrosion. Our self-flowing castable is particularly well adapted to this environment.

Furthermore the corundum build-up is deeply reduced through the addition of a dedicated ant-wetting agent.

Our standard range is covering the major request, but this can be customized in regard to local specificities. This was lastly the case in particular for the incineration industry where we proposed some slurry with a high amount of SiC (figure 4).



Figure 4: SiC-containing block

If the slurry is essential for the good properties at high temperature of the material, the choice of steel fibre is also fundamental on 2 aspects:

- The price: as this is covering 30 wt% of material and steel fibres are wide more expensive than the refractory material (sometimes three times more)
- The proper choice of the fibre is calibrating the operating temperature of the material in a steady state.

However it is not so simple to choose the right steel fibre as for example only after their chemical composition.

The type of surface is playing an important role in the composite, as for e.g. the melt extracted are presenting a rougher surface as the slit material. The rheology of the slurry has to be optimized and only the right type of steel fibre will

allow penetrating homogeny straight pieces sometimes on a height close two meters.

Filling with a slurry a frame constituted of up to 30 weight percent of fibre requires special fibres surface.

#### a. Main Properties

One of the most important properties claimed for the new precast system is the top abrasion resistance.

In a study we have compared some of our best actual material, installed by cast (A) or shotcreting (B) used for abrasion with the equivalent composite material (C).

The abrasion resistance after ASTM C-704 from our reference is under 5 respectively 6 cm<sup>3</sup>, a quite very performant number! The new precast equivalent material is 20% more resistant to abrasion as the cast vibrated best material! (Table 1)

Material		Installation	Erosion loss [cm <sup>3</sup> ]	Bulk density [t/m <sup>3</sup> ]
A	Type	cast	<5	2.55
B	LC castable High alumina + SiC	Shotcrete	<6	2.4
		LC castable High alumina + SiC	<6	2.4
C	New system	Precast	<4	2.96

Table 1: Abrasion resistance after ASTM C-704

Next important test concerns the thermal shock resistance. Referring to ISO-norm we considered the result of the CMoR after 5 cycles (Figure 5).

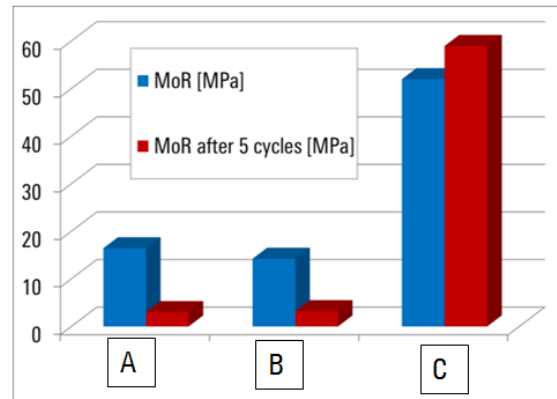


Figure 5: Thermal shock resistance

Furthermore the Young modulus is slightly lower than for the castables (5 times lower) enabling a much better resistance to crack initiation as defined in the Hasselman's R-criteria.

Material	Temperature [°C]	PLC [%]
Slurry:	1000	0.08
Tab-Alumina - Spinel and steel fibre from Type H	1200	0.32
	1400	1.49
	1600	1.5

Table 2: Refractoriness of the best composite

The highest refractoriness obtained with the top slurry and upper grade of steel fibre enables performance over 1500°C under steady and cyclic operation (Table 2)

### Some Applications

The aluminium industry is a field particularly dedicated due to the even low temperature of processing (Figure 6.). The maximum of temperature is always under 1200°C!

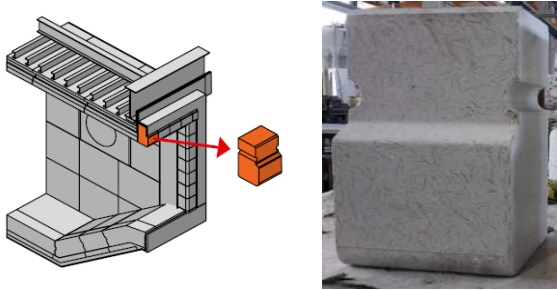


Figure 6: Block door in aluminium furnace

In steelmaking the number of possible applications is huge, starting in ironmaking with the shield for the protection of the torpedo ladle, the iron ladle mouth part. In steelmaking the upper ring of the steel ladle can reach more than four campaigns with such blocks. Ladle cover or preheating covers can be designed for complementary achieve a high insulation and long life close to 1 year without any repair. The outer ring has to be fixed with the new system blocks, avoiding the wear in contact to the steel ladle upper part and the inner part gunned or cast with an insulating castable (Figure 7).



Figure 7: Left: upper block for steel ladle  
Right: Ladle preheater cover

### REPAIR SPRAY CONCEPT

#### Concept Introduction

The new spray line of products has been designed in the focus of the quick repair by cold or hot in the foundry. These products are cement-containing and can be applied with a simple peristaltic pump by gunning under very low pressure (see Figure 8).

#### Main Properties

Some of the major products physical and chemical properties have been given exemplary in the following table 3.

Main raw materials for the basis formula are possible from the chamotte up to the top grade of the alumina system

### Some applications



Figure 8: Peristaltic pump

NEW SPRAY Range	D	E	F	G
Application	ferrous	aluminium	ferrous	ferrous
Max Temperature	°C 1450	1250	1700	1700
Bulk density	t/m <sup>3</sup> 2.2	2.5	2.55	2.65
Al <sub>2</sub> O <sub>3</sub>	% >50	>64	>72	>88
MgO	% -	-	-	<6
CCS at max temperature	MPa 40	30	40	45
PLC at max temperature	% +0.4	+0.2	+0.3	+0.3

Table 3: Some typical spray material properties

Following example (figure. 9) shows some repair of a ladle. This operation allows saving time as the original repair done in 1 day was realized in less than 2 hours. This solution is now very popular for the foundry ladle repair.



Fig.9: Ladle repair with the G- product

Other possibility is the repair by cold of the EAF tap hole and by hot of the roof or the runner (figure 10, 11).

Typical wear for the roof is located in the centre of the electrodes triangle but also in case of additions around the hole of addition due to high abrasion. Next point of wear is around the hole for fume exhausting. In this area the wear is very intensive due to high hot abrasion and high temperature.

Next critical area to be prolonged as it is sometimes a bottleneck in the campaign of the furnace is the tap hole and following runner area.

Starting with the inner part of the tap hole where the repair compensate the high erosion due to the vortex at this level



Fig.10: Repair of the EAF cover with the B-product

and following high hot abrasion in cone-form at the entrance of the tap hole (upper photo from Figure 14).



Figure.11: Cold and hot repair in an EAF

The runner shows a typical V-wear profile during the campaign. Furthermore the mechanical cleaning of the runner can also induce some weaknesses. All these weak points can be overpassed by a hot intermediate repair (lower photo in Figure 11).

## CONCLUSION

The need for high productivity and high reliability in the industry is the main challenge for the user but this is our

mission as supplier to innovate and to differentiate from a simple garage production.

Thanks our R&D facilities we could propose at 1<sup>st</sup> the brand new precast concept allowing a response to high thermal shock, abrasion and mechanical stress at very high temperature, without missing a good corrosion resistance.

Prolonging the life of the vessels can be also essential without losing too much time during the intermediate repair. Our new spray technology is the perfect solution for the foundry sector allowing a repair by cold or by hot without complicated and expensive equipment.

## REFERENCES

<sup>1</sup> OECD report, April 18th 2016, Brussels, Excess Capacity and Structure Adjustment in the Steel Sector.

<sup>2</sup> Llyod E. Hackman, David R. Lankard, „Metal fiber mat reinforced composites“, Patent WO 1993018912 A1, from March 1992.