Nanobond – the New Cement Free Castable for Quick Lining and Fast Repairing*

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During the last decades monolithic refractories have been improved and further developed. Consequently, the amount of monolithic products on the world wide refractory market increases year by year. Nevertheless, one main drawback by using such materials is the long and complex curing and drying phase of cement bonded castables. Besides cooling down of the kiln and its repair, the heating-up procedure takes the longest time of the shutdown. In order to reduce such expensive downtimes *Refratechnik* developed a unique and novel product series: Nanobond. These materials can be heated up very fast and very safe. This paper argues theoretical aspects, as well as it reports on the mechanical and physical properties. This work is complemented with different examples and a practical experience report in order to demonstrate the potential.

1 Theoretical aspects and laboratory results

Cement containing castables such as RCC, MCC, LCC or ULCC are considered standard in many refractory applications. Over the years a wide range of possible raw materials and practical installation methods have been developed. However, all of these cement bonded refractories possess one main important drawback: such materials are characterized by the hydration of the cement bonding. As a result the physical bonded and the hydraulic water has to be removed in a relatively complicated drying procedure. The hydraulic water specifically demands a very careful and cautious heating-up procedure. Most of the dreaded steam explosions can occur at a furnace temperature of approx. 250 °C [1]. To avoid such destructions, the heating-up of a new lined or repaired furnace can be very complex and slow. Depending on the furnace or the cast part a drying time of several days with long curing times are common. Besides cooling down the furnace and its repair, the heating-up procedure account the longest time of the shutdown. Additionally the cement bonding of usual castables is very often a weak point regarding the chemical wear of refractory materials. In order to solve such problems Refratechnik developed a unique, novel and patented product series: Nanobond. Nanobond is typically free of cement and water. It is a dry refractory mix that comes with a special liquid binder, which acts as a mixing and binding agent. By adjusting the amount of the binder the setting time of the castable can be controlled individually. In contrast to other available cement free castables this two-component-system is completely safe to use and represents no health hazard. In addition the absence of any acids means that no corrosion of the metallic anchors can take place. There are no restrictions regarding transport or usage at plant. The introduced Nanobond system is available for all type of alumina-based raw materials and has been tested in numerous different applications successfully. In addition to the mentioned castable and self-flow castable it is also available as a jet cast material. Tab. 1 pro-

Tab. 1 Comparison of the main properties of usual cement bonded castables and Nanobond

	Usual Cement Castables	Nanobond
Type	regular, medium, low cement or ultra-low cement castable	no cement castable
Mixing agent	water	special liquid binder
Variation of the setting time	usual additives	amount on liquid binder
Mechanical and physical properties	comparable	
Available raw materials	no technical restrictions: chamotte, bauxite, tabular alumina, andalusite, fused corundum etc.	
Shelf life	max. 6 months	max. 12 months

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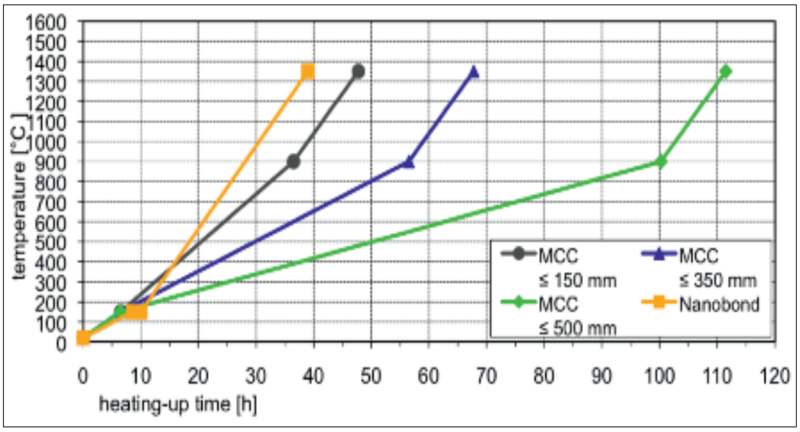


Fig. 1 **Heating-up procedure of different medium cement castables samples compared to Nanobond**

vides a short comparison of cement bonded castables and Nanobond castables.

The Nanobond binder technology is mainly based on colloidal silica. It is a colloidal dispersion of nano-sized silicon dioxide (SiO_2) particles. By drying the non-cross-linked or uncured sol a stable and cross linked gel is formed. After this gelation the binder system is temperature stable, insoluble in water and characterized by a very high mechanical strength.

Fig. 1 clearly shows the main advantage of the Nanobond product series. The initial heating-up procedure of typical medium cement castables is strongly depending on the size and the shape of the specimens, which is shown in black, blue and green curves. For larger samples or prefabricated parts the heating-up time is significantly longer (green curve). In the example shown the recommended heating-up time triples to ~110 h as the sample increases from 150 to 500 mm. For the shown Nanobond material (orange curve) the heating-up time is constant for specimens <500 mm : 42 h. In Tab. 2 below some highlights of conventional medium cement castables with that of Nanobond material are shown. The raw material base (corundum) and the installation method (casting, vibrating) are the same.

Aside from the obvious economic advantages of the fast and uncritical heating up procedure, the Nanobond materials possess another significant benefit for customers. After the initial heat-up the refractory lining is 100 % free of water. Consequently no hydrogen is delivered to the liquid metal. Especially in aluminium foundries the hydrogen pickup of the metal by the monolithic refractory lining is a serious problem. Therefore, by choosing the novel Nanobond bonded materials the quality of sensitive or demanding alloys and casted parts can be improved.

Tab. 2 **Main properties of a medium cement castables compared to Nanobond castables**

	Medium Cement Castable	Nanobond
Main raw material	corundum	
Installation method	casting, vibrating	
Bonding system	hydraulic	inorganic, chemic
Mixing liquid	water	special liquid binder
Apparent porosity [%]	22	15
Cold crushing strength [N/mm²] After curing at 110 °C 500 °C 800–1500 °C	 110 110 110	 40 50 100
Cold modulus of rupture [N/mm²] After curing at 110 °C 500 °C 800–1500 °C 1200 °C 2100 °C	 10 10 10 10 15	 5 7 15 20 20

2 Nanobond castables as covering material for the upper free board of steel ladles

The top layer of steel ladle linings is very often a problematic area regarding the lifetime of the whole ladle. For most of the steel plants MgO-C bricks with low carbon contents are showing good results due to good mechanical properties and a fair oxidation resistance. But some customers with high demands and very high loads in this upper area of the ladle report on massive problems. Especially during mechanical cleaning the ladle the edge covering is damaged and several bricks of the ladle lining can fall out. As a result the ladle has to be repaired or break out. Different trials with special MgO-C, AMC and sintered MgO based bricks revealed only a minor improvement. Conventional cement based castables showed better results but their application with a long heating-up procedure (>24 h) is unpractical and inefficient. In order to combine the advantages of a brick lining (easy heat-up procedure) and a monolithic covering of the upper free board (good life time) trials with a high alumina based Nanobond material were carried out. The installation method is arguably identical to usual cement bonded castables. Instead of water a special liquid binder was used as mixing agent. The highlight of this installation is the very fast heat-up procedure. In contrast to conventional castables the drying procedure can be started right after the installation; no special curing time or a free drying is needed. As a result of the new castable these partially cast ladles were heated up like any other brick lined ladles (12 h to 1200 °C). Fig. 2 a–e are showing the upper free board of a ladle casted with Nanobond during installation and after 16 and 65 batches. Even after 65 batches the upper free board covering is still stable with a remaining thickness of ~50 %.

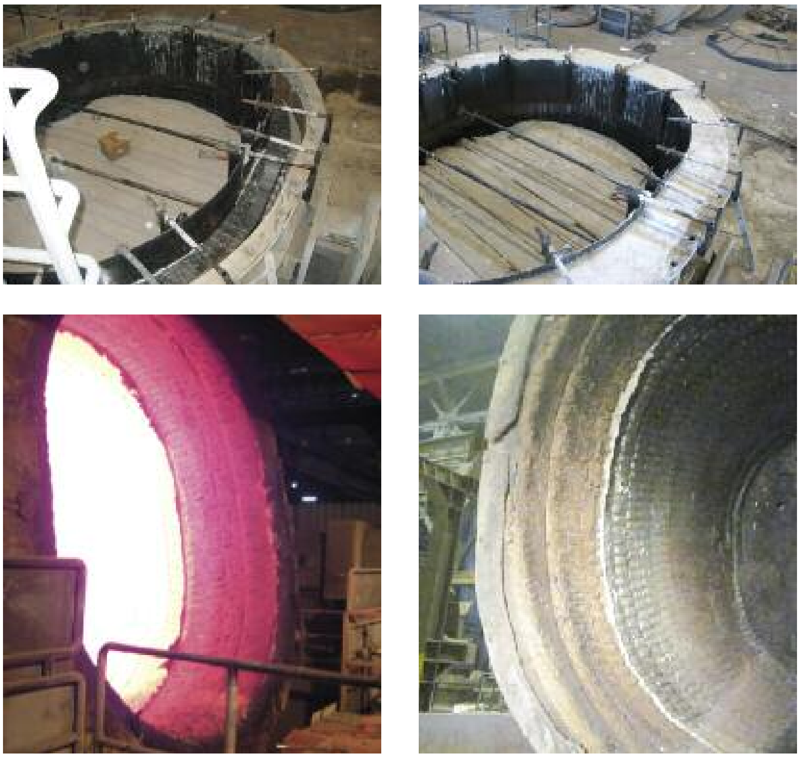
3 Hot repair of blast furnaces (robotic jetcasting)

The refractory lining of a blast furnace shaft normally consists of alumina bricks. Repairs are either done by replacing the brickwork or by applying conventional dry gunning concretes. Pre-burnt bricks of course guarantee highest quality, but may be very time-consuming. Hence, it may take several weeks – depending on the blast furnace dimensions – to install a completely new refractory lining in the blast furnace shaft. Looking for a faster installation method, conventional dry gunning concretes were applied at first. The properties of which did not meet the high technical standard. Due to their high rebound rates and the low physical properties, the dry gunites were only suitable for use as repair materials. Even the development of physically improved medium cement gunning mixes – as an alternative to the used refractory bricks – could not meet the blast furnace operators' high demands. However, due to their enormous time saving potential dry gunites have become the standard solution worldwide for intermediate repairs and start-up protection linings in blast furnace shafts. Based on the novel Nanobond bonding system a jetcasting material was developed which combines the advantages of a brick and a castable or gunning lining. The following Fig. 3 a–b showing some impressions from the repairing of the blast furnace and a comparison of the timetable. Jetcasting enables a quick refractory installation with a minimum of material loss at the same time. According to Refratechnik's experience, the rebound rate in case of a remote-controlled installation by means of an automatic shooter is less than 2 %, in case of manually applied mixes on a working platform it is even less than 1 %.

4 Nanobond lining in an aluminium melting furnace (practical experience report from TRIMET Aluminum AG)

To demonstrate the potential and to highlight some practical experience a report of the repair of a melting furnace lining at *TRIMET ALUMINIUM AG* (Essen/DE) is discussed.

In the moment of writing this paper different Nanobond materials are already widely used in the aluminium industry. Especially for the repairing and relining of aluminum melting furnaces, such castables provide many advantages for the customer. For the given example a service repair of the melting furnace no. 6 at TRIMET was necessary after only four years of production. The furnace showed a premature wear in the bottom and the ramp. This choice of using Nanobond materials allowed the facility to shorten the stoppage and to recommence to production as soon as possible. After cooling down and breaking out, the furnace was relined with the novel castable. Beside the usage of the special liquid binder the procedure of mix-



Figs. 2 a–e **Steel ladle before and after casting the upper free board with Nanobond (top) and after 16 (lower left) and after 65 batches (lower right)**

Figs. 3 a–b **Hot robotic jetcasting (l.) and cold manual jetcasting from working platform (r.)**

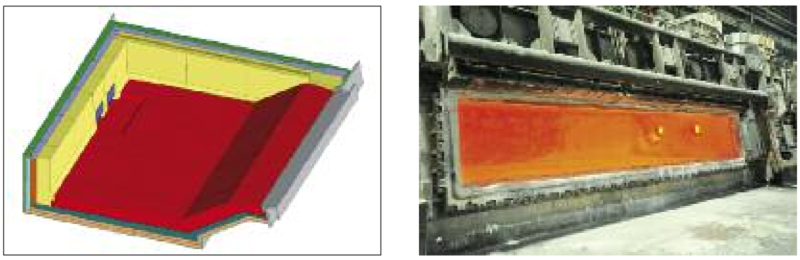


Fig. 4 a–b **Melting furnace no. 6 at TRIMET (Essen): relined areas of the aluminium melting furnace (red colour) and a view into the furnace after heating up and during sintering with liquid metal**

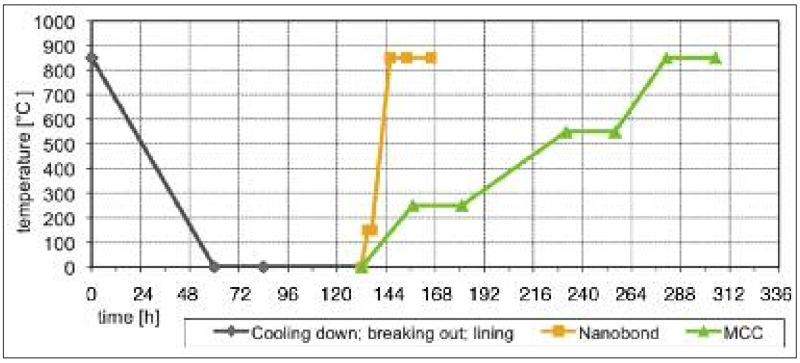


Fig. 5 **Total time schedule for relining the aluminium melting furnace: Nanobond and medium cement castable (MCC)**

ing, casting and vibrating is comparable to any other typical refractory castables. The setting time of the castable was controlled by the amount of the liquid binder. No special additives were needed to react on different ambient temperatures. Due to the perfect adhesive and bonding properties to the existing refractory lining no special pretreatment was required. In total ~20 t of the corundum based Nanobond material was mixed and installed into the furnace. Due to its perfect condition no repair of the safety lining was necessary. After installation and a short drying time at ambient temperature the heating-up procedure was started. After only 22 h of heating-up and 12 h of sintering with liquid metal at 850 °C the furnace was ready to return to production. In total the complete relining of the bottom and the ramp took only 1 week.

The chart diagram in Fig. 5 shows the total timeline of the described relining of the melting furnace. The usual relining with common medium cement castables (MCC) is shown for comparative purposes (green curve). Therefore it is evident that by using Nanobond the total repairing time was significantly shorter. Compared to a lining with an usual medium cement castable the facility can win 5–6 days of production (orange curve). Ultimately for an aluminum producer like TRIMET this means an additional production of ~15 batches. Besides the shorter curing time and the increased reproduction ability, the easier heating up procedure is a mayor benefit to the Nanobond user. The drawn-out heating-up procedure of cement bonded castables requires special equipment. To maintain the essential low temperature increase external heating equipment is needed. In total the heating device including measurement technique and manpower can cause cost of in the region of USD 30 000. In contrast the Nanobond material does not need any special heating equipment. It can be simply cured with the furnace burners.

5 Conclusion

Nanobond is a new product series especially developed for a fast, save and secure relining of different furnaces and applications. Due to the absence of water and the cement free bonding system the installed lining can be heated up 70 % quicker than common medium cement castables. In addition to a straight forward curing process, Nanobond exhibits the following technical and economic benefits:

- long shelf time
- 100 % safe and harmless liquid binder
- adjustable setting times
- perfect adhesion and bonding on existing and even hot refractory linings
- no risk of introducing hydrogen into the process
- is available as casting, gunning, jet-casting and self-flowing material
- can be offered in a wide range of raw materials, such as chamotte, mullite, bauxite and tabular alumina.

Reference

[1] Routschka, G.; Wuthnow, H.: Pocket manual refractory materials. 3rd Ed., Essen 2008