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NANOBOND - THE NEW CEMENT FREE CASTABLE FOR QUICK LINING AND FAST REPAIRING[1]

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Abstract

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. Anyhow, 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 talks about the theoretical aspects, as well as the mechanical and physical properties and especially practical experience of using Nanobond. To demonstrate the potential different reports and examples are given.

Key words: Cement free castables; Monolithic refractories; Repairing and installation.

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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 were 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 casted 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. 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. Table 1 provides a short comparison of cement bonded castables and Nanobond castables. As a result of the cement free bonding system the shelf life doubles to maximum 12 months.

Table 1: Comparison of the main properties of usual cement bonded castables and Nanobond

	Usual cement bonded 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

The Nanobond binder technology is mainly based on colloidal silica. It is a colloidal dispersion of nano-sized Silicon Dioxide (SiO_2) particles. The binders systems hardens just by drying the installed castable. 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. In comparison to cement bonded castables no setting time to

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form the different hydraulic phases is needed. The drying procedure can be started right after installation.
It is a well-known fact that the initial heating-up procedure of typical medium cement castables is strongly depending on the size and the shape of the specimens. For larger samples or prefabricated parts the heating-up time is significantly longer. In the example shown in figure 1 the recommended heating-up time triples to ~110 h as the sample increases from 150 to 500 mm. For the shown Nanobond material the heating-up time is constant for specimens < 500 mm: 42 h.

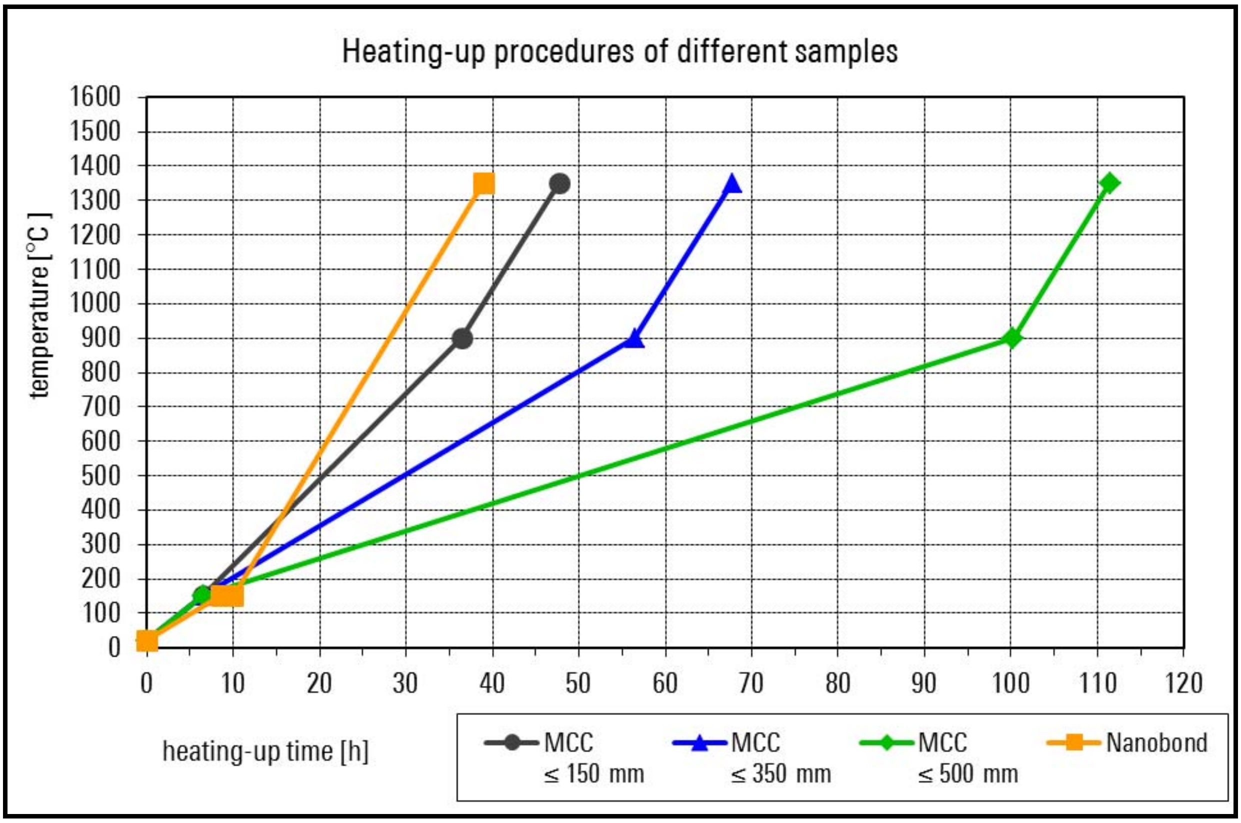

Figure 1: Heating-up procedure of different medium cement castables samples compared to Nanobond.

Figure 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. For larger samples or prefabricated parts the heating-up time is significantly longer. 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 the heating-up time is constant for specimens < 500 mm: 42 h.
One main reason for this very easy, fast and secure heating-up behavior of the Nanobond material is that these novel castables are almost free of any water at curing temperatures >110°C. As no physical or chemical water has to be removed anymore, there is no risk of any steam caused explosions. Figure 2 shows the mass loss of different cement bonded castables compared to the new cement free one. As seen the total mass loss (in fact the water loss) and the needed curing temperature is depending on the cement content of the castables. The higher the cement content of the castable is the more water has to be removed during the drying process. For the shown example the water in the Nanobond sample is only needed for mixing

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purposes. As no water is trapped in any hydraulic phases it can be removed very easy and very fast.

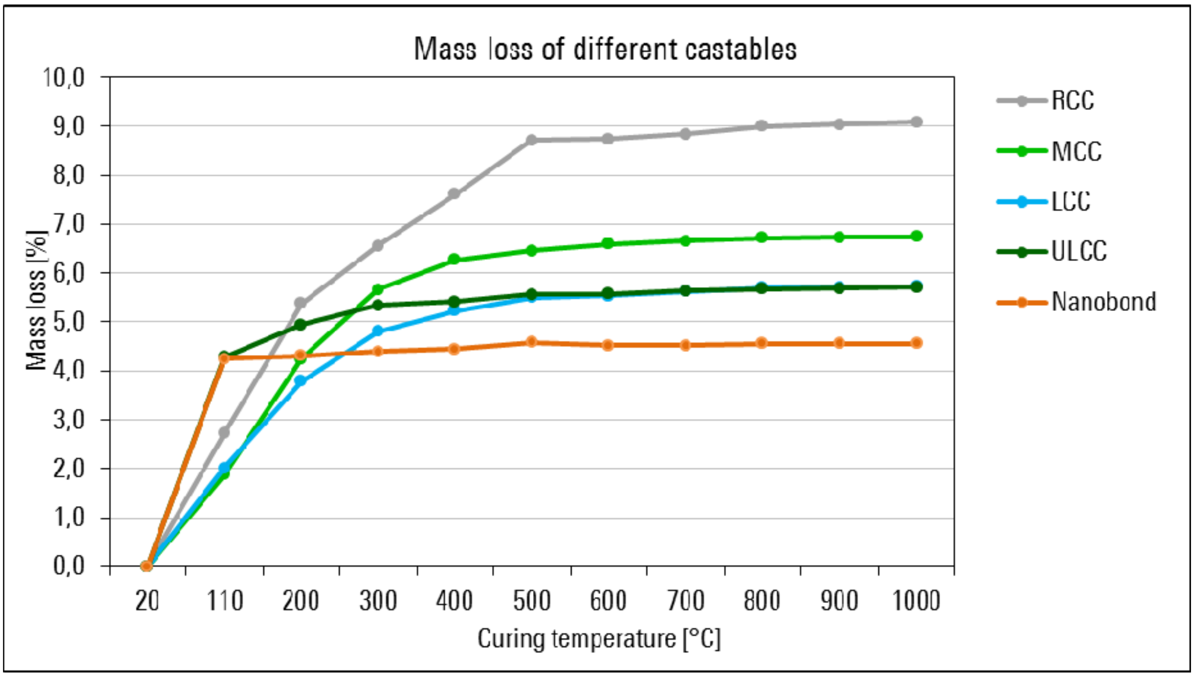

Figure 2: Mass loss of different cement bonded castables compared to Nanobond.

In the Table 2 below some highlights and a short summary of different properties of conventional medium cement castables with that of Nanobond material are shown. The raw material base (corundum) and the installation method (casting and vibrating) for preparing the samples are the same. After having a first look at the data there might be an issue with the crushing and bending strength of the Nanobond at lower curing temperatures. But in fact, usual preheating procedures exceed always 800°C. Beyond this temperature the Nanobond material overruns the strength of the shown medium cement castable.

Table 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	110	40
500°C	110	50
800 – 1500°C	110	120
Cold modulus of rupture [N/mm²]		
After curing at 110°C	10	5
500°C	10	7
800°C	10	15
1200°C	10	20
1500°C	15	20

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2 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 requirements. For their high rebound rates and the simple 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 world-wide 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 Figure 3 shows some impressions from the repairing of the blast furnace. Figure 4 gives a time line comparison of different installation methods to repair blast furnace shafts. It is evident that by using the Jetcasting Nanobond method the total repairing time is significantly shorter. Compared to a lining with bricks or an LC Jetcasting material the facility can win at least 4 days of production. 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%.

Figure 3: Hot robotic Jetcasting (left) and cold manual Jetcasting from working platform (right).

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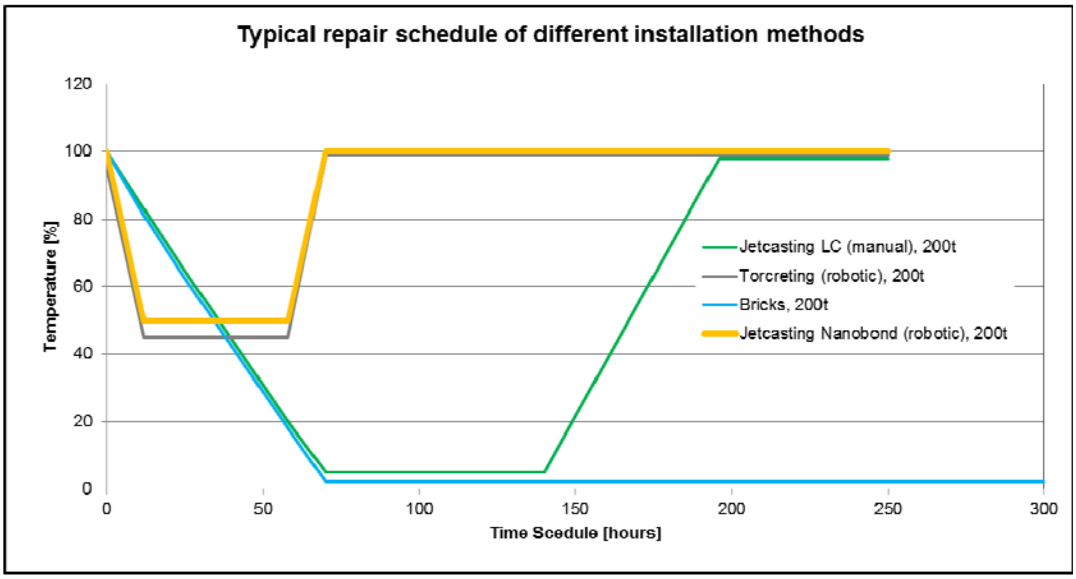

Figure 4: Repair schedule of different installation methods for blast furnace linings.

3 NANOBOND CASTABLES AS EDGE COVERING MATERIAL FOR IRON AND STEEL LADLES

The top layer of iron and steel ladle linings is very often a problematic area regarding the life time of the whole ladle. For most of the steel plants burnt alumina bricks (iron ladles) or MgO-C bricks with low carbon contents (steel ladles) are showing good results due to good mechanical properties. But some customers with high demands and very high loads in this upper area of the ladles report on massive problems. Especially during cleaning the ladles 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 or Al_2O_3-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 edge covering (good life time) trials with a high alumina based Nanobond material were carried out. The installation method is more or less 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 casted ladles were heated up like any other brick lined ladles.


Figure 5: Nanobond Jetcasting of the edge covering of iron ladles.

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Figure 5 is showing a Nanobond Jetcasting installation in an iron ladle ladle. Beside the Jetcasting installation method Refratechnik has a wide experience in casting of ladles. The Figure 6 shows a steel ladle with a Nanobond casted edge covering during installation and after 16 heats. Even after 16 batches the covering is in a perfect condition and after 65 batches still stable with a remaining thickness of ~50%.

Figure 6: Steel ladle before and after casting the edge covering with Nanobond (top) and after 16 (lower left) and after 65 batches (lower right).

By using the Nanobond materials in the upper ladle area the whole ladle lining will be stabilized. The risk of fallen out bricks is minimized and the life time of the iron and steel ladles can be increased significantly.

4 CONCLUSIONS

Nanobond is a new product series especially developed for a fast, secure and save lining and 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 the straight forward curing process, Nanobond exhibits the following technical and economic benefits:

- long shelf time;
- 100% safe and harmless liquid binder and adjustable setting times;
- perfect adhesion and bonding on existing and even hot refractory linings;
- very good physical and mechanical properties;
- no risk of explosions due to remaining water in insufficient heated-up areas.

REFERENCE

1 G. Routschka, H. Wuthnow: Pocket Manual Refractory Materials. 3rd Edition 2008, Vulkan-Verlag Essen, Germany.