

A New Non-Regulated Fibre for Use in Iron and Steel as 1430 °C RCF Substitute

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Throughout the last few decades RCF (Refractory Ceramic Fibre) also known as ASW (Alumino Silicate Wool) has been considered the state-of-the-art material for lining reheating kilns for steel, such as forging shuttle kilns. This is largely due to its excellent properties, which include low thermal conductivity and thermal mass, low density and ease of installation, providing a highly adaptable insulation system.

Due to proven concerns with asbestos, fibrous materials were placed under scrutiny and RCF was given high priority as it was used in many applications asbestos had been used in. After numerous studies, RCF was classified as a category 1b carcinogen in Europe and is considered a substance of very high concern (SVHC) under REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals).

With the first generation of low biopersistent AES (alkaline earth silicate) fibre types, a strong alternative was introduced to the market in the 1990s. However it was found that both AES had low temperature use limits (initially approximately 1000 °C) and their resistance to pollutants, especially with alkalis, was poor, limiting potential usage in many applications especially for the Iron and Steel industry.

Further improvements to AES fibres have been introduced to the market, improving their use limit to 1150 °C, but all AES fibres still have the problem of poor pollution resistance. Morgan's Thermal Ceramics Product Division, has continued to develop low biopersistent fibre insulation and is now extending its product range with a new high temperature fibre called Superwool® XT. The latter has a classification temperature of 1450 °C and comparative if not better pollution resistance than RCF. Superwool® XT was put to the test in a field trial using stack modules in shuttle kilns operating at 1280 °C, at Dillinger, Dillingen/Saar in Germany. Results showed that Superwool® XT demonstrated excellent performance in the harsh conditions found within this application.

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1 Introduction

As a category 1b carcinogen, falling under the scope of the Carcinogens and Mutagens Directive (2004/37/EC), RCF is now the subject of a proposal to tighten occupational exposure limits from 1 fibre/ml to 0,3 fibre/ml in the EU and remains listed as a substance of very high concern under REACH regulation (1907/2006/EC). Other countries also continue to review the regulation of the use of RCF, including Japan, Australia, South Korea and Brazil. These countries have either introduced or amended the regulation and control of RCF. For example, Japan has introduced a stringent workplace use policy, with users required to show compliance with a 0,3 fibres/ml occupational exposure limit, as well as providing additional amenities for worker hygiene, segregating work

areas for RCF use and instigating a worker health surveillance programme. These regulations increase pressure on multinational users of RCF to seek alternatives wherever possible.

Europe remains the only regulatory arena to provide a route of exoneration for man-made vitreous (silicate) fibres (MMVFs) containing more than 18 % alkaline earth oxide [1]. Using bioassays to demonstrate low bio-persistence and/or a lack of pathogenicity. Other countries use a weight of evidence in their assessment of MMVFs. All Superwool® fibres are exonerated from classification in Europe and unclassified throughout the rest of the world [2].

Superwool® XT has been developed as a low biopersistent fibre with 1450 °C classification temperature capable of replacing Cerachem®. It has less than 18 % alkali

metal oxide and has been tested and exonerated according to EU protocol ECB/TM/27 (rev 7). It is a potassium aluminosilicate based fibre with a melting point in excess of 1650 °C. Customer trials have been ongoing in many applications, which began in 2015. Extensive internal testing of fibres fired from 900–1400 °C has shown no crystalline silica forms even after almost one year at temperature. Its physical properties as a blanket and in module form are very similar to RCF and other AES fibres. Superwool® XT also has a unique behaviour that is beneficial, courtesy of its higher thermal expansion coefficient. It exhibits a small expansion on heating up to high temperatures that counteracts the irreversible shrinkage. Any shrinkage gaps between modules close up as the furnace heats. This means that there is no need to fill shrinkage gaps, as is the usual practice, in an RCF installation shortly after commissioning. Superwool® XT is also more resistant to many pollutants (especially alkalis) than RCF at high temperatures and this results in a more stable furnace lining over time. The latter is covered in more detail below.

2 Chemical resistance

Resistance to pollutants at high temperatures is a very important property for fibrous insulation, particularly since it is installed and used as modules or blanket. As such the insulation has a relatively high surface area compared to bricks and monolithics and is porous to infiltration of pollutants in the furnace atmosphere. This makes fibrous insulation particularly vulnerable to chemical attack. It is important to be able to assess how resistant any new fibre composition is to pollutants and to understand which pollutants are a problem prior to installing them in a customer application. A method based on one used by a Polycrystalline Wool (PCW) producer is used by Morgan's Thermal Products Division. In this test a blanket sample is immersed in water containing 3 % of the pollutant in the form of a water soluble salt (e.g. nitrate, chloride, carbonate). This is then dried at 110 °C, which results in a pollutant pick up of ~10 mass-%. This is the equivalent of ~2–10 years exposure in a heavily polluted furnace (Tab. 1). The blanket sample is then linear shrinkage tested at both the classification and continuous use temperature and the sample assessed

Tab. 1 Pollution resistance of Superwool® XT versus Cerachem® at 1300 °C/24 h

Pollutant	Superwool® XT	Cerachem®	Superwool® XT vs. Cerachem®
Pb	Green	Yellow	Superwool® XT better
Na	Yellow	Red	Superwool® XT better
Mn	Yellow	Red	Superwool® XT better
Ni	Green	Green	Same
Sn	Green	Green	Same
K	Yellow	Yellow	Same
Fe	Yellow	Yellow	Same
Cr	Yellow	Yellow	Same
Bi	Yellow	Yellow	Same
B	Red	Red	Same
Cu	Red	Red	Same
V	Red	Red	Same
P	Yellow	Green	Cerachem® better
Zn	Yellow	Green	Cerachem® better
Mo	Red	Green	Cerachem® better

via linear and thickness shrinkage (>4 % linear and/or >10 % thickness is poor) and crystallisation (assessed by ability to handle blanket without damaging it). A typical test result for sodium attack is demonstrated in Fig. 1 comparing Superwool® XT and Cerachem®. Superwool® XT was tested against a number of selected pollutants; including sodium, potassium, boron, iron and many more. Superwool® XT was found to be similar or better than Cerachem® with 12 of the 15 pollutants tested. Tab. 1 shows a comparison between Superwool® XT and Cerachem® for all the pollutants tested at 1300 °C, the top continuous use temperature of these two fibre types.

3 Industrial application

As mentioned, new EHS regulations drive operators and also installers to find alternatives for RCF [3]. Whilst IFB or insulating monolithics often do not meet the requirements of flexibility of the insulation in in-

dustrial applications, solutions implying the use of PCW's are often limited for economic reasons as the price of PCW is known to be in the range of 5–10 times higher than established RCF solutions. Regarding restricted furnace operation flexibility (duration of heating cycles, hot charging vs. thermal shock resistance of lining) in the past a combination of RCF with PCW was often used to compensate for RCF's temperature and pollutant-resilience constraints. These combined modules consisting of PCW as the front layer with an RCF backup, have been widely used instead of full PCW modules to keep costs on an acceptable level for the furnace operators. In light of EHS regulations today this is often not accepted because large quantities of RCF fibres are released into the environment during installation and wrecking.

Combined modules consisting of PCW and available AES fibre types have been found unsuitable due to chemical cross reaction

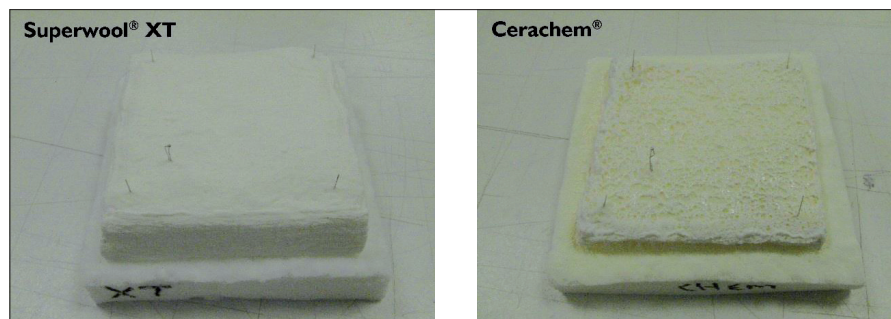


Fig. 1 Pollution testing with sodium at 1300 °C/24 h

between those materials, resulting in lining failures.

3.1 Industrial field trial: Dillinger

Dillinger, located in Dillingen/DE operates a mill for heavy plates. Annual tonnage is around 1,9 million, milled to customers' needs. Reheating is carried out in three pusher type furnaces lined with monolithic refractories. As Dillinger is also producing special grades and sizes, with pre-material being produced using the bottom pouring ingot casting route, three additional shuttle kilns are available for reheating ingots as well as slabs on high load events or during downtime of pusher furnaces. These kilns were built in the early 2000's over a period of several years. The original linings were made from Cerachem® stack modules with a monolithic gate and monolithic pre-formed burner blocks.

The furnaces are typically operated at a nominal temperature between 1250–1300 °C using blast furnace and coking gas as primary fuels. Hot charging of the furnaces is performed regularly. A cool down is only instigated for maintenance reasons, every few weeks when required.

Charging of the furnaces, as well as the roller path, roughing stand and pusher type furnaces nearby, result in a high mechanical stress for the lining.

A severe issue is the presence of multiple impurities in the atmospheres of these furnaces, particularly alkalis (sodium and potassium) but also iron and chromium which come from residual casting powders stuck to the ingots being reheated as well as the steel itself. These impurities end up in the

hot face of the lining and result in increased shrinkage over time and hardening/densification of the module front face. This is then subjected to thermal shock, cracking and spalling. Tab. 2 compares the chemical composition of a "typical as delivered" module versus one exposed to four years of use in a shuttle kiln at Dillinger. In Fig. 2, the appearance of the lining after several years of service is shown. It is apparent that major repairs have been carried out, including module replacement and gap filling. The high shrinkage resulting in open gaps also causes the module anchor system to become unstable as the latter become exposed to higher temperatures than they are designed for.

3.1.1 Initial feasibility test in side wall of shuttle kiln No. 2

Dillinger was one of the first customers chosen to test Superwool® XT in their furnaces. It was agreed to start with a small section of the wall in shuttle kiln No. 2, where the risk of any problems resulting in long downtime issues was considered to be low.

Two rows of five Superwool® XT stack modules with type T anchors were installed with 1 Cerachem® stack module with type Y anchor finishing each row for comparison of results.

Fig. 3 demonstrates that due to high shrinkage of the surrounding existing lining, it was necessary to fill the large shrinkage gaps, with several folds made from PCW blanket. In between the two rows, one fold of PCW blanket was placed. Shrinkage of modules was found to be approximately 1,3 % after about two months of firing. On

Tab. 2 Chemical composition of Cerachem®

Weight [%]	Typical	After 4 Years
Na ₂ O	–	7,3
Al ₂ O ₃	36,3	16,2
SiO ₂	49,3	54
SO ₃	–	1,8
K ₂ O	–	1,4
Fe ₂ O ₃	–	4,1
ZrO ₂	14,8	15,2

further inspection, after six months of firing, it was determined that Superwool® XT shrinkage had increased to 4 % whilst Cerachem® had shown a shrinkage of 5,7 % at this stage. A further notable difference in the appearance became obvious at this stage: in Fig. 4 the surface of both materials is shown. Whilst the surface of Cerachem® had hardened significantly, with large cracks forming on the surface, the appearance of Superwool® XT was quite different, showing a surface that remained soft and partly resilient, with no surface shrinkage cracks. It was also clear that Superwool® XT was not absorbing large levels of pollutants from the furnace atmosphere and the module colour remained a light grey from minor iron pick up. This is unlike the Cerachem® modules which rapidly became dark brown in colour and eventually went black like the rest of the Cerachem® modules in the furnace lining. In Fig. 5 the appearance of the field at this state is shown. Marked damage is due to samples being removed for laboratory testing purposes and does not indicate poor performance of any of the materials under test.



Fig. 2 Typical appearance of lining after several years of operation, here shuttle kiln No. 1

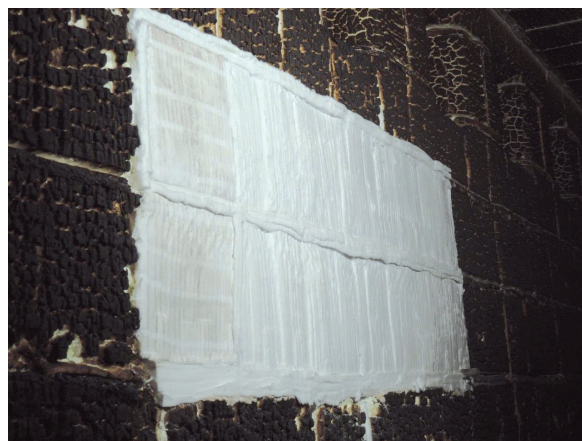


Fig. 3 Finished test-field lined with Superwool® XT stack modules

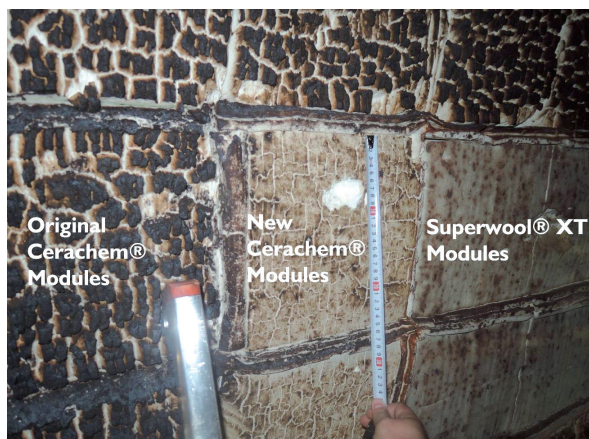


Fig. 4 Surface of Cerachem® (l.) and Superwool® XT (r.) after 6 months in service

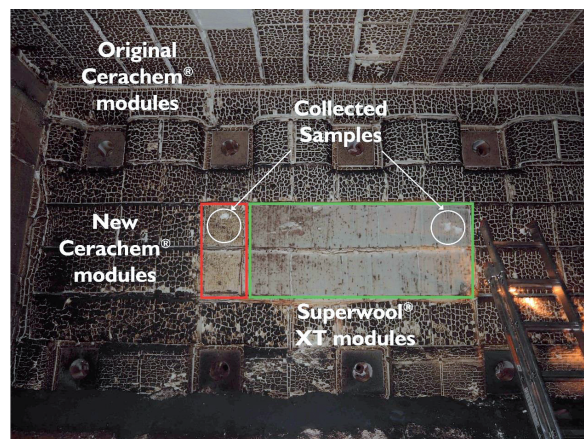


Fig. 5 Overall appearance after six months in service

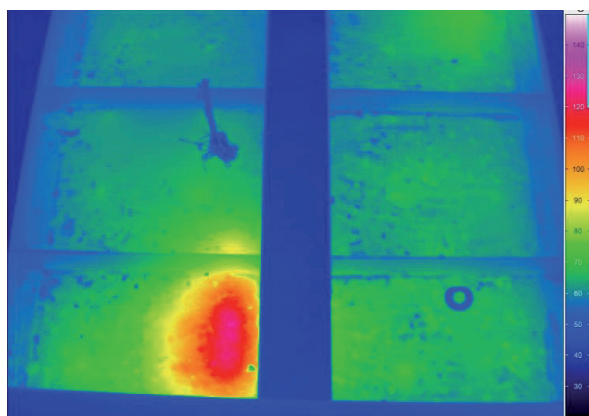


Fig. 6 Infra-red thermography of roof of shuttle kiln No. 3

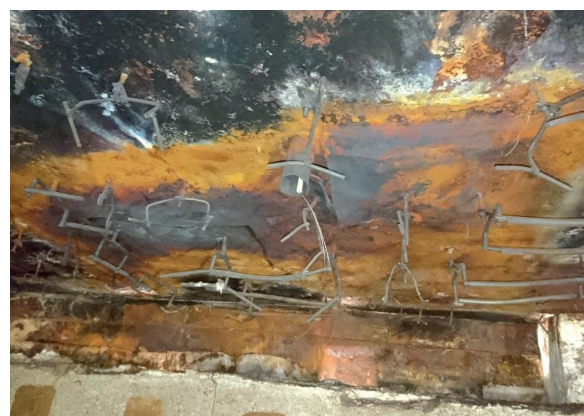


Fig. 7 Example of damaged steel shell which made part replacement necessary

3.1.2 Installation of half of the roof of shuttle kiln No. 3 at Dillinger

Based on the positive experience when installing Superwool® XT in the side wall of shuttle kiln No. 2, Dillinger mill operations decided to reline half of the roof of shuttle kiln No. 3 with the newly developed Superwool® XT.

The old lining was wrecked, bagged up and disposed of as hazardous waste – something which becomes increasingly important to take into cost considerations today. Due to RCF's carcinogen status, special provisions have to be adopted, e.g. cover of the entire furnace for installation and wrecking work, to prevent RCF fibres entering the surrounding workplace. Specialist disposal is required for both the old lining and any protective clothing used each day. The creation of black and white areas for involved personnel may also be necessary to prevent crossover of material to the general workplace. This can easily cost an organisation

several thousand Euros and was not previously a consideration of the cost of ownership of an RCF lined furnace; but certainly needs to be factored in now. Due to the high shrinkage of the Cerachem® modules resulting in open gaps between the modules, even when the furnace was hot, the steel shell had gradually become damaged and replacement was necessary in many areas. The roof is usually the hottest area of the furnace and most susceptible to thermal damage. Hotspots were found using a thermal vision scan of the furnace roof and an example is shown in Fig. 6. The damage to the steel shell, is shown in Fig. 7.

The refractory insulation lining is constructed using a back-up of lower temperature classification board and blanket – 1 mm × 25 mm layer of blanket and board, with 250 mm thick stack modules made from Superwool® XT as the hot face lining. A single fold of PCW blanket is installed in between each row of modules to avoid open

gaps due to shrinkage. The furnace after relining before it went back into service is shown in Fig. 8.

At maximum temperature, the furnace shows distinct hot spots above the burners, as can be observed in Fig. 9.

After 6 months of service, first inspection of this second installation was possible. The new lining was in a good state and no additional gap filling has been required at any stage so far. This second Superwool® XT installation has now been working for 10 months. Fig. 10 highlights the good appearance of the roof after six months of service.

4 Conclusions and future outlook

Results presented here have shown that there is now a non-regulated high temperature fibre alternative to RCF, the latter's use being viewed as increasingly problematical due to environmental, health and safety issues. Dillinger has now decided, to switch



Fig. 8 Finished roof, Superwool® XT stack modules with PCW blanket fold in between



Fig. 9 Shuttle kiln No. 3 in service at 1280 °C

entirely to the new Superwool® XT grade, for the benefit of both the non-regulated status of this product and its superior chemical resistance and shrinkage performance, relative to RCF. The refractory maintenance department managers at Dillinger are

therefore very happy to present to their EHS department a working alternative that will reduce risk for the workers as well as costs for installation, wrecking and disposal. Further positive results have been obtained in other fields, such as the petrochemical



Fig. 10 Appearance after 6 months in service

industries, with successful trials in advanced stages at numerous reformers and crackers. Superwool® XT will help customers to meet the requirements of replacement regulations (e.g. European regulation 619: Substitute materials for aluminosilicate wool products).

Furthermore, the performance drop expected from fibres with low bio-persistence has not been observed in the applications under test so far. On the contrary, it was shown that the material is outperforming existing RCF solutions in environments with high pollutant levels.

References

- [1] Regulation (EC) No. 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures
- [2] Superwool products all full under harmonized classification and labelling entry written CLP under index number 650-016-00-02
- [3] Alexander, I.C.; Jubb, G.: Development of soluble high temperature fibre. *Glastechn. Ber.* **70** (1997) [12] 382–388