Etex Group

Fibrecement recycling - From the grave back to the cradle

This article describes a practical case that illustrates how different players in the construction industry can achieve improvements in sustainability by joining forces, namely a collaboration between Eternit and CBR to use Eternit's waste fibrecement products in CBR's clinker plant in Antoing, Belgium.

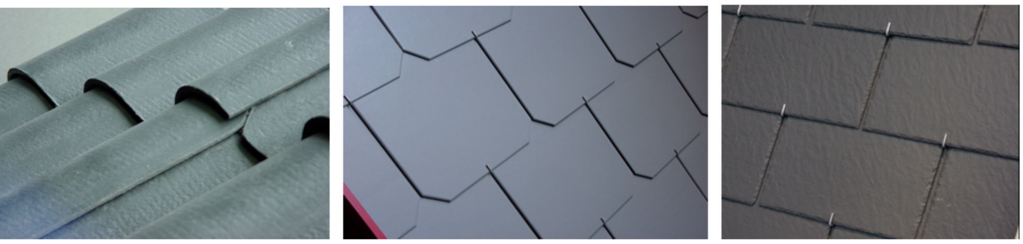
Above: Fibrecement being crushed into sizes, suitable for introduction to a clinker kiln.

The concept of sustainability has grown in importance within the construction industry in recent years, such that it now constitutes a core priority of most companies in the sector. Three important aspects of sustainability are i) sparing limited natural resources, ii) continuous reduction of non-recyclable waste and iii) recycling of products as valuable materials after their initial service lifetime. In line with these principles, fibrecement products can become a valuable component of the Portland clinker raw meal.

Fibrecement

Fibrecement is the generic term given to a variety of composite materials consisting of cement, inert and/or reactive mineral fillers and a cocktail of organic fibres.

Within the Etex Group, fibrecement products are produced by means of Hatschek technology, named after its Austrian inventor Ludwig Hatschek in the late 1800s. Initially it used asbestos fibres although these are obviously no longer used. Hatschek technology uses a set of rotating cylindrical sieves that dredge up fine layers of fibrecement from a watery slurry that contains all of the components of the fibrecement composite. Subsequently these primary layers are assembled into a fibrecement product of a predesignated thickness.



Below (Figure 1): Some examples of Hatschek technology based products. From left to right, corrugated sheets, smooth slate and textured slate.

Absence of aggregates

The sheet formation principle excludes the use of coarse mix ingredients such as coarse sand or gravel. In most Hatschek-technology-based fibrecement products, the matrix fraction comprises a fine flour typically consisting of CEM I cement, some carbonaceous filler such as limestone flour and possibly a fine pozzolan, for example condensed silica fume. The fibre fraction consists of process fibres, typically cellulose and re-inforcing fibres, typically PVA. The process fibres help the mixture to adhere to the sieves and ensure that the primary fibrecement layers have a sufficiently homogeneous texture.

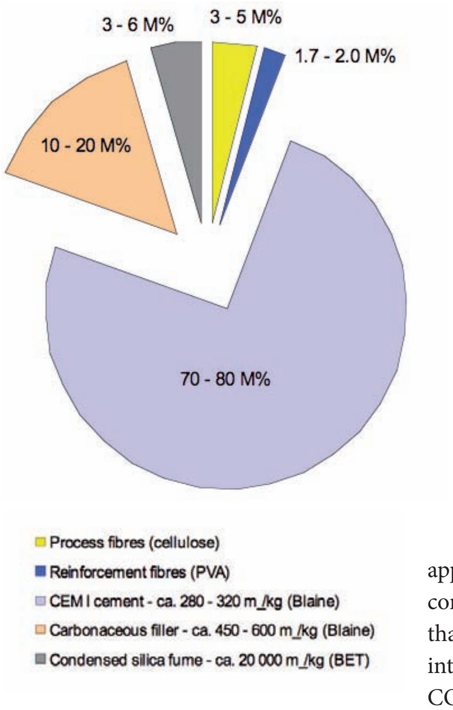
The absence of even fine aggregate fractions automatically requires significantly higher binder content than in the case of standard concrete or mortar mixtures. Depending on the product, the CEM I content of the initial formulation is 70–80% for air-cured fibrecement products. In order to ensure a sufficiently fast partial dehydration of the fresh fibrecement layers on the machine, it is important to keep the heat development in the stacks of hardening fibrecement sheets under control and to limit the dimensional changes upon wetting and drying of the hardened product. This is achieved by using CEM I cements which have reduced fineness, typically with specific surface areas between 280m^2/kg and 320m^2/kg (by Blaine's method). A typical initial dry compound composition of common air-cured fibrecement products is shown in Figure 2.

Low water/cement ratio

Taking into account the free water as well as the chemically bound water in the fibrecement product at the start of the curing, the initial water/cement-ratio is between 0.23 and 0.27 for post pressed slate and 0.45 – 0.50 for un-pressed corrugated sheet. A significant part of the water is captured by the cellulose fibres and thus is not readily available for hydration. Compared to typical concrete and mortar, therefore, most air-cured fibrecement products are characterised by a lower effective initial water/cement-ratio.

Changes upon hardening and ageing

The air-cured fibrecement product gains its mechanical performance characteristics by the hydration of the Portland cement and fine pozzolan if this is



Above (Figure 2): Typical initial dry composition of common air-cured fibrecement products.

present. These reactions may go on long after the product has been installed in its application. The degree to which the cement becomes hydrated during the product's lifetime will significantly vary depending on the local atmosphere.

Of more importance is how fibrecement products interact with atmospheric CO_2 through carbonation reactions. As with the hydration process, the way in which the carbonation reactions proceed depends on many factors such as the choice of raw materials, the curing conditions applied in the factory and exposure conditions. It is important to note that air-cured fibrecement products interact to a much greater extent with CO_2 than normal concrete and mortar products. This is because they are typically thin (4mm-6mm) and are significantly more porous due to the presence of cellulose fibres.

Table 1 gives ranges for the amount of water and CO_2 that are chemically bound in two fibrecement products as a result of hydration and carbonation reactions. For the products containing carbonaceous filler in their formulation, some of the bound CO_2 originates from the filler. The figures presented are based on the analysis of a large amount of data obtained from both accelerated and natural ageing studies, of up to 20 years duration. The values given cover a wide range of formulations because older slates and corrugated sheets either do not contain carbonaceous filler or contain less than the 15% of carbonaceous filler commonly used today.

Right (Table 1): Amount of chemically-bound water and carbon dioxide in slate and corrugated sheets. For each type of product initial (leaving the factory) and aged (end of life) values are given.

	Slate - Initial	Slate - Aged	Corrugated sheet - Iinitial	Corrugated Sheet - Aged
H_2O (%)	4 - 7	4 - 6	5 - 8	8 - 13
CO_2 (%)	1 - 7	4 - 12	2 - 10	6 - 20

Fibrecement in Portland clinker raw meal

Since hardened air-cured fibrecement mainly consists of partially carbonated Portland cement hydrates, residual anhydrous clinker and carbonaceous filler, the use of hardened fibrecement for the production of Portland clinker seems to be an obvious recycling solution. This is a suitable route irrespective of whether production, construction or demolition fibrecement waste is used.

Table 2 gives an approximate chemical analysis for ignited clinker raw mix.[2] It also shows the chemical composition of ignited aged fibrecement slate and ignited corrugated sheets as well as the initial formulation of these. The exact chemical composition of the cement, the carbonaceous filler and the fine pozzolan are of minor importance for the purposes of this article. Similarly, the ash residues of the fibres and the limited residues of acrylic paints that are occasionally applied to fibrecement products can be omitted.

Right (Table 2): Comparison of the chemical composition (by %) of ignited clinker raw meal and two fibrecement products. Also shown are the average initial components of the two fibrecement products.

	Clinker or ingnited clinker raw meal	Ignited slate	Ignited corrugated sheet
CaO	65 - 68	65.7	64.3
SiO_2	20 -23	22.5	24.2
Al_2O_3	4 -6	4.3	4.2
Fe_2O_3	2 - 4	3.1	3.0
MgO	1 - 5	1.6	1.5
SO_2	0.1 - 2	2.0	2.0
K_2O	0.1 -1	0.5	0.5
Na_2O	0.1 - 0.5	0.3	0.3

As all the chemical analysis data refer to ignited materials they are valid irrespective of the degree of hydration and carbonation of the fibrecement products. The data clearly illustrate that the fibrecement products are very suitable for recycling into the Portland clinker production process. The ageing of the products only influences the amount of hydration water and CO_2 that is liberated upon calcination.

Table 2 shows that even for aged fibrecement products the extent of that CO_2 generation is well below 35%, an approximate value reported for the calcination of a normal clinker raw meal.[1] This is a welcome advantage in terms of sustainability. Figure 3 illustrates an idealised closed-loop system.

Full-scale system

This type of system has been in operation since 2004, when the hardened air-cured fibrecement waste of Eternit's fibrecement plant at Kapelle-op-den-Bos, Belgium has been successfully recycled in CBR's clinker plant at Antoing, Belgium.

Pretreatment of the waste

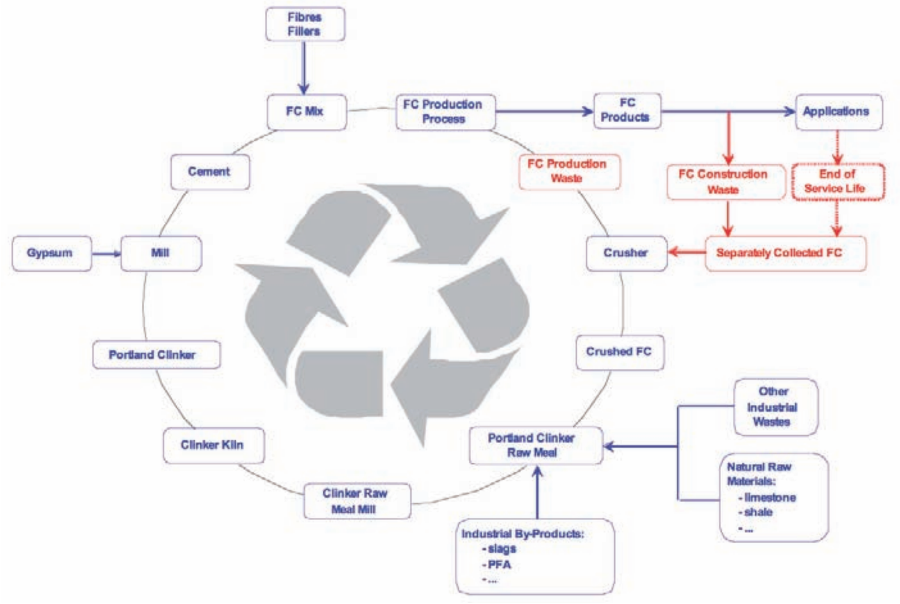
Although typically between 4mm and 6mm, fibrecement waste sheets can come in a range of sizes, as seen in Figure 5. Therefore the waste is crushed using a mobile crusher such that it is ready to be taken to the cement plant. The crusher concerns a standard impact crusher (MOBIREX MRB130ZH), as used for the size reduction of demolition waste. The feeding is done by means of a wheel loader or by crawler excavator. The crusher transforms the waste into a product with a diameter of not more than 50 mm. The fracture mechanics of the fibrecement waste clearly differ from that of the masonry and concrete waste. Indeed, because it is significantly softer and has higher internal cohesion brought about by the organic fibres, fibrecement is mauled in the crusher, rather than shattered. To avoid clogging of the crusher, it is best to crush fibrecement after renewal of the crusher's blades. The crusher is equipped with a final screening unit.

Recycling at the cement plant

At the time that Eternit proposed fibrecement waste to CBR as a secondary clinker raw meal component, CBR was already very experienced in the screening and the application of a wide variety of industrial by-products in its clinker and cement production processes. Three major parts can be highlighted in CBR's procedure: i) the technical specification of the proposed secondary raw material, ii) health and safety considerations and iii) legal implications of using the materials.

Chemical and mineralogical analysis of several samples of the fibrecement products were taken by the cement plant's lab to check results provided by Eternit's own lab. The extensive analysis programme also allowed confirmation of the homogeneity of the waste material and to verify that it fulfilled the requirements as a secondary material. Concerns were initially raised that cellulose and PVA fibres would cause problems inside raw meal grinding mills and dust filters, as well as having an adverse effect on the chemistry of the kiln's exhaust gases.

Below (Figure 3): Recycling of fibrecement waste into Portland clinker production - the obvious closed loop.



With regard to ensuring the safety of all employees, CBR tried to visualise the possible health risks for its employees and the protective measures that would be needed to neutralise such risks. All components of the fibrecement products, including the finished product's coating, were critically evaluated with a view to ensuring an hygienic and healthy working environment and the technical data sheets and material safety data sheets were assessed.

To enable it to use fibrecement as a secondary kiln material, CBR first had to get a European classification number which enabled it to inform the local authorities about its new ingredients. The next step consisted of getting permission for the execution of industrial trials with the waste.

Below (Figure 4): Fibrecement comes in a variety of sizes.

Industrial trials

The two problems expected at the industrial evaluation stage were i) possible reduction in clinker quantity and quality and ii) possible adverse effects on the composition of the flue gases.

Based on the chemical and mineralogical data of the fibrecement waste that were gathered in the preliminary study, CBR decided to conduct a series of production runs in which the amount of fibrecement was gradually increased from zero to 2% in 0.5% steps. Each step was only conducted after checking that no adverse effects had been observed during the preceding step.

The trials were executed as planned with no problems reported. It was concluded that i) the quality of the clinker still met all quality requirements, ii) the emissions to atmosphere at the kiln's chimney still met all emission limiting values stipulated in the exploitation permit and iii) the production process was smooth, without negative impact on reliability. Fears regarding blockages at the raw meal mill's air filter system were not realised. After taking into account the other kiln ingredients, technical, economical and logistical optimisation led to an applied fibrecement production waste dosage of 1.5%.

Full-scale operation

The fibrecement waste is supplied to the clinker plant on a continuous basis and upon arrival it is stored in a dedicated storage bunker. Regular checks confirm that the chemistry of the crushed fibrecement production waste can be considered constant. The waste is recuperated from the storage bunker by a wheel loader, and fed into a hopper from where it falls into the feeder of the raw clinker meal mill.

Conclusion

Safeguarding the future of the planet is the responsibility of each individual and by extension that of each association and company. Translation of this awareness into action is not always straightforward, but often involves a complex, multidisciplinary development process. The search for viable and sustainable methods for the recycling of a given production waste is just one illustration of this.

The article features an operation that fully fits with this type of approach. At present, the project is just at an intermediate stage. At the moment, the practicalities of the process have been proven, but the economics and 'ecologics' will have to be continually evaluated.

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References

1. *'The Cement Sustainability Initiative – Our agenda for action,'* World Business Council for Sustainable Development, July 2002.

2. Alsop, P.A. *'The Cement Plant Operations Handbook - Fifth Edition,'* October 2007.