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Out of aluminium waste

by Dr Yves C Zimmermann, Regain Services Pty Ltd, Australia

To reduce natural raw material use, the cement industry is increasingly considering byproducts from other industrial processes such as spent pot liners supplied by the aluminium industry. However, these often need to be refined to adapt them to the demands of the end-product.

Refined byproducts derived from the primary aluminium industry's spent pot lining (SPL) waste can become a valuable source of fluoride, alkali, alumina and carbon for clinker manufacturing. As a result, significant savings in terms of energy, CO_2 emissions, natural raw material consumption and ultimately production costs can be achieved.

For the cement industry to capture the full value of SPL materials, three main aspects have to be addressed:
1. The SPL refinement process should result in a material that is safe and easy to handle with a stable chemical composition.
2. The most suitable clinker manufacturing processes where value generation is possible should be identified.
3. Efficient logistics should be established to deliver the refined byproducts.

From waste to byproduct

The result can be a closed 'industrial ecosystem' where the toxic and heterogeneous waste of one industry (aluminium industry) becomes a specified, quality-controlled and safe byproduct, which is used as a valuable raw material for another industry (cement industry). The SPL generation per tonne of primary aluminium is about equal to the potential consumption of refined byproducts per tonne of Portland cement clinker (around 20kg each). But as worldwide clinker production (4bnt in 2013) is around 100 times greater than worldwide primary aluminium production (47Mt in 2013) then statistically, only one in a hundred cement plants is required to participate in this industrial ecosystem.

This global approach, based on the utilisation of refined byproducts at the optimum location is very different from local waste management solutions, where the use of heterogeneous, untreated or partially-treated SPL can result in value destruction in the cement plant. Such value destruction could be process upsets due to variable SPL composition fed to the kiln system and/or reduction of late cement strength development by higher soluble alkali levels. Disposal fees can compensate for these problems. Ultimately, the global perspective is one of opportunity cost. The 'waste' is in fact caused by not exploiting the value of SPL.

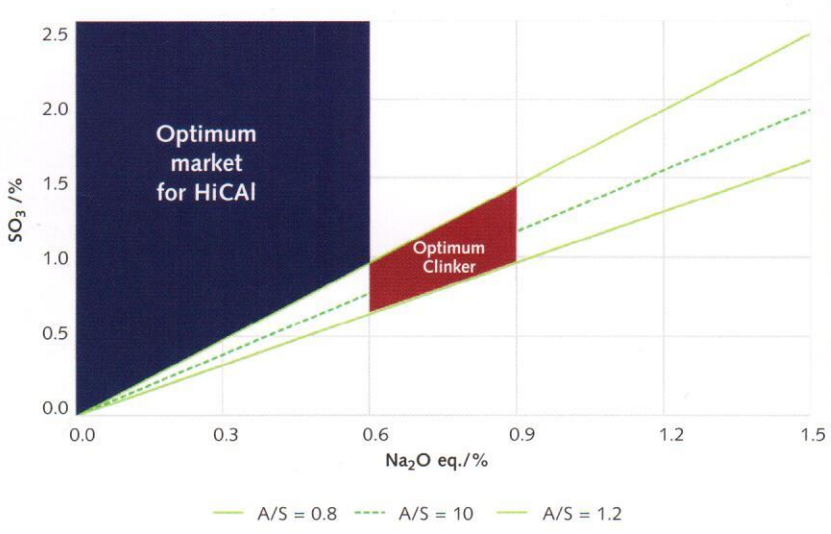

Figure 1: molar alkali-sulphur balance in Portland cement clinker

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Clinker fluoride mineralisation

Clinker mineralisation with natural fluorspar (or alternative sources of calcium fluoride) has been successfully implemented in the cement industry since the 1990s. In simple terms, fluoride improves clinker burnability. This effect can industrially be exploited in two ways:
1. reduced specific thermal energy consumption of clinker manufacturing (up to 100MJ/t of clinker)
2. burning clinker with higher lime saturation to achieve higher alite contents up to 80 per cent. This allows reduction of the cement clinker factor in blended cements of up to 10 per cent, providing savings in energy, CO_2 emissions and cost per tonne of cement.

Table 1 shows the typical composition of a refined byproduct from the aluminium industry. Due to its stable chemical composition and despite its lower fluoride content compared to fluorspar, this material is a suitable

Table 1: refined byproduct from the aluminium industry

	HiCAl 30
Carbon – C (%)	30 to 35
Calorific value (MJ/kg)	> 9
Silica – SiO_2 (%)	11 to 17
Alumina – Al_2O_3 (%)	18 to 23
Iron – Fe_2O_3 (%)	2 to 7
Calcium – CaO (%)	1 to 3
Magnesium – MgO (%)	0 to 1
Sulphur – SO_3 (%)	0 to 2
Potassium – K_2O (%)	0 to 1
Sodium – Na_2O (%)	15 to 20
Fluoride – F (%)	8 to 12

fluoride mineraliser for clinker manufacturing. Typically, around 20kg of refined byproduct material is required to mineralise one tonne of clinker. Laboratory tests and industrial applications have shown that there are no significant differences between the mineralising effects of fluorspar and byproduct mineralisers.

To refine waste materials from the primary aluminium industry and make them suitable for use in the cement industry, Regain has developed dedicated processes and technology and as a result, supplies HiCAl (Higher Clinker Alite) as a safe product.

Alkalis, alumina and carbon value

Beside the fluoride for clinker mineralisation, refined byproducts from the aluminium industry contain sodium as another valuable element for certain clinker manufacturing processes. Alkalis are very suitable for clinker that contains low to moderate natural alkali levels and an excess of sulphur (eg when using petcoke as fuel). A better balance between alkali and sulphur in clinker helps to reduce sulphur volatility and build-up formation, therefore improving kiln operation. However, an increase of soluble alkali sulphates increases clinker reactivity and early cement strength development. Figure 1 shows the molar alkali-sulphur balance in clinker with the optimum market for the refined byproducts.

Furthermore, depending on the raw material situation at a specific cement plant, the alumina content of refined byproducts can also become valuable. Obviously, plants using alumina correctives such as bauxite or kaolin in their raw mix to lift their alumina ratio can reduce their consumption of these expensive materials by using refined byproducts.

Finally, refined byproducts contain a carbon portion of around one third, making them a viable alternative fuel. Using around 20kg of such refined byproduct per tonne of clinker results in a heat input of at least 200MJ/t of clinker. This corresponds to a thermal substitution rate of around seven per cent for a modern kiln system.

Cement industry business case example

The following scenario describes a potential business case for a fictional 1Mta clinker plant which produces 1.16Mta of cement with a clinker factor of 86 per cent. The plant uses low-sulphur coal, has low alkali and sulphur levels of 0.3 and 0.4 per cent, respectively in clinker, and an alite level of 60 per cent. By using 20,000tpa of refined byproducts the plant could implement clinker mineralisation, increase the alite level to 70 per cent and reduce the clinker factor by five per cent. This could increase production by an additional 70,000t of cement, generating around US$5m in additional revenue.

Simultaneously the plant could double the sulphur input to the kiln system using five per cent cheaper higher-sulphur coal while maintaining its perfect alkali-sulphur balance. Together with the thermal substitution value of the refined byproducts themselves, the plant's thermal energy bill could be reduced by US$1.5m.

Finally assuming an extra one per cent clinker factor reduction due to the higher content of soluble alkalis in clinker, some additional US$1m in sales revenue could be achieved. So overall more than US$7m business value could be generated per year by using 20,000t of refined byproducts.

But as hinted at previously, it is key that the refined byproduct materials are made available at the right cement plant.

Regain's HiCAl solution

To refine waste materials from the primary aluminium industry and make them suitable for use in the cement industry, Regain has developed dedicated processes and technology and as a result, supplies HiCAl (Higher Clinker Alite) as a safe product. Product sales are backed up with tailored and professional customer support for implementation of clinker mineralisation.

So far, around 250,000t of different products have been supplied to the cement industry. In addition, Regain conducts research activities in clinker mineralisation together with academic institutes and cement industry partners.

Finally, Regain, with offices in Australia and Switzerland, maintains a knowledge network comprising internal and external experts from specialised fields in clinker and cement manufacturing.