Characterisation of Mineral Wastes, Resources and Processing technologies – Integrated waste management for the production of construction material

WRT 177 / WR0115

Case Study:

Residues from aluminium dross recycling in cement

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Introduction

Aluminium dross represents a residue from primary and secondary aluminium production. Drosses are classified according to their metal content into white and black dross. White dross is of higher metal aluminium content and it is produced from primary and secondary aluminium smelters, whereas black dross has a lower metal content and is generated during aluminium recycling (secondary industry sector). White dross may contain from 15 to 70% recoverable metallic aluminium and it comprises a fine powder from skimming the molten aluminium[1]. Black dross typically contains a mixture of aluminium oxides and slag, with recoverable aluminium content ranging between 12 to 18%, and much higher salt content (typically higher than 40%[2]) than the white dross[1]. The non-metallic residues generated from dross smelting operations is often termed ‘salt cake’ and contains 3 to 5% residual metallic aluminium [1].

Approximately, up to 4 million tonnes of white dross and more than a million tonnes of black dross are reported throughout the world each year, and around 95% of this material is landfilled [2,3]. According to research undertaken during 2002, in the UK, the industry disposes of around 200,000 tonnes of white and black dross [2,3]. The quantities of dross landfilled nowadays are expected to be lower, as part of this material is reprocessed by manufacturing firms such as JBM International Ltd, to recover metal aluminium as well as aluminium oxides.

Figure 1: White dross in lump form with high aluminium content

Figure 2: White dross with low aluminium content

Figure 3: Black dross with high salt

Figure 4: Black dross in lumps

This case study investigates the use of aluminium oxides generated from dross processing, in cement. The terms non-metallic residues, aluminium oxides and 'salt cake' are used interchangeably in this case study.

Potential applications for white/black dross

The composition of aluminium dross is highly variable and usually unique to the plant generating the waste, hence finding potential applications for this material is often seen as a difficult task. However, economically viable recovery processes have now become available and allow part of this material to be recycled. Through this recycling process aluminium metal is recovered and aluminium oxides can find application into powder metallurgical products and construction uses.

Research investigated the use of white/black dross in concrete and asphalt products and concluded that there is significant potential for use as a filler (<700μm). Utilization of this material as filler in asphalt may improve stiffness and it is thought that could also improve abrasion resistance and control micro-cracking [4]. The potential use of dross (as filler) in concrete products (such as, non-aerated concrete, concrete bricks and concrete roof tiles) was thought as more likely however, further study is recommended as there is still no proven added value information for this applications [3]. Other references [5,6] are also relevant sources on the recovery and use of aluminium dross and subsequent residues are.

Aluminium recycling

The dross produced by the aluminium industry, although a waste, contains aluminium and other valuable elements (aluminium oxides), which could be recovered and reused. Conventional methods recycle less than half of all white dross and all black dross is sent to landfill. However, a new method has been developed, currently in use by Jesse Brough Metals Group (JBM International), which could recover 100% of aluminium dross. The processing steps involved are described in Figure 5.

Aluminium dross initially is milled and screened (sieve aperture 1.2mm). Material above 1.2mm is fed in the furnace to produce metal aluminium, which is subsequently cast in ingots. The melting process also produces some residual dross of very low grade, which is recycled into the process to recover as much of metal aluminium as possible. The material below 1.2 mm produced during milling and screening, consists primarily of aluminium oxides with very low metal content .The use of the eddy current separator allows the removal of any residual metal and the beneficiated material is delivered to Plasmet UK Ltd, for further processing. The scope of the activities undertaken by Plasmet is to produce saleable commodities for use in steelworks. Aluminium oxides are blended and classified to manufacture a product to specification.

JBM International currently produces aluminium oxide mixtures for use in metallurgical applications only, as the utilization of these materials in construction and ceramic products, hence in lower value markets, has not proven profitable. JBM processes at the moment approximately 20,000 tonnes of dross per annum, with a 50/50 cut between the two primary end products namely aluminium metal and aluminium oxides for powder metallurgy products. Around 6000 tonnes per annum are used in metallurgical applications, whereas the remaining 4000 tonnes represent a residue without an end market.

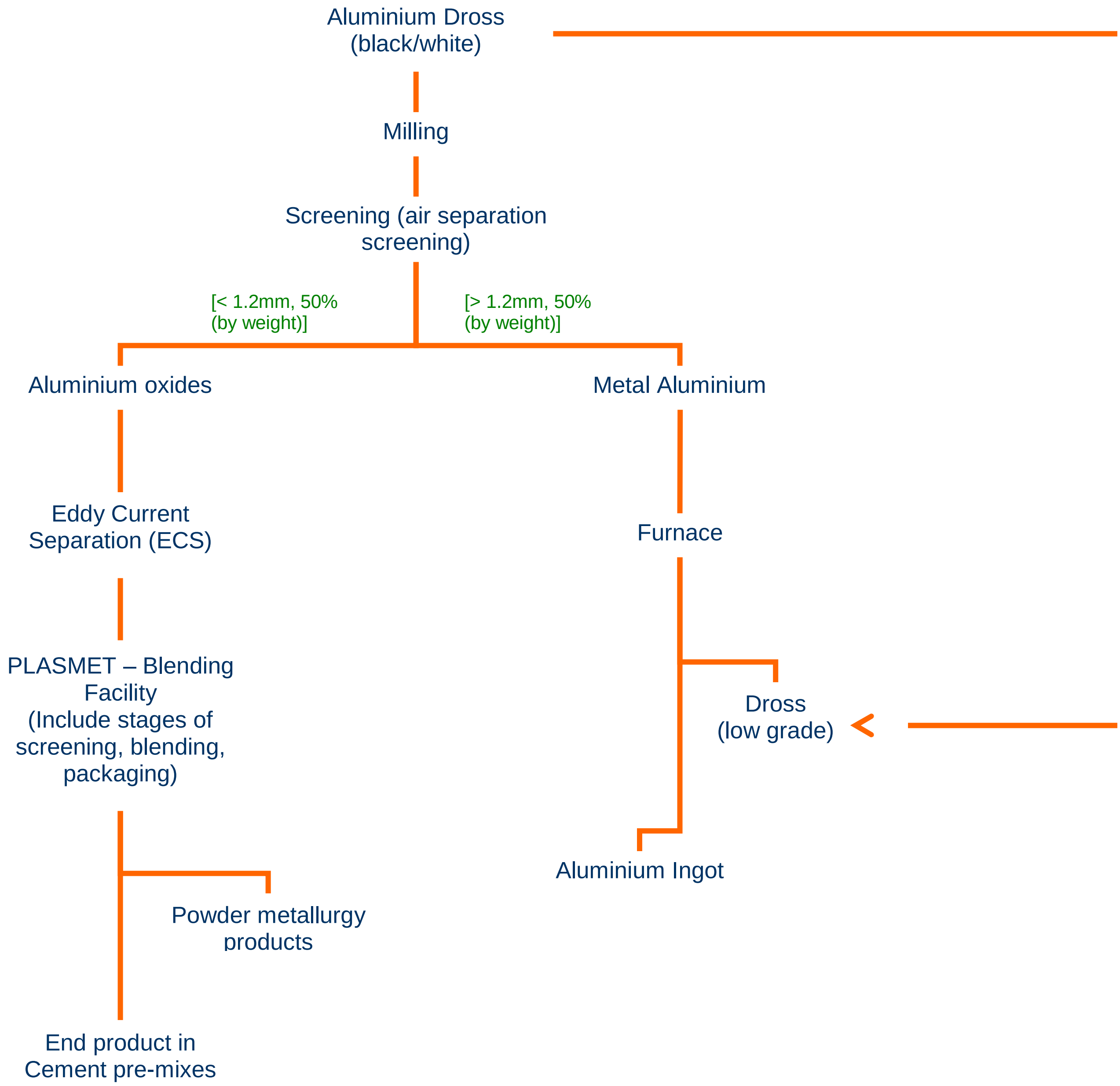

Figure 5: Aluminium recycling flowsheet - JBM International

	
Figure 6: The casting process of metal aluminium produced from dross reprocessing	Figure 7: Aluminium ingots from aluminium dross recycling

Benefits and Barriers **(extracted from the Waste-Product Pairings database)**

Non-metallic residues produced during processing of aluminium dross could be used as a source of aluminium oxide in cement's recipe. Information regarding the referred match on potential benefits, barriers and analysis requirements were extracted from the WPP database and they are presented below.

1. Contribution to the end product.
   A source of aluminium oxide (Al_2O_3)

2. Potential benefits:
   - Material related
     i. Aluminium oxides from dross recycling comprise an alternative source to primary materials
   - Economic:
     i. Aluminium smelters benefit by charging a gate fee for handling and processing waste dross.
     ii. The end products of the aluminium recycling process (aluminium ingots, powder metallurgy products) are considered as high value.
   - Environmental
     i. Less waste is disposed of to landfill.

3. Potential barriers:
   - Material related:
     i. Both white and black dross may include undesirable compounds such as chlorides, fluorides, heavy metals and metal aluminium, which could adversely influence the composition of feedstock for cement manufacture. It is common practices to include blending and classification stages for cement kiln meal constituents to minimise the impact of such contaminants
     ii. Aluminium dross is generated in small volumes and the availability of such materials may reduce further due to the decline of the primary aluminium industry in the UK
     iii. Aluminium dross is generated in small amounts from all around the UK and it needs gathering, hence finding local sources is not always possible.
     iv. The cement sector would require a critical mass of suitable aluminium oxide to match end market demand.

4. Analysis requirements:
   Testing is carried out to identify the properties and characteristics of alternative materials and end products, as well as to determine that the inclusion of certain alternative materials provide desirable results during lab-based experimentation.

   - Testing on alternative materials:
     particle size analysis, mineralogy, chemistry, total sulphur, chlorine content, heavy metals, loss on ignition

   - Testing on kiln feed:
     Al_2O_3 content (% by mass); MgO content (% by mass)

   - Testing on end products :
     in accordance with BS EN 197-1:2000

Residues from aluminium dross in cement

As discussed in the 'Aluminium Recycling' section of this case study, only part of the aluminium oxides produced from Plasmet UK Ltd have an end market at the moment with the remaining staying unused.

Aluminium oxides could be blended together with other waste materials to prepare appropriate premixes for cement kilns. Feedstock materials used in clinker production consist of four major components lime (CaO), silica (SiO_2), alumina (Al_2O_3) and iron oxide (Fe_2O_3). Commonly these principal constituents derive from primary materials however alternative materials could also be used to produce suitable feedstock. Aluminium oxide is provided to cement recipe through the inclusion of clay materials. Pre-mixes can be prepared based on the specific needs of each cement work and appropriate materials are selected according to their properties (physical and chemical). The proposed model provides flexibility to cement manufacture in acquiring fit-for-purpose feedstock from alternative sources and assists the sector to achieve sustainability targets on the use of alternative materials. The model is also presented in Figure 8.

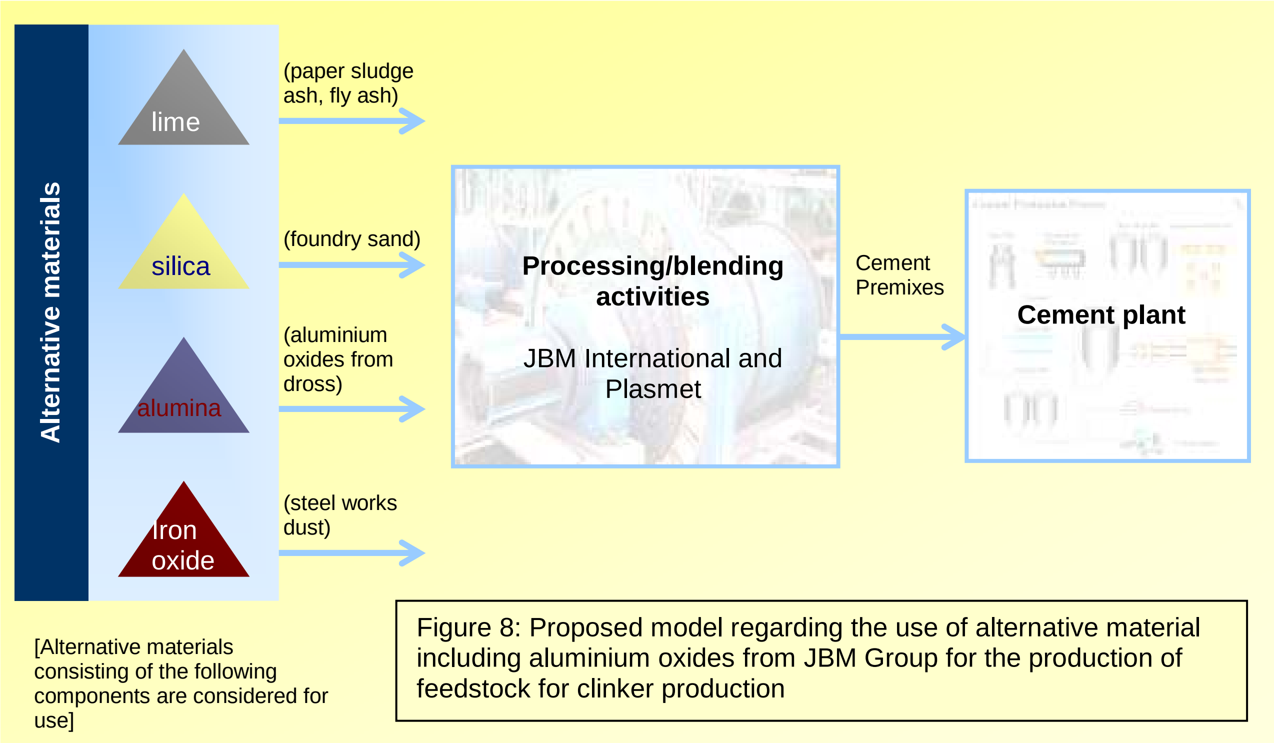

Figure 8: Proposed model regarding the use of alternative material including aluminium oxides from JBM Group for the production of feedstock for clinker production

JBM International and Plasmet are looking in implementing the above model, with the objective to utilise aluminium oxides produced from their process together with other alternative materials which will provide the sources for the remaining three components used in cement kiln meal. Alternative materials such as foundry sand, (source of SiO_2), fly ash (source of CaO), steel industry dust (source of Fe_2O_3) as well as several other type of wastes (for example, filter residues from combustion and water treatment, spent catalysts, paper ash, flue gas dust) are considered for use. The developers expect to gain benefits by making a profit for accepting and processing various alternative materials, but also from producing and selling a suitable end product for cement manufacture. The use of alternative materials assists the cement manufacturer to achieve sustainability targets through the re-use of valuable resources currently available, and conservation of natural resources. The preparation of appropriate feedstock for clinker production elsewhere, in this case study in JBM International and Plasmet, removes the burden from the cement industry, of identifying and sourcing suitable alternative materials, as well as testing, blending and processing. Environmental benefits can also be seen through reduction of waste disposed of in landfill.

In order to allow the production of premixes for the cement industry, JBM International and Plasmet will require appropriate infrastructure to be in place, hence some development work is anticipated. Also, due to the highly variable composition of alternative materials processing and blending should be accompanied by comprehensive testing to ensure that the quality of feedstock follows the cement industry's specifications. Finally, JBM International and Plasmet will need to develop synergies with other industries that can provide suitable alternative materials over long periods and thus satisfy market's demand. Feasibility studies will have to be carried out to ensure the development of the proposed model. Other parameters, such as changes in legislation, the relationships with partners from the cement manufacture and waste producers as well as technical issues could also influence the prospects of this project.

Conclusions and further work

Aluminium oxides produced from aluminium dross recycling could be utilised together with other alternative materials to produce premixes for clinker production. This can be achieved by using alternative materials that contribute essential components in cement's recipe, namely lime, silica, alumina and iron oxide. A project, currently under development by JBM International and Plasmet, investigates whether the production of appropriate premixes is feasible. It is anticipated that a 'new plant' will be in full operation once positive results have been demonstrated.

References

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