Recycled Alumina from Aluminium Salt Slag: Origins & Applications

Howard Epstein
Recycled Alumina - Agenda

- Where it comes from
- What it is
- How it may be applied
- The drivers of demand
RVA’s Business

The conversion of salt slag, a hazardous waste of the aluminium industry, into sustainable, value-added materials:

- **Aluminium Granules**
  Returned to secondary aluminium production cycle

- **Salt**
  Returned to refiners for melting process

- **Recycled Alumina (Valoxy)**
  Non-metallurgical applications as substitute bauxite/alumina
RVA – located at the Heart of Europe
Aluminium Value Chain and Life Cycle

1. Bauxite Mining
2. Alumina Production
3. Primary Aluminium Production
4. Semi-fabrication
5. Product Manufacturing
6. Use Phase
7. Recycling

The Aluminium Value Chain
Life Cycle Origins of Recycled Alumina

Scrap Al

Al users

Secondary Al
Life Cycle Origins of Recycled Alumina

- Scrap Al
- Secondary Al
- Salt slag
- Al granules & regenerated salt
- Al users
Life Cycle Origins of Recycled Alumina

Scrap Al → Secondary Al → Al users

Salt slag → Al granules & regenerated salt → VALOXY
RVA Process

Salt Slags → Dissolution Reaction → Filtration → Crystallization → Regenerated Salt

- Mill Screen Magnet
- Al granules
- Heat recovery
- Water recirculation
- VALOY®
Slag arisings as a function of $2^Y$ Al production

![Graph showing slag arisings as a function of $2^Y$ Al production from 2004 to 2014. The y-axis represents million tonnes, and the x-axis represents years from 2004 to 2014.]
Slag arisings as a function of $2^Y$ Al production

Million Tonnes


2Y Al Output Slag Arisings
Secondary Aluminas Production – Global Potential

1 tonne

Secondary Aluminium
10.3 million Tpa

550 kg

Salt Slag
5.7 million Tpa

300 kg

Secondary Aluminas
3.1 million Tpa
Drivers for Development of Secondary Aluminas

• Regulatory → Salt slag: prohibition of landfill → Waste processing into useful products

• Economic → Secondary aluminas: potential savings in operating cost
Conventional aluminas: comparatively higher production cost
Typical Al Salt Slag Composition

- Oxides: 55%
- NaCl/KCl: 40%
- Aluminium metal: 5%

[Diagram showing the composition]
# VALOXY – Chemical Composition

<table>
<thead>
<tr>
<th></th>
<th>Typical composition dry weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Al}_2\text{O}_3$</td>
<td>67%</td>
</tr>
<tr>
<td>MgO</td>
<td>8%</td>
</tr>
<tr>
<td>SiO$_2$</td>
<td>4%</td>
</tr>
<tr>
<td>CaO</td>
<td>2%</td>
</tr>
<tr>
<td>Cl$^-$</td>
<td>&lt;0.5%</td>
</tr>
</tbody>
</table>
1. Cement
2. Insulation products
3. Stainless steel slag stabilization
4. Fire resistant geopolymers
5. Calcium aluminate steel refining powder
VALOXY: A source of alumina in cement production
More efficient combination of raw materials

Facilitates formation of clinker minerals

Improved early age strength development

Lower milling costs
% Water Absorption at 1250°C

100% fireclay

20% 30% 40% 50% Valoxy substitution
VALOXY in Insulation Products - Benefits

- Strengthening of ceramic lattice
- Increased resistance to volume shrinkage
- More open and stable ceramic structure
- Application in insulating firebricks
The Problem
Stainless Steel Converter Slags:
7 MT
and growing at >5% p.a.
Argon-Oxygen Decarburization
AOD Slag Stability - a function of $C_2S$ form

Melt

2150°C

$\alpha$ (Hexagonal)

1425°C

$\alpha'_H$ (Hexagonal)

1177°C

$\alpha'_L$ (Hexagonal)

850°C

$\beta$ (Monoclinic)

490°C

675°C

$\gamma$ (Orthorombic)
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Volume increase: 12%
Conversion of $\beta$-$C_2S$ to $\gamma$-$C_2S$ causes structural collapse (dusting) of the slag making it difficult to:

- handle
- store
- valorize

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- store
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Potential for Cr leaching

Volume increase: 12%
Add boron compounds after tapping the slag.

But

- Borax is expensive
- Boron usage may be restricted in the future
Alternative Solution – Stabilize with Alumina

CaO - Al$_2$O$_3$ - SiO$_2$ - 1200°C
Data from FToxid - FACT oxide database 2010
### Properties of VALOXY-treated AOD Slag

<table>
<thead>
<tr>
<th>Valoxy addition (w/w)</th>
<th>5%</th>
<th>10%</th>
<th>12.5%</th>
<th>15%</th>
</tr>
</thead>
<tbody>
<tr>
<td>γ-C₂S</td>
<td>4.4%</td>
<td>3.9%</td>
<td>3.3%</td>
<td>1.9%</td>
</tr>
<tr>
<td>Volumetric stability</td>
<td>Unstable</td>
<td>Stable</td>
<td>Stable</td>
<td>Stable</td>
</tr>
<tr>
<td>Micro-hardness (HV)</td>
<td></td>
<td></td>
<td>475</td>
<td>775</td>
</tr>
<tr>
<td>Spinel</td>
<td>6.1%</td>
<td>13.0%</td>
<td>12.1%</td>
<td>12.2%</td>
</tr>
</tbody>
</table>

AOD slag stabilized by Valoxy 12.5% w/w
Compared to conventionally treated slag:

- Improved mechanical properties
- Improved health and environmental properties

Implying:

- Higher market value for the slag
VALOY in Fire Resistant Geopolymers

\[(M)_n(-\text{Si}-\text{O}-\text{Al}-\text{O}-)_n\]

-\text{Si}-\text{O}-\text{Si}-\text{O}-
-\text{Si}-\text{O}-\text{Al}-\text{O}-
-\text{Si}-\text{O}-\text{Al}-\text{O}-\text{Si}-\text{O}-
-\text{P}-\text{O}-\text{Si}-\text{O}-\text{Al}-\text{O}-\text{P}-\text{O}-
-(\text{R})-\text{Si}-\text{O}-\text{Si}-\text{O}-(\text{R})
-\text{Al}-\text{O}-\text{P}-\text{O}-
-\text{Fe}-\text{O}-\text{Si}-\text{O}-\text{Al}-\text{O}-\text{Si}-\text{O}-

Sodium-Poly(sialate) Sodalite framework Na-PS
Sanidine framework K-PSDS

Potassium-Poly(sialate) Kalsilite framework K-PS

Potassium-Poly(sialate-siloxo) Leucite framework K-PSS

Calcium-Poly(disialate) Anorthite framework Ca-PS
Geopolymer System | KOH / SiO₂ | K₂SiO₃
--- | --- | ---
Valoxy (w/w) | 27% | 16%
Compressive strength | ≥ 10 MPa |  |
Water absorption (24 hr) | 14% | 15%
Fire resistance | No damage, no creep |  |
VALOXY in Fire Resistant Geopolymers

Geopolymer formulations based on Valoxy met Europe’s most rigorous standards for fire resistance.

- Low water absorption
- High compressive strength
- No fire damage
VALOXY in Steel Refining Powder

Valoxy

Heated to 1500°C

Cooled to 1350°C

Calcium aluminate pre-melted slag
- Calcium aluminate samples successfully synthesized from VALOXY and calcined lime.
- Melting pt. 1350°C – excellent for steel refining.
- Chemical analysis suitable for intended application (CaO/Al$_2$O$_3$ ratio $\approx 70\%$)
# VALOXY – Technical Benefits

<table>
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<tr>
<th>Application</th>
<th>Benefit</th>
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| Cement                             | • Improved sintering  
                                 | • Early setting                                                       |
| Insulation Products                | • More robust ceramic lattice  
                                 | • Stable micro-structure  
                                 | • Reduce shrinkage                                                   |
| Stainless Steel Slag               | • Phase transformation inhibited  
                                 | • Increased micro-hardness  
                                 | • Cr (III) containment – reduced leaching                            |
| Fire-resistant Geopolymers         | • Met RWS standards for fire protection                                 |
| Refining powder for steel          | • Suitable calcium aluminate produced                                 |
Recycled Alumina: Economic Drivers of Demand

- Supply stability
- Long-term fixed price structures
- Inexpensive compared to conventional raw materials
- Potential savings in operating costs
Recycled Alumina: Health, Safety and Environmental Drivers of Demand

- Sustainable product derived from existing industrial process
- Eliminates need for extraction of non-renewable raw materials
- Pre-empts future health & safety concerns (borax)
Commercial Benefits + Environmental Benefits = A Cost-Effective, Sustainable Alumina Source
Profitability
Sustainable Development

Profitability
Valoxy: turning a tug of war

Sustainable Development

Profitability

Valoxy
.....into a handshake
Thanks for your attention

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