NordMin workshop

Sustainable Fibres from Basalt Mining
GREENBAS

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6 of 10 GREENBAS members in the field in Iceland
Aim:
- Assess applicability of Icelandic basalt for production of Basalt fibres for industrial application
- Measure chemical composition and map potential location of mines
- Evaluate compatibility of Basalt fibres with concrete
- Make a Life Cycle Assessment of Basalt fibres
- Investigate addition of oxides to modify natural Basalt
- Set up a business plan for Basalt fibre plant in Iceland
154 samples collected from the 103,000 km² island area
Selection process for Continuous Basalt Fibres

1. Measure composition
2. Analysis for Acidity and Viscosity Moduli
3. Application of criteria for Ma and Mv
4. Measure viscosity, resistivity, crystallisation etc.
5. Final selection (mine, roads, sensitivity of location...)
The Window

Compositional window:

<table>
<thead>
<tr>
<th>Oxides</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO2</td>
<td>45-60%</td>
</tr>
<tr>
<td>Al2O3</td>
<td>12-19%</td>
</tr>
<tr>
<td>FeO/Fe2O3</td>
<td>5-15%</td>
</tr>
<tr>
<td>CaO</td>
<td>6-12%</td>
</tr>
<tr>
<td>MgO</td>
<td>3-7%</td>
</tr>
<tr>
<td>TiO2</td>
<td>0.1-2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Moduli</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ma (Acidity)</td>
<td>3-6</td>
</tr>
<tr>
<td>Mv (Viscosity)</td>
<td>2-3</td>
</tr>
</tbody>
</table>

\[ M_a = \frac{SiO_2 + Al_2O_3}{CaO + MgO} \]

\[ M_v = \frac{x_{SiO_2} + x_{Al_2O_3}}{2x_{Fe_2O_3} + x_{FeO} + x_{CaO} + x_{MgO} + x_{K_2O} + x_{Na_2O}} \]
\[ M_a = \frac{SiO_2 + Al_2O_3}{CaO + MgO} \]

\[ M_V = \frac{x_{SiO_2} + x_{Al_2O_3}}{2x_{Fe_2O_3} + x_{FeO} + x_{CaO} + x_{MgO} + x_{K_2O} + x_{Na_2O}} \]
154 samples have been collected and analysed
Three samples have been selected for further analysis

BTR 13 – Borgarfjörður
Næfurholt – Hekla eruption 1845
Skjólkvíar – Hekla eruption 1970

These samples are being measured for suitability for Basalt fibre production
Basalt fiber products have been tested for structural use:

- Renovation of concrete columns by wrapping with basalt fiber sheets
- Concrete beams reinforced with BFRP
- BFRP relaxation – ongoing long term test
- Glulam beams strengthened with basalt fiber
- Concrete facade panels and precast elements with basalt reinforcement
- Fire resistance of basalt fiber concrete
• Goal:
  o Evaluate the environmental impacts for the production of CBF for the Icelandic context.
  o To perform an analytical comparison of the gas based heating method to the electric method using renewable electricity from the grid in Iceland.
  o Comparison with Russian production with Basalt from Ukraine
  o Comparison with other fiber material (glass and carbon fibres)
• Scope: The boundaries of the system are selected to include extraction of basalt raw material, transport of raw materials, and the manufacture of CBF.
• Functional unit: 1 kg of produced CBF
• Life Cycle Inventory: Two types of data have been used, REAL DATA and data from databases included in SIMAPRO with modifications to fit the Icelandic and Russian context. Impact assessment: Use of the software Simapro 8, method: ReCiPe Midpoint Hierarchist
- Russian Scenario: Ukraine Basalt, Electricity + Gas
- Iceland Scenario 1: Iceland Basalt, Electricity + Gas
- Iceland Scenario 2: Iceland Basalt, only Electricity
LCA Conclusions

• Icelandic production results in lower emissions than Russian gas and electric production.
• In both cases furnace energy consumption is identified as the largest contributor to emissions. Even with a basalt from Ukraine and a production in Iceland with its renewable energy would result in a greener CBF than the Russian one.
• Compared to other alternative fibers, CBF is much greener and especially if it is produced with a renewable energy.
• CBF produced in Iceland with hydroelectric power has probably the lowest carbon footprint in the world.
Main task of VTT was to investigate options of using other sources of oxides to modify composition of Icelandic Basalt
Icelandic basalt for CBF Production

- Composition limits are defined by production and property requirements
- Literature study suggest that ground Basalt could be modified with additives to adjust oxide compositions into the desirable range
- No Icelandic basalt sample has shown ideal composition and thus modification would be needed
- The policy in this study was to adjust the CaO + MgO content, Al2O3 content and SiO2 content to match the Ukrainian target
- Adjustment was made on the basis of minimum amount required to achieve ideal composition
Modification for CBF production

- The addition materials was either a mix of SiO2 and Al2O3 or a mix of Al2O3 and CaO
- These materials are available as common industrial minerals but their production have relatively high impact compared to the mined basalt
- Metakaolin, quartz, aluminate cement and quicklime could be used
- Icelandic basalts have either high CaO + MgO content or small CaO + MgO content. There is a gap between values 7.6 – 12 but Ukrainian basalts, suitable for CBF, are located within that range
Business model

A rudimentary business model has been set up for a plant Producing Continuous Basalt Fibres in Iceland

Input parameters need to be refined and improved

First results:
For a plant producing 50 tons per year, the price has to be €11 per kg for breakeven

Market price of Continuous Basalt Fibres ranges from 2 to 15 €/kg
GREENBAS – Main conclusions

- 154 Basalt samples have been collected and analysed
- To make Icelandic Basalt suitable for production of continuous fibres it is necessary to add some basic oxides – This is easily achievable
- Methods have been developed for addition of oxides to Icelandic Basalt
- Life Cycle Assessment shows that carbon footprint of Basalt fibres produced in Iceland is considerably smaller than elsewhere
- A rudimentary business model has been developed for a Basalt Fibre Plant in Iceland

The GREENBAS team thanks NordMin for providing funding and making this project possible
Application has been sent to Nordforsk / Nordic Innovation for the so-called NORBAS project Nordic Sustainable Basalt Fibre Reinforced Composites

NORBAS aims to optimise the mechanical, environmental and economical performance of the entire valued chain of Basalt Fibre reinforced polymers and thus pave the way for industrial production
Thank you

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