GLASSY PRODUCTS AS CONSTRUCTION MATERIAL OUT OF MINERAL SLAG

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ABSTRACT

The article deals with the problem of using mineral slag as raw material for building products. In a project with a semi-industrial scale (1 ton per day) all technical, environmental and economic problems have been examined producing material like roof and floor tiles: Some of the concerns are fluctuating composition of the mineral slags, incorporation of heavy metals, appropriate melting technology, lifetime of the refractory material, environmental concerns during the production, appropriate forming techniques, possibilities to improve the material properties concerning colour and shape, mechanical and chemical resistance and other aspects. A program has been developed to achieve similar physical properties with strong changes in the glass composition for soda lime and alum silicate glasses. This enables the technique to deal with total different and changing compositions of the mineral slags ensuring to have similar product properties. Using classical glass techniques like enamelling, surface crystallisation, thermal strengthening, $AlCl_3$ *vapour treatment of the hot glass surface and other means it has become possible to create a great number of different shapes, properties and products being superior to classical building materials. The most important aspect has been the economic situation of this new products compared with classical building material. Depending on the cost to deal with the mineral slags (legal restrictions, deposition costs) the new glassy products appeared to be an interesting economic alternative, with the additional advantage to create products which could be easily recycled after the product lifetime as any glass products.*

INTRODUCTION

Most of industrial activities result in the end in mineral slag. Because of increasing problems concerning the deposition the use as raw material for new products becomes more and more interesting. Due to the huge mass of mineral slag being produced every year it is necessary to find a market which is able to absorb at least some parts of this material. Only the building industry seems suitable. The aim of the project was the identification and the solution of technical and economical problems in using mineral slags as raw material for the production of glassy construction materials. In contrary to other building materials it was clear from the beginning that this new material could be 100% recycled, which will be a decisive advantage of the technology.

METHODOLOGY

Beside laboratory tests in a semi-industrial scale project (1 ton per day) all technical, environmental and economic problems have been studied concerning the producing of building materials like roof and floor tiles: Some of the concerns are:

- Fluctuating composition of the mineral slag
- Incorporation of heavy metals
- Appropriate melting technology
- Lifetime of the refractory material
- Environmental concerns during the production
- Appropriate forming techniques
- Possibilities to improve the material properties concerning colour and shape, mechanical and chemical resistance and other aspects.

A program has been developed [1] to achieve similar physical properties with strong changes in the glass composition for soda lime and alum silicate glasses. This enables the technique to deal with total different and changing compositions of the mineral slag's ensuring to have similar product properties. In Figure 1 and Table 1 some results are shown. A wide range of similar properties with total different glass compositions are possible. This tool enables the producer to choose from a wide range of different slag those with the most promising technical and economic potentials from different industries.

Table 1: Examples for chosen properties

Glass composition in wt.-%							Glass properties			
Glass No.	SiO_2	Al_2O_3	CaO	MgO	$Fe2O_3$	Alkali	Expansion coefficient $\alpha*10^{-6}$ K^{-1}	Transformation temperature T_G [°C]	density ρ [g/cm^3]	Liquidus temperature T_{Liq} [°C]
1	46	21	23	2	2	6	7.02	696	2.74	1232
2	61	10	18	3	3	5	7.07	662	2.65	1230
3	44	23	22	2	2	7	7.12	688	2.74	1192
4	49	15	19	7	5	5	6.91	674	2.78	1236
5	45	16	18	9	6	6	7.14	662	2.83	1257
6	46	19	15	3	10	7	7.22	655	2.82	1220
7	53	15	17	8	2	5	7.19	677	2.72	1249

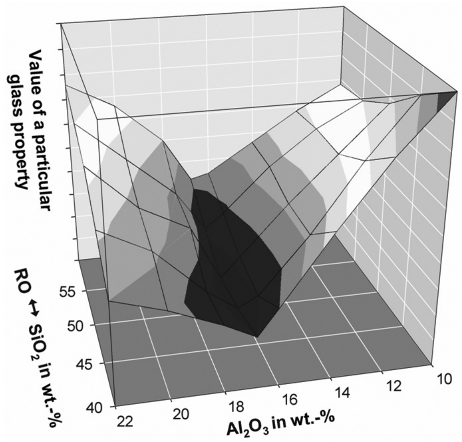


Figure 1: Similar properties with changing composition

Another problem is the changing slag compositions every day in the same raw material. Here a fine tuning is necessary as shown in Figure 2. The online viscosimeter being developed for glass industry, measured very precise any viscosity changes. These changes are linked with varying compositions and these effects the properties. Keeping the viscosity stable by adding network formers like SiO_2 for example from the casting industry, the properties will be stabilised.

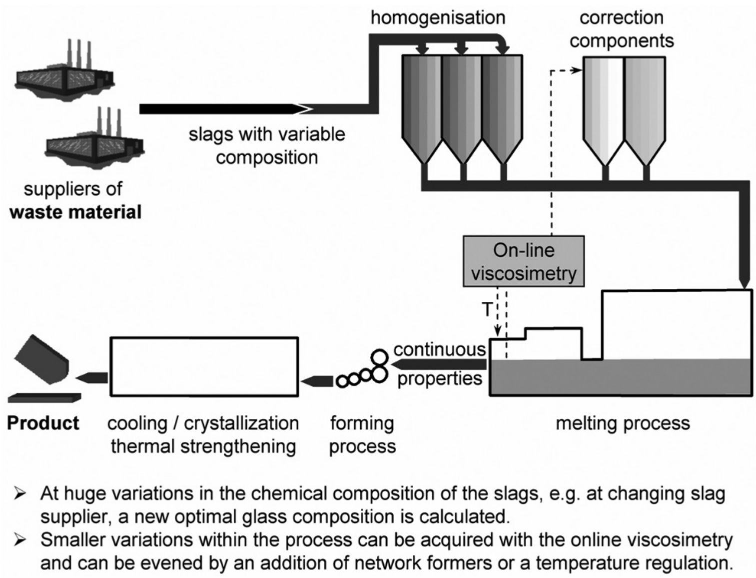


Figure 2: Concept for dealing with changing raw material composition

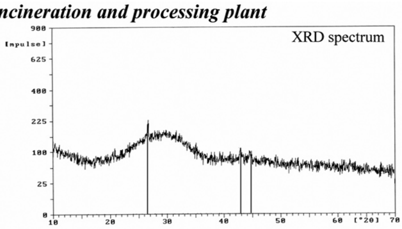
RESULTS AND DISCUSSION

Melting: Out of our laboratory tests and the trials with the semi-industrial furnace we reached the following results:

- Every slag is carrying one or more heavy metal(s). The use of this raw material creating new building materials is linked to the question if these contamination is incorporated in the glassy products in a secure way while being attacked for instance by water or humidity. Following certain test procedures (water attack 90°C for one hour with CO_2 enriched water: Glass created from slag taken from a thermal waste treatment factory, enriched with 1.5 weight % each Pb and Cd) it was not possible to detect heavy metal in the eluate unless the glass was grinded to dimensions less than 60 µm.
- Different slags have been used. They differed in chemical and phase composition. Examples from different industries are shown in Figure 3. The pull rate of the furnace was strongly dependant from these properties. Similar composition but more already glassy slag enables in this small furnace a pull rate of nearly 4 tons/m^2 and day, which is a good value for the glass production in big furnaces. Another problem was the heat transfer. With high iron content the melt has a bad heat transfer by radiation. All electric furnaces are too expensive. In addition a high gas, especially sulphur content could be detected. The solution has been a furnace construction with a partly thin layer melting technique, partly electrical and partly classical fossil heated, oxygen bubbler systems and other details. The lifetime of the refractory was another concern due to the aggressive slag melt. After extensive tests an optimal refractory material in contact with the melt was found, chromium based, which enabled a continuous run of a furnace for a minimum period of four years.

a) Slag from a waste incineration and processing plant

composition in wt.-%	
SiO_2	34,3%
Al_2O_3	17,4%
CaO	24,6%
MgO	4,9%
Na_2O	2,7%
K_2O	0,7%
Fe_2O_3	3,8%
SO_3	0,7%



b) Slag from a zinc recycling plant

composition in wt.-%	
SiO_2	34,6%
Al_2O_3	17,7%
CaO	24,5%
MgO	4,9%
Na_2O	1,4%
K_2O	0,5%
Fe_2O_3	6,4%
SO_3	2,7%

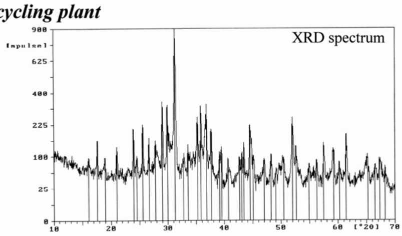


Figure 3: Characterisation of the used slags

Forming: Concerning the forming process the classical rolling technique has been chosen for cost reason. At the same time a great number of different techniques could be added to create different properties and shapes of the new product. Using classical glass techniques like enamelling, surface crystallisation, thermal strengthening, $AlCl_3$ vapour treatment of the hot glass surface and other means it has become possible to create a great number of different properties and products. These effects are shown in Figure 4 and 5.

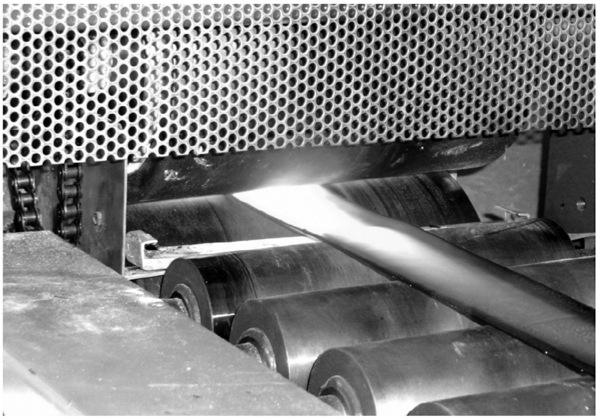


Figure 4: Forming process

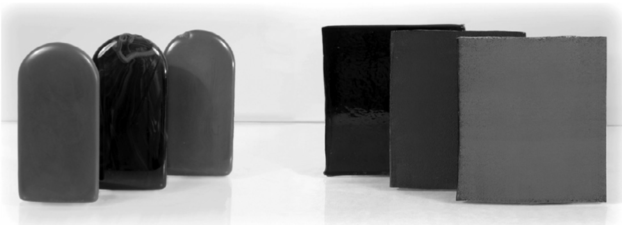


Figure 5: Products made from mineral slags

CONCLUSIONS

The developed concept has proved of value. The main problems that result form the usage of mineral slags can be solved with this technology:

- Acceptable melting rate, whereas the crystallisation grade of the slags has a considerable influence
- Fast degassing of the melt already in the smelting area
- Combination of fossil heating and electrical boosting is very suitable
- Materials with a high chromium content have a sufficient corrosion resistance
- Partial crystallisation by thermal post-treatment is possible
- Rolling is suitable for the fabrication of glass plates
- By the coating with glass enamel the properties of the product can be affected manifold
- Many colours, shapes and effects are possible.

The most important aspect has been the economic situation of this new products compared with classical building material. Depending on the cost to deal with the mineral slags (legal restrictions, deposition costs) the new glassy products appeared to be an interesting economic alternative, which has been demonstrated in a business model. The economic perspective is bright especially due to the fact that mainly square meters between normal building materials and the new glassy products have to be compared and not tons, because even improved properties compared to classical building material could be achieved with strong decreased weight. Last but not least: After the lifetime cycle of this material, which is much longer than the normal material, it could be recycled as cullet without any restriction. Classical building material mainly has to be down cycled or deposited. Altogether a very promising economical and ecological technique has been developed to deal with the problems of mineral slags.

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