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## **Evaluation and Discussion of Steel Slag Mineralogy after Ageing under Laboratory and Field Conditions**

S. DIENER\*<sup>1</sup>, L. ANDREAS<sup>1</sup>, E. BRÄNNVALL<sup>1</sup>, A. LAGERKVIST<sup>1</sup>

<sup>1</sup>Division of Waste Science and Technology, Luleå University of Technology, SE-971 87, Luleå, Sweden

\*Corresponding author (Silvia.Diener@ltu.se)

### **Introduction**

Capping of landfills consumes large quantities of construction materials. Some industrial wastes such as steel slags have properties that would render them useful e.g. in liners. However, the long term stability of such constructions has not been demonstrated yet, and in order to do so, a series of investigations has been undertaken. In both laboratory and field tests, a steel slag mixture of two electric-arc-furnace steel slags and ladle slag has been used. In the field the material has been used in the construction of a liner on a part of a municipal landfill containing degradable organic material, thus exposing the liner to various stresses like redox gradients, mechanical stress due to settling processes, temperature gradients et c.

The landfill cover construction started 2005 and different samples from different points of the liner layer were taken two years later. In the year 2007, a laboratory experiment was started to analyse and evaluate mineral transformations due to ageing under controlled conditions and to find out if the materials suitability for such a construction is endangered in the long-term due to ageing processes. The laboratory samples have been exposed to a variation of different factors assumed to be important for the ageing processes, such as CO<sub>2</sub>-content, humidity and temperature.

### **Research question**

Laboratory experiments are usually used to assess the ageing behaviour of a material in a construction. In this study, field samples are included and compared with samples aged in the laboratory in order to examine differences in the mineralogical composition and their relevance for the long-term stability of the liner material.

### **Material and methods**

Before the various analyses, samples were dried for two hrs at 105°C and ground in a vibratory mill for 20 s. The X-ray diffraction instrument was a Siemens D5000 diffractometer using Cu K $\alpha$  radiation (40 kV, 40 mA). The diffractograms were evaluated using the EVA program to determine the present phases. The analyses were done at a step size of 0.02° and a step time of 2 s per step from 5 to 70 °2 $\theta$ . The thermal analyses (TG/DTA and analysis of CO<sub>2</sub> content in gas) were performed with a Netzsch STA 409 instrument where the samples where four field samples and one laboratory sample were heated in an argon atmosphere at 10°/min up to 1000°C.

## Results

The biggest and most obvious difference among all samples acc. to the XRD results is the degree of calcite formation (Fig. 1). The field samples *g* and *f* showed the highest calcite content which can be explained by the fact that they remained uncovered for about two years directly exposed to environmental conditions (rain etc.). This shortcoming could not be avoided due to construction issues but does not represent the normal case in which the liner directly is covered by the drainage and the protection layer. The environmental conditions at a liner protected by overlying layers will be less intensive. This was shown by sample *e* which showed a lower calcite formation than sample *g* and *f*. Field sample *c* which was taken right after construction and was exposed to field conditions only about 1 day showed about the same pattern as the laboratory sample aged for 22 months under high CO<sub>2</sub> content. According to thermal analyses, sample *a* and *c* seem to have about the same calcite (or carbonate) content and sample *e* less than half the calcite content of sample *g*. To sum up, the ageing of the field samples was more effective than it was for the laboratory specimen.

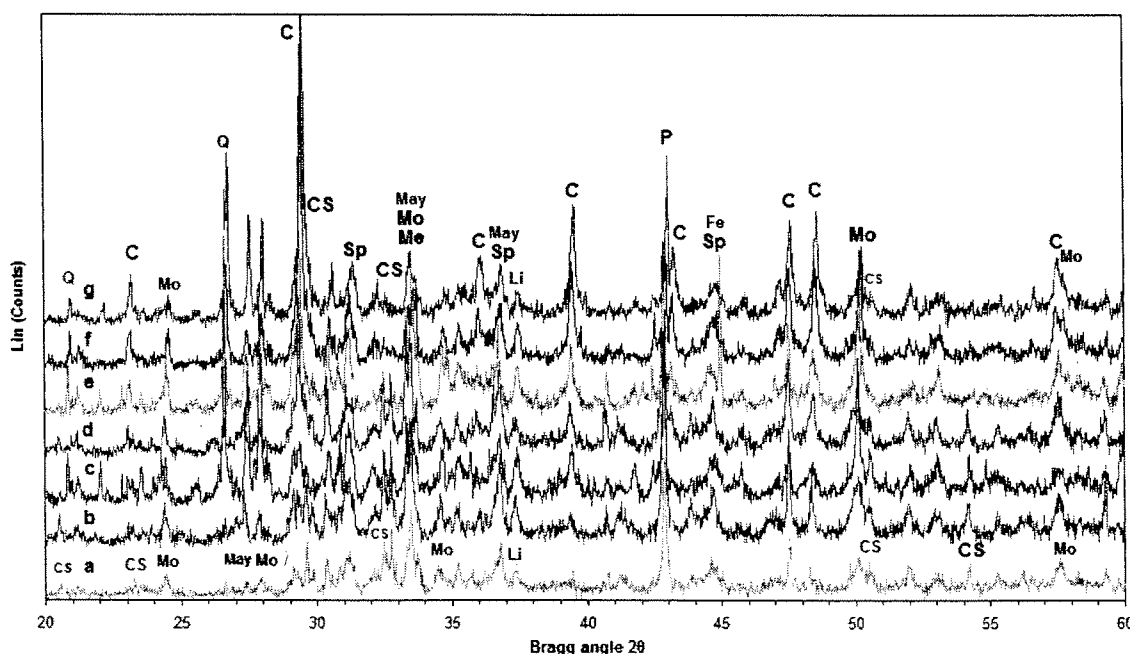


Figure 1. XRD patterns of laboratory and field samples. Diffractograms were sorted acc. to the height of the main Calcite peak (29.4 °2θ). *a*: sample aged in laboratory in air, low humidity and temperature for 3 months, *b*: sample aged in laboratory in high CO<sub>2</sub>, low humidity and temperature for 22 months, *c*: field sample taken right after liner construction, *d*: sample aged in laboratory in medium CO<sub>2</sub>, medium humidity and temperature, *e*: field sample from the very top of the liner about two years after construction (liner below protection layer), *f*: field sample from the uncovered liner two years after construction, *g*: field sample from the surface of the uncovered liner two years after construction. Identified minerals: C = Calcite (CaCO<sub>3</sub>), CS = Calcium silicate (Ca<sub>2</sub>SiO<sub>4</sub>), P = Periclase (MgO), Mo = Monticellite (CaMgSiO<sub>4</sub>), May = Mayenite (Ca<sub>12</sub>Al<sub>14</sub>O<sub>33</sub>), Me = Merwinite (Ca<sub>3</sub>Mg(SiO<sub>4</sub>)<sub>2</sub>), Sp = Spinel (MgAl<sub>2</sub>O<sub>4</sub>), Q = Quartz (SiO<sub>2</sub>), Li = Lime (CaO), Fe = Iron (Fe).

Despite calcite formation, mineralogical changes were found among the silicate minerals such as (Di)calcium silicate and Mayenite. Their intensity seemed to decrease from pattern *a* to *g* (Fig. 1). A clear example can be seen between 32 and 33 °2θ and 54.2 °2θ (Calcium silicate peaks). At the same time, quartz intensities rose from diffractogram *a* to *g*.

## **Conclusions**

Ageing intensity - according to indicators such as the increased intensities of calcite and quartz peaks and the decreased intensities of some silicate minerals - was greater in the field than under laboratory conditions. The acceleration of ageing processes does not only depend on the intensity of one factor such as CO<sub>2</sub>-content. Even though a part of the laboratory samples was exposed to high CO<sub>2</sub> contents, calcite formation was higher in the samples exposed to medium CO<sub>2</sub> content and much higher for the field samples. It is rather the combination of all environmental conditions that together accelerate ageing. Consequently, varying humidity, temperatures and processes such as leaching which are present under field conditions supported ageing reactions.