Mineral phases in steel industry slags used in a landfill cover constuction

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Research question

In 2004, the European steel industry generated about 15.2 million tonnes of different steel slags. Out of these, electric arc furnace (EAF) slags and secondary metallurgical slags account for almost 6 million tonnes (Euroslag, 2006). Steel slags can potentially be reused, e.g. as construction material in landfill liners or cover constructions. Their physical and chemical properties have been investigated by e.g. Herrmann et al. (2005), Shen H. et al. (2004), Shi (2002), Motz and Geiseler (2001) and Fällman (1997). However, not much is known with regard to their long-term behaviour. The presented project deals with alterations of the mineralogical composition of steel slags as a base for estimations of the long-term stability.

Material and Methods

Two types of steel slags, electric arc furnace (EAF) slag and ladle slag were mixed in different proportions and analysed with calorimetry, infrared (IR) spectroscopy and X-ray diffraction (XRD). In the mixture ladle slag reacts with water by hydration, while the EAF slag works as filler.
The study focused on the cement reaction as well as on the mineralogical composition. The cement reaction was tested with the aid of calorimetry, whereas IR spectroscopy (FTIR spectrometer) and XRD were used to analyse the amorphous and crystalline mineral phases. A method for preparing specimens was developed.

Results and conclusions

The temperature development of five different mixtures of EAF and ladle slag recorded by the calorimeter showed an activation of the mixture by Al-rich ladle slag: higher portions of ladle slag resulted in an increased development of heat. However, higher portions of ladle slag also involve a delay of the maximum heat build-up.
The IR analyses showed that changes in the sample spectra were proportional to the EAF content. Additionally, one IR analysis of non-hydrated (dry) ladle slag was performed. During qualitative analysis of the IR spectra, absorption bands were identified in the wave number ranges of inorganic carbonates, calcium silicates and aluminium oxide. The biggest differences between the samples could be seen in the region from 3500 to 3200 cm^{-1}. Ladle slag showed clear absorption peaks, while EAF slag did not. In this wave number range, absorption of O-H bonds occurred representing the integration and absorption of water molecules in the minerals.
With the help of XRD (see figure 1), the main minerals in a 100 % ladle slag were identified as γ- Calcium silicate (γ-Ca_2SiO_4) and Mayenite ($Ca_{12}Al_{14}O_{33}$), whereas Merwinite ($CaMgSiO_4$) and Monticellite ($Ca_3Mg(SiO_4)_2$) were most common in 100 % EAF slag. New mineral phases after mixing both slag types could not be detected with XRD. Certain phases as dicalcium silicates, detected by XRD in both slag types, result in limited cementitious properties of the material. Both slag types consist predominantly of crystalline phases.

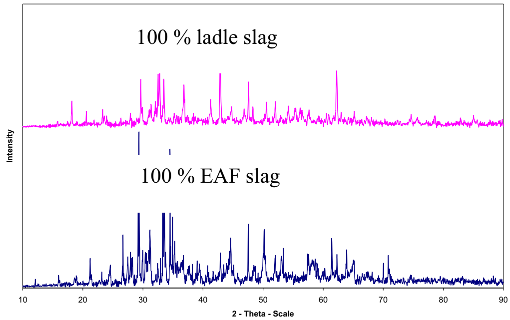

Figure 1. Diffraction pattern of 100 % ladle slag and 100 % EAF slag

Mineralogy determines steel slag properties and liner performance. Mineral alterations include the formation of secondary minerals through weathering of the analysed primary minerals. Estimations for these aging reactions of primary minerals have been outlined. The long-term behaviour of the steel slag minerals is affected by processes as weathering, including carbonation and pH changes, leaching and stability changes during aging. Finally, a mixture of EAF slag and ladle slag is recommended for a landfill cover.

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