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Research Initiative on the Use of Steel Slag in Concrete and Cement

Industry Assessment

Technical Brief

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Environmental Stabilization and Solidification of Contaminated Soils and Sediments Using Steel Slag

Overview

Steel slag generated from basic oxygen furnaces (BOF) and electric arc furnaces (EAF) has been investigated as a viable alternative to portland cement for stabilization/solidification (S/S) of contaminated soils and sediments. Its high alkalinity, hydraulic reactivity, and mineralogy enable the formation of C–S–H and C–A–S–H gels that immobilize metals, reduce the hydraulic conductivity, and consequently reduce leaching potential. Studies investigating the use of steel slag in S/S applications reported significant reductions in leachability of Pb, Zn, Cd, Cu, Ni, and Cr and favorable microstructure development. Chemical activation of slag can further enhance the hydration and immobilization performance. The long-term durability of steel slag S/S is comparable to typical cement-based approaches.

Key Takeaways

- Steel slag can be an effective binder for S/S of contaminated soils and sediments.
- Contaminated soils treated with steel slag can meet environmental regulations for transportation infrastructure material.
- Strong immobilization is documented for Pb, Zn, Cd, Cu, Ni, and Cr.
- Chemical activation can enhance hydration and performance.
- Long-term durability is comparable to cement-based S/S systems, with improved sulfate resistance.

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Material Characteristics and Reactivity

- Steel slag exhibits latent hydraulic and chemical reactivity, supporting its suitability for S/S applications.
- Steel slag exhibits cementitious behavior due to reactive mineral phases such as C_2S, C_3S, ferrites, free CaO/MgO, and RO components, which facilitate solidification of soil matrices.
- Cementitious bonds formed through the hydration of steel slag reduce hydraulic conductivity, which in turn reduces the potential leaching of contaminants.
- During hydration, steel slag generates a highly alkaline environment and forms C–S–H and C–A–S–H gels capable of binding and immobilizing contaminants.

Heavy-Metal Immobilization in Soils

Steel slag helps solidify and stabilize heavy metals in contaminated soils by forming cementitious bonds and creating a high-pH environment that limits metal mobility.

- The solubility of many metals (e.g., Pb, Cu, Ni) is directly related to pH, with high pH conditions reducing their leachability.
- Hydration products chemically bind contaminants in gels while enabling physical encapsulation within a denser, hardened matrix.
- Up to 95% reduction in lead leachability has been observed in steel slag treated material.
- Chemical additives can be introduced to accelerate slag hydration and produce a denser structure capable of immobilizing metals at levels comparable to conventional cement-based treatments.
- Ferrous iron in slag can reduce toxic Cr(VI) to the less toxic Cr(III) form, which can then be immobilized within the cementitious matrix.
- Iron oxide–rich components of slag strongly sorb metals, such as Cu and Ni, lowering mobility under common environmental conditions.
- Heavy metals within the steel slag will be sequestered by the same mechanisms as the treated soil

Durability

Carbonation and degradation of organic material in sediment treated through S/S with steel slag can experience reduced pore water pH, which may increase the mobility of certain metals, but they also provide notably improved resistance to sulfate attack compared with conventional cement. Overall, long-term evaluations have indicated that steel slag-based S/S approaches maintain generally stable leaching performance despite these durability and environmental considerations.

This brief summarizes findings on Steel Slag Stabilization and Solidification as part of the Industry Assessment for USDOT-SLAG, “Research Initiative on the Use of Steel Slag in Concrete and Cement” under cooperative agreement 693JK42550005. Information supporting these findings can be found at: https://cait.rutgers.edu/usdotsteelslag/publications/. Inquiries about this work can be sent to: usdotsteelslaginitiative@rutgers.edu

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