BOLIDEN HARJAVALTA COPPER AND NICKEL SMELTER - REVIEW OF SMELTER OPERATIONS, SLAGS AND SLAG VALORISATION STUDIES

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Introduction

Boliden is a metal refining company with operations mainly in northern Europe with core competence in the field of mining, smelting and metal recycling. Boliden Harjavalta, located in Finland, operates copper and nickel smelters in Harjavalta. The copper smelter produces annually more than 400 000 tonnes of final slag and the nickel line more than 200 000 tonnes of slag. Part of the nickel slag is utilised as a sand blasting, cement industry and roofing material, but there is no valorisation for copper slag yet. In this paper, Harjavalta smelter operations, mineralogy of copper and nickel slags are described together with the valorisation study results.

Boliden Harjavalta and production of Copper and Nickel

Boliden Harjavalta has a long tradition in Finnish metal industry originating from the early 20th century when Outokumpu orebody was discovered. Currently, our operations consist of copper and nickel flash smelting lines, sulphuric acid plants, and of copper refinery.

Boliden Harjavalta smelts sulfidic copper and nickel concentrates and refines copper in western part of Finland. The copper concentrates come from external copper mines mainly in South America and Europe. Main supplier of nickel concentrates is Boliden Kevitsa mine in Finland.

Boliden Harjavalta has operations in Harjavalta and Pori. The smelter in Harjavalta produces copper anodes that are transported *via* railway to the copper refinery in Pori. The anodes are electro-refined into copper cathodes and by-products like Se, Ag, Au and Pt/Pd concentrate. The nickel smelter smelts nickel concentrates to produce nickel matte for customer needs. SO_2 containing off-gases from both smelters are delivered to the sulphuric acid plant where sulphuric acid and liquid

sulphur dioxide are produced. Figure 1 presents a simplified process flow sheet of Boliden Harjavalta.

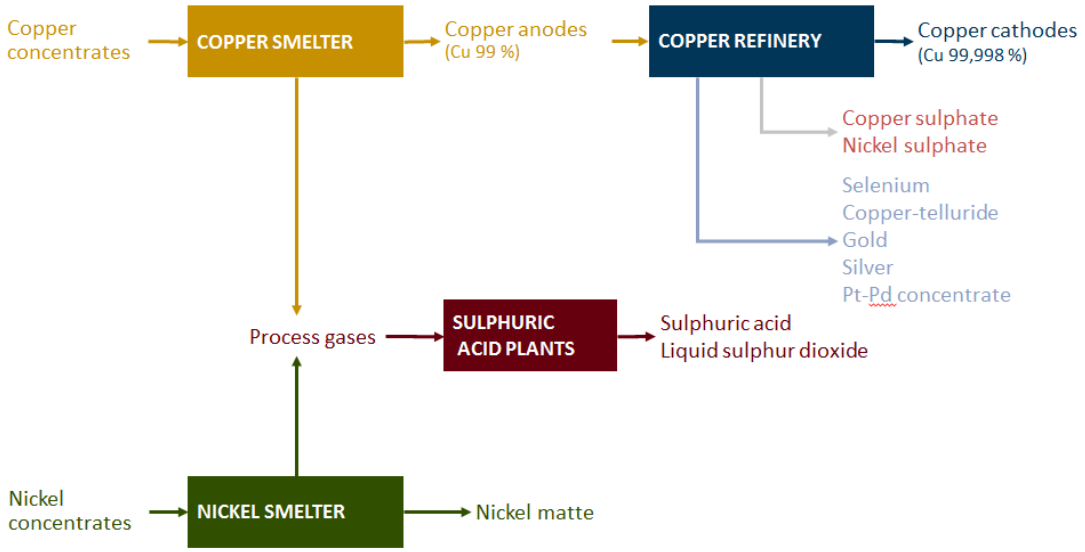

Figure 1: Production chain of Boliden Harjavalta

Formation of slags and mineralogy

Both copper and nickel smelter produce fayalite slag. The slag cleaning method and the properties of the slag differ from each other. In the copper line, there is a concentration plant for recovering copper from flash smelting furnace and converting slags, including two-stage grinding and several froth flotation steps. After the concentrator, the final slag particle size is less than 40 µm (D80). Main phases are fayalite 58%, glass 20%, magnetite 17% and small amounts of chalcosite, copper arsenides, galena and sphalerite.

In the nickel smelter, there is a 8 MW reductive electric furnace for slag cleaning. This electric furnace reduces Ni and Co from flash smelting furnace slag. After electric furnace, nickel slag is granulated with water jets, forming 1.6 mm particles (D80). The mineral composition is glass 64%, fayalite 32%, magnetite 2.5% and small quantities of nickel sulphides and metallic nickel. The chemical composition of copper and nickel slags are shown in Table 1.

Table 1: Chemical composition (wt%) of copper and nickel slag

	Fe	SiO_2	Zn	Pb	MgO	Al_2O_3	CaO
Copper slag	40	32	2.5	0.6			
Nickel slag	40	35	0.06	0.005	6	2.5	1.9

Valorisation studies of Boliden Harjavalta nickel slag

Earlier studies have shown the potential of using fayalite slags as precursor for alkali activated materials.[1-4] Within the Geodesign-project, high-strength alkali-activated concretes have been obtained with our nickel slag as shown in Figure 2 (unpublished results), part of the slag was milled and the rest was original granule. Particle size optimisation software (EMMA Elkem) provided good workability despite the low alkali activator (a mix of NaOH and Na-silicate) to binder ratio (0.10-0.15). The low amount of alkali activator used decreases the environmental impact and costs caused by the alkali activator.

The high specific gravity of the fayalite slag (3500-3900 kg/m^3) increases the density of the alkali-activated concrete (~ 3000 kg/m^3) which may be seen as a negative or positive aspect depending on the application. Pilot-scale tests have proven the possibility to up-scale the process, so alkali activation is seen as a potential valorisation solution for nickel slag (Figure 2).

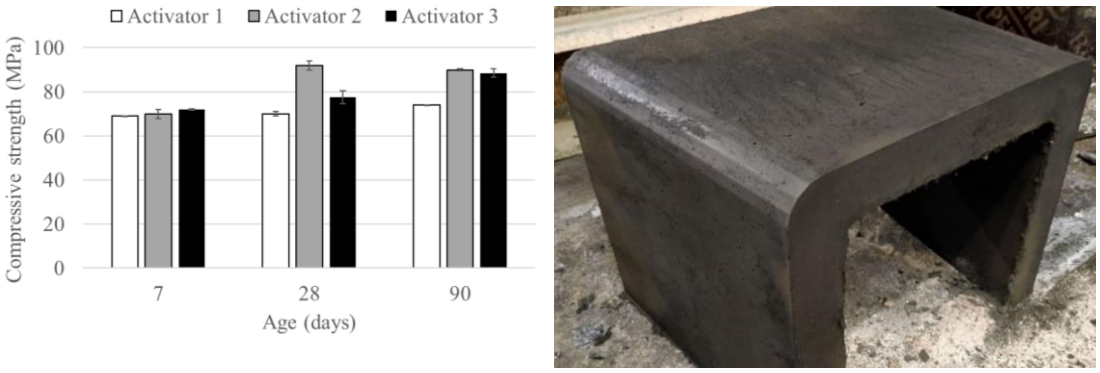

Figure 2: (Left) Compressive strength of alkali-activated nickel slag mortars using different alkali activators (a mix of NaOH and Na-silicate), (Right) In a pilot-scale test alkali-activated concrete bench was manufactured using only nickel slag as precursor

Another option for nickel slag utilisation is the production of ferrite-rich calcium-sulfo aluminate belite (CSAB) cement which is studied in CECIRE project. For CSAB cement production certain ratios of CaO, SiO_2, Fe_2O_3, Al_2O_3 and SO_3 are needed according to Bogue calculation and desired cement phase composition (ye'elimite, belite, ferrite). Ni-slag can be utilised up to 17% (of cement wt%) to replace virgin raw material chemicals if cement ferrite content is 10% (Figure 3). Nickel slag contains other minor components which decrease the mechanical properties of the mortars when compared to reference (100% virgin chemicals). However eco-CSAB cement can be utilised in lower strength applications like earth construction.

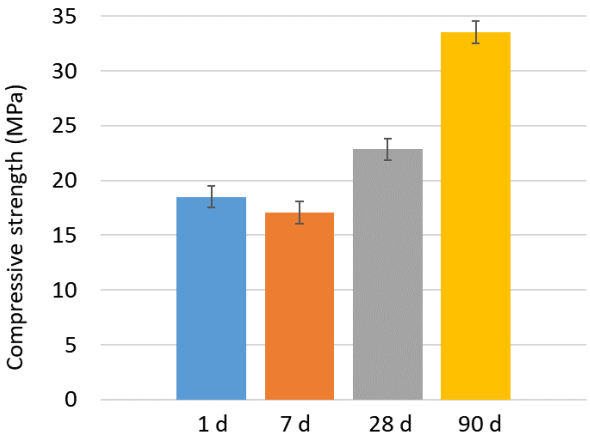

Figure 3: Compressive strengths of mortar samples prepared from CSAB cement containing Ni-slag 17 wt%; for comparison: reference sample has 36 MPa strength at 28 d

Conclusions

Results have shown that nickel slag can be utilised as a raw material for alkali activated concrete (geopolymer) and CSAB-cement. According to the results, high compressive strength geopolymers can be made using nickel slag, optimal alkali activator and optimised particle size distribution. Despite of many projects there are not yet utilisation for copper slag. Boliden Harjavalta has benefited from University collaboration related to slag valorisation. The company is open to new slag valorisation initiatives and proposals from research institutes and from other companies.

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