AL18 - Valorization of Treated Spent Pot Lining By-Product in Concrete

Claudiane Ouellet- Plamondon[1], Victor Brial[2], Hang Tran[3], Luca Sorelli[4], David Conciatori[5], Laurent Birry[6] and Houshang Alamdari[7]

[1]Associate Professor, École de technologie supérieure, Montréal, Canada
[2]PhD Candidate, École de technologie supérieure, Montréal, Canada
[3]PhD Candidate, Université Laval, Québec, Canada
[4]Professor, Université Laval, Québec, Canada
[5]Associate Professor, Université Laval, Québec, Canada
[6]R&D Principal Adviser, Rio Tinto, Saguenay, Canada
[7] Professor, Université Laval, Aluminium Research Centre – REGAL, Québec, Canada
Corresponding author: Claudiane.Ouellet-Plamondon@etsmtl.ca

Abstract

About 20 kt Spent Pot Lining (SPL) is generated by Rio Tinto in Québec each year from aluminum electrolysis cells and listed as industrial hazardous waste. After treatment by the Low Caustic Leaching and Liming (LCL&L) process, the refractory SPL becomes an inert non-hazardous material, called LCLL ash.

The project discussed aims to valorize this by-product into safe supplementary cementitious materials (SCM). This article evaluates the potential of LCLL ash as a supplementary cementitious material with isothermal calorimetry. The expected results of the research project are expected to greatly contribute to the potential for reuse of LCLL ash as part of sustainable concrete, which addresses an important issue for the sustainable development of the combined aluminium, cement and concrete sectors.

Keywords: Primary aluminum production, low caustic leaching liming (LCLL), spent pot lining (SPL) treatment, supplementary cementitious materials, calorimetry, sustainable development, LCLL ash.

1. Introduction

Each tonne of aluminum produced generates approximately 22 kg of spent pot lining (SPL). For Rio Tinto in Québec, nearly 20 000 tonnes of SPL is generated per year. SPL is listed as industrial hazardous waste because it contains significant concentrations of toxic and leachable constituents (cyanide and fluoride) [1]. After treatment in the Low Caustic Leaching and Liming (LCLL) process used in the SPL treatment plant in Jonquière (Quebec), the refractory part of SPL (also called Second Cut) becomes an inert non-hazardous material. This material can be reused and is called LCLL ash. Due to its chemical composition, this industrial by-product has the potential to become supplementary cementitious materials (SCM), which can then be used in the concrete industry to reduce the carbon footprint [2]. Replacing parts of Portland cement by materials that does not require clinkering at high temperature can lead to a significant reduction of CO_2 emissions that is caused by the limestone transformation to CaO and the heating process. Commonly used SCM materials are fly ash from coal combustion and granulated blast furnace slag, a by-product from pig iron production. However, these common SCM materials are becoming less available and they can require long distances for transportation, which impacts the sustainability of its use. Therefore, there is a need to identify new sources of SCM according to local/regional economic activities, which then also becomes a demonstration of a circular economy where the by-products from one industry feed into another industrial sector.

Isothermal calorimetry measures the rate of heat production during cement hydration over time and it is used to assess the reactivity of SCM [3]. This is an exothermic process and the cement clinker is formed of tricalcium silicate (C_3S in cement notation, $3CaO.SiO_2$ in chemical notation), dicalcium silicate (C_2S in cement notation, $2CaO.SiO_2$ in chemical notation), tricalcium aluminate (C_3A in cement notation, $3CaO.Al_2O_3$ in chemical notation) and tetracalcium ferroaluminate (C_4AF, or $4CaO.Al_2O_3Fe_2O_3$) [4]. A small percentage of gypsum ($CaSO_4.2H_2O$) is added to control the aluminate reaction. The heat flow curve developed during the first 20 hours is characterized first by a silicate reaction peak and then a sulfate depletion peak [5]. The C3A dissolution is visible in the sulfate depletion peak, which is indicative of the aluminum reaction in the hydration process.

The project aims to valorize the refractory part of SPL after it is treated by the LCLL process at the Rio Tinto treatment plant into safe supplementary cementitious materials (SCM) called LCLL ash. The innovation is to identify the conditions for safe and optimized use of LCLL ash into Portland cement and to develop new industry expertise. The first step is to identify the effect of the LCLL ash on cement hydration. In this study, we studied the effect that particle size and proportion of LCLL ash have on cement hydration. We compared LCLL ash with both fly ash and limestone filler. Quartz was also selected as a comparative inert material. This assessment will help guide potential end users to the optimum conditions to include LCLL ash into sustainable concrete.

2. Materials and Methods

2.1. Materials

In this study, the main raw material considered is LCLL ash is produced at the Rio Tinto treatment plant located in Jonquière, QC, Canada. On average 10 000 tonnes per year of LCLL ash are produced in this plant. A standard type Portland cement (Type GU, Ciment Quebec, St Basile, QC, Canada) was used in the calorimetry tests. The LCLL ash was compared to fly ash, CV (Class F fly ash, Ciment Quebec, Laval, QC, Canada). Furthermore, two inert materials were used, a limestone filler, FC (Pulverized limestone, Ciment Québec, St Basile, QC, Canada) and a quartz powder Q made by grinding graded Ottawa sand. These materials were chosen to access a potential pozzolanic reactivity of LCLL ash by comparing it to the heat released of reactive and inert SCMs. The LCLL ash was calcined by placing 10 g of LCLL ash in an alumina crucible at 1000 °C for 1 h in a muffle furnace. The chemical composition of cement used for the blended mixes and SCM was measured by X-ray fluorescence (XRF) bed fusion and the results are shown in Table 1.

For each material, the particle size distribution (PSD) was measured using Malvern Mastersizer\E by laser diffraction granulometry with isopropanol as the dispersant. The particle size distributions are presented in Figure 1. To study the effect of the PSD of LCLL ash on cement, three granulometries were studied: G0 (ungrounded), G1 and G2 ground with a planetary grinder to reach a d50 of 7.5 μm and 4 μm respectively.

5. References

1. Laurent Birry, Stéphane Poirier and Simon Leclerc, The LCL&L process: A sustainable Solution for the Treatment and Recycling of Spent Potlining, *Proceedings of 34th International ICSOBA Conference,* 3-6 October 2016: Québec, Canada, Paper AL23, *Travaux* 45, 705-712.
2. B. Lothenbach, K. Scrivener and R.D. Hooton, Supplementary cementitious materials, *Cement and Concrete Research,* 2011 **41**(12), 1244-1256.
3. L. Wadsö et al., Chaper 2 Calorimetry, in A Practical Guide to Microstructural Analysis of Cementitious Materials, K. Scrivener, R. Snellings, and B. Lothenbach, Editors, 2017, *CRC Press,* New York, 37-74.
4. M. Pigeon, Composition and hydration of Portland cement, *ACI Progress in Concrete,* 1981, 36-72.
5. D. Jansen et al., The early hydration of Ordinary Portland Cement (OPC): An approach comparing measured heat flow with calculated heat flow from QXRD, *Cement and Concrete Research*, 2012 **42**(1), 134-138.