Valorization of Treated Spend Pot Lining Byproduct from the Primary Aluminum Production as Supplementary Cementitious Materials

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Abstract

About 22 kg of spent pot lining (SPL) is generated per tonne of aluminium from electrolysis cells and listed as industrial hazardous waste. After the hydrometallurgical treatment in the Low Caustic Leaching and Liming (LCL&L) process, the refractory part of SPL is separated and becomes an inert non-hazardous material, called LCLL ash. This article presents the conditions for LCLL ash to be a suitable supplementary cementitious material (SCM) for use in the production of concrete. Multiple tests, including Frattini test, Rilem R3 and XRD, are used to evaluate the reactivity of LCLL ash and calcined LCLL ash. The rheology and mechanical properties of concrete with LCLL ash as SCM were determined for the optimum conditions. The results also showed that the utilization of LCLL ash is feasible to use in ultrahigh performance concrete with acceptable flow and strength. In addition, the LCLL ash can potentially be also used in mine backfill production. This makes that LCLL ash, a by-product from primary aluminum production, has several promising valorization avenues in the applications of cement and concrete.

Keywords: Aluminum primary production, Low Caustic Leaching & Liming, Treated spent pot lining (SPL), Calcination, Supplementary cementitious materials (SCM), Ultra-high-performance concrete (UHPC).

1. Introduction

The production of primary aluminium generates about 22 kg of spent pot lining (SPL) per tonne of aluminium from electrolysis cells. Because of its nature and properties SPL is listed as industrial hazardous waste and has to be treated in a special process such as the LCLL process developed by Rio Tinto. During the hydrometallurgical treatment by the Low Caustic Leaching and Liming (LCL&L) process, the refractory part of SPL becomes an inert non-hazardous material, called LCLL ash. This LCLL ash material has the potential to be used as supplementary cementitious materials (SCM) in the production of concrete and backfill. Cement production is known to generate 4-8% of global carbon emissions [1]. Globally endeavors are taking place to reduce the use of cement in concrete mixes. This article presents the conditions for LCLL ash to be a suitable SCM for applications in concrete, ultrahigh resistance concrete (UHPC), and mining backfill. The summary of the results to evaluate the reactivity of LCLL ash and calcined LCLL ash is explained. More details are found in a recent article [2]. The compressive strength and the flow table values of the designed UHPC mixtures were measured to find the optimum dosage of LCLL ash. First recipes of LCLL ash were tested for cemented paste backfill for mining.

2. Materials and methods

2.1 Materials

In this study, the LCLL Ash comes from the Rio Tinto SPL treatment plant based in Jonquière, QC, Canada. For the rest of the paper, LCLL will refer to LCLL Ash. Different materials were used for this study: plain Portland cement (OPC), two fly ashes type F (FA-E and FA-PA), slag from blast furnaces (GGBS), blue silica fume (SF), limestone filler (FC) and quartz powder (Q). The chemical composition of the materials tested, was measured in anhydrous conditions by X-ray fluorescence (XRF), see results in Table 1.

Table 1. Chemical composition of cement and SCMs used.

Oxide	Percentage in weight (wt%)								
	OPC	**FC**	**SF**	**LCLL ash**	**Calcined LCLL ash**	**Q**	**FA-E**	**FA-PA**	**GGBS**
SiO_2	19.17	2.21	96.48	37.18	38.83	91.40	58.53	58.54	38.64
Al_2O_3	4.69	0.37	0.48	36.29	36.57	4.94	19.64	20.91	10.28
Fe_2O_3	3.61	0.14	0.45	7.36	8.59	1.72	5.89	7.23	2.13
CaO	61.52	53.57	0.35	3.04	4.00	0.55	5.54	3.60	35.69
MgO	2.40	0.51	0.41	0.38	0.39	0.04	2.01	1.96	8.82
SO_3	3.98	0.10	0.08	0.06	0.12	0.00	0.21	0.14	2.08
K_2O	1.06	0.13	0.66	0.77	0.79	0.10	1.91	2.35	0.78
Na_2O	0.25	0.02	0.11	8.23	8.03	1.09	1.03	1.10	0.43
TiO_2	0.25	0.01	0.00	0.75	0.78	0.10	0.82	0.90	0.56
P_2O_5	0.14	0.01	0.10	0.12	0.10	0.01	0.58	0.21	0.04
V_2O_5	0.01	0.00	0.00	0.03	0.03	0.01	0.04	0.69	0.11
LOI at 1000° C	2.62	42.89	0.56	5.72	1.11	0.00	3.63	2.89	0.13

LCLL ash was provided by Rio Tinto Quebec. To increase the LCLL ash reactivity, an additional treatment was made by calcination of the LCLL ash at 1050°C for 2h in an alumina crucible. For UHPC testing, LCLL ash was ground as fineness of cement and was used as a cement substitution by 0 %, 6 % and 12 % by weight.

2.2 Reactivity testing of SCM

The procedure to evaluate the reactivity of the LCLL ash required to be used as supplementary cementitious materials is summarized in the figure 1. Frattini test was carried out to evaluate the pozzolanic reactivity, following the procedures in [3], [4]. This test evaluates the reactivity of SCM alumino-silicate phases with the portlandite to precipitates more hydrates. R^3 tests are based on a mix that recreates the chemical behavior of limestone cement, without cement particles [5]. The heat generated by the precipitation of hydrates was measured by isothermal calorimetry and the consumption of portlandite was measured by thermogravimetrically analysis (ATG). The

3.3 LCLL ash for mine backfilling

Figure 4 shows the mechanical behavior of cemented paste backfill produced with LCLL ash and without it. By applying a normal compressive stress on the sample, the maximum strength is 950 kPa for 80S+20GU, 537 kPa for 60S+20LCLLash+20GU and lower at 405 kPa for 100 GU. The mix with LCLL ash is better than only general use cement, but still not as good as the mix with only slag and cement. More research is better to improve the mix design.

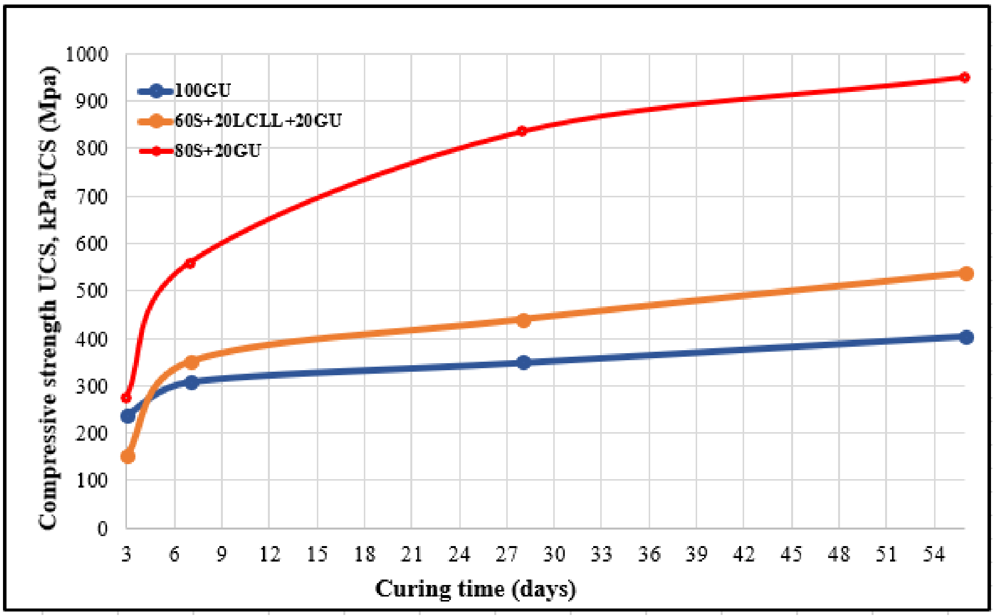

Figure 4. Measurement of uniaxial stresses of samples

4. Conclusion

In summary, the LCLL ash that is generated from the LCLL process for treatment spent pot lining from primary aluminum production, is lightly reactive. Calcination of the material improves its reactivity and that makes it potentially a suitable cementitious material to replace Portland cement in concrete. In ultrahigh performance concrete, LCLL ash can replace cement up to 12 % with no detrimental effect on acceptable strength and flowability. A mix design of cemented paste backfill with LCLL is still under investigation to find the optimum dosage. For this application there is no firm conclusion yet.

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