Summary report regarding use of aluminium oxide (Norox) as a raw material at Padeswood

Introduction

In December 2021 Hanson Cement, Padeswood works, asked permission from Natural Resources Wales, NRW, to trial the use of aluminium oxide as a raw material for the production of cement clinker in place of lagoon pfa. Permission was granted for a 1000 tonne trial to be conducted with a request for a summary report to be prepared outlining the results of that trial.

Trial results

The trial use of aluminium oxide commenced at 0800 on 2nd February 2022. The raw meal manufactured with the aluminium oxide was milled in to silo L2 and initially 'split fed' to the kiln with meal from silo L1 that had been produced with lagoon pfa. By the evening of the 2nd February, sufficient stock of meal made with aluminium oxide was available to allow for feeding of meal from silo L2 only. The trial has continued, with some minor interruptions related to logistics of having material delivered to site, through to the 4th February. In that time around 550 tonnes of the 1000 tonnes permitted have been used.

In the documentation supplied to NRW outlining how the trial would be conducted Hanson Cement identified a number of parameters that could be affected by the use of aluminium oxide in place of lagoon pfa. The table is reproduced below together with observations of what has actually occurred.

Parameter	**Expected Changes**	**Observed Changes**
Raw Mill Throughput	Decreased	Increased
Raw Mill Differential Pressure	To be monitored	Unchanged
Raw Mill motor power	Increased	Decreased
Raw Mill BC02 power	Unchanged	Unchanged
Cyclone temperatures	Lower, C5 maintained	Lower, C5 within range
Carbon Monoxide – top of tower	Reduced	Reduced
Cyclone 5 top temperature	Unchanged	Unchanged
Coal input to calciner	Unchanged	Chloride plan initiated due to lack of bypass, so increased
SRF input to calciner	Unchanged	Chloride plan initiated due to lack of bypass, no alternative fuels
Fuel inputs to burner	Unchanged	Chloride plan initiated due to lack of bypass, so increased coal no alternative fuels
Kiln shell temperature	Unchanged	Decreased

I.D. fan speed	Potentially reduced	Unchanged
FN04 speed	Potentially reduced	Unchanged
GCT operation	Reduced water consumption	Reduced water consumption

Comments

It was anticipated that the raw mill throughput would decrease due to additional sand being required in the meal to maintain the correct chemistry (sand is difficult to grind). However, the raw mill throughput actually increased as a result of the mill power reducing when aluminium oxide is used, allowing for more grinding pressure to be applied and better grinding bed stability.

As expected, the removal of lagoon pfa from the raw meal resulted in a reduction of the temperatures of the cyclones with the temperature of the outlet of cyclone 1, the topmost cyclone reducing from 460^{O}C to 390^{O}C. The reduction is a result of no unburnt carbon in the lagoon pfa being introduced to the preheater tower as part of the raw meal mix. This has also had a positive effect on the concentration of carbon monoxide (CO) in the preheater tower with lower CO concentration being detected at the top of the tower and a reduction in CO measured by the kiln stack CEM analyser.

The kiln shell temperature reduced rather than increased due to a good coating being formed in the kiln. The coating will be a result of the improved burnability of the meal which should be reflected in a lower specific heat consumption.

Prior to the use of aluminium oxide commencing, alternative fuels had been in use. These had to be stopped during the use of the aluminium oxide due to an increase in clinker chloride and no bypass being available (the new bypass system is currently under construction). The use of aluminium oxide was not a contributary factor to the increase in clinker chloride but a process related condition prior to starting the trial.

Raw meal and clinker samples have shown more variability using aluminium oxide compared to lagoon pfa. Some of this will be due to the interruptions in supply of aluminium oxide mentioned previously. The trial identified minor modifications to the sand and pfa/aluminium oxide feeders being required and these have been actioned. It is anticipated that the variability will be removed and the clinker will be similar in composition to that made with lagoon pfa. Continued use of aluminium oxide is now required to tune the feeders. A proposal to extend the trial is at the end of this report.

Continuous emission monitor data

The table below shows the normalised emission data taken from the CEMs analyser in the kiln stack for week commencing 31 January. The values highlighted in yellow indicate days when aluminium oxide has been used in the process.

	Dust	SO_2	NO_X	TOC	HCl	CO	NH_3
ELV	10	200	450	50	10	1200	70
31 Jan	2	7	403	17	1	628	13
1 Feb	2	24	400	22	2	654	13
2 Feb	2	13	406	20	1	583	26
3 Feb	3	10	414	20	1	457	28

The results indicate that the use of aluminium oxide has no detrimental effect on emissions of particulates, sulfur dioxide, nitrous oxides, TOC, and hydrogen chloride. The use of aluminium oxide has had a positive effect on emissions of CO due to the reduction in carbon fed to the preheater tower. The increase in ammonia emission is due to the presence of small quantities of ammonia in the aluminium oxide. The ammonia is driven out of the aluminium oxide in the raw mill when the materials are dried and is not related to ammonia slip from the SNCR NOx abatement equipment.

Conclusion

The initial data and observation show that aluminium oxide has had a positive effect on the operation of the raw mill, reduced power consumption and increased throughput.

It also appears to have a positive impact on kiln operations. There was a clearly observable reduction in cyclone and top of tower temperatures. There was also a noticeable reduction in kiln shell temperature and reduced CO emissions in the top of tower.

To confirm these initial findings Hanson Cement intend to continue the trial and utilise the 1000 tonnes that permission was given for. Following this we propose to extend the trial and use the remaining 2200 tonnes, approx., that we have access to in order to demonstrate more fully the benefits of aluminium oxide as a raw material in comparison to lagoon pfa.

Use of Norox as a raw material, updated report - w/c 8th August at 10am

Approval to use up to 3200 tonnes of Norox requested above was granted on 8th February 2022, however, the use of the material did not start immediately as the findings from the initial use indicated two key parameters that required improvement prior to recommencement:

1. Improvement in chloride management in the preheater tower (PHT)
2. Improvement to the raw meal chemistry control

The site has a chloride management plan which is triggered when chloride is present at high levels in either hot meal or clinker. The plan is in place to prevent blockages in the PHT and control the chloride concentration in the finished product. This plan was triggered several times on the initial trial due to no operational bypass system. Since the trial, the new bypass system has been commissioned and optimised and has demonstrated efficient control of chlorides in the kiln system.

As stated in the initial report, the raw meal chemistry exhibited more variability when using Norox than PFA. Options to improve control were reviewed and following the review, the site purchased an automated fused bead machine.

The raw meal is analysed using an x-ray spectrometer using pressed powder pellets. This analysis is used to set the feed rates of the raw mill feeders to achieve the required raw meal chemistry to produce clinker of the correct quality. This is a cost-effective, straightforward means of controlling chemistry. A more accurate method is by means of fusion where the raw meal is melted in a furnace together with a flux to make a 'glass bead' which is then analysed in the x-ray spectrometer. However, this accuracy comes at a cost since automation and consumables for this technique are relatively more expensive. Although expensive, the decision was made to purchase a fused bead machine, with installation and commissioning completed on 3rd August. Following this the site was ready to use Norox again.

At 10 a.m. on 8th August 2022 the change from PFA to Norox was initiated. Manual setpoints were applied to the raw mill feeders calculated from the known chemistry of the individual raw materials. Once the raw mill was settled and the new meal analysed, the raw meal control was changed to automatic control.

As in the initial trial, the feed to the kiln was 'split fed' and this continued for approx. 48 hours. Once demonstrated that the raw meal was consistent, Norox only raw meal was fed to the kiln from the evening of 10th August.

The kiln has run on full Norox raw meal since 10th August and clinker quality has been excellent, process parameters have all been in expected ranges and the environmental improvements have been shown once again.

The table below shows the latest CEMs data:

Source	Dust	SO2	NOx	TOC	HCL	CO	NH3
Date	(mg/Nm3)	(mg/Nm3)	(mg/Nm3)	(mg/Nm3)	(mg/Nm3)	(mg/Nm3)	(mg/Nm3)
Emission limit value	**10**	**200**	**450**	**50**	**10**	**1200**	**70**
01/08/2022	2	21	416	23	1	423	7
02/08/2022	2	22	410	29	2	492	9
03/08/2022	2	20	410	27	2	519	8
04/08/2022	2	13	411	31	0	520	10
05/08/2022	1	9	411	25	2	515	8
06/08/2022	2	10	410	25	3	541	10
07/08/2022	2	18	410	30	3	486	10
08/08/2022	2	11	412	25	2	354	14
09/08/2022	2	10	410	30	2	322	14
10/08/2022	2	10	409	26	2	267	16
11/08/2022	2	13	397	30	2	355	16
12/08/2022	2	10	409	31	1	265	18
13/08/2022	2	8	413	30	1	261	20
14/08/2022	2	9	415	32	2	263	18
15/08/2022	2	9	411	29	2	246	17

Daily averages for the 8th and 9th August are from the split feed of Norox and PFA raw meal. Data from the 10th is Norox only raw meal. There have been no breaches of any of the continuously monitored ELV's whilst using Norox as a raw material.

Initial estimates indicate that emissions of carbon dioxide will reduce by 12,000 tonnes per year based on typical clinker production when using Norox. This estimate is based upon the difference in the content of the organic carbon of the Norox and the pulverised fuel ash that it replaces. Additionally, there will be a reduction in carbon dioxide of approximately 600 tonnes per year due to the reduced emission of carbon monoxide from the kiln stack when processing Norox. Exact data will be produced for emissions trading and the annual Pollution Inventory.

It has not been possible to carry out extractive testing of the kiln emissions, however, this is planned for week commencing 5th September. At this time, it is anticipated that a reduction in the mercury emission will be seen due to the elimination of pulverised fuel ash from the raw materials.

The screenshot below shows the change in temperature of the top cyclone. When PFA raw meal was in use, a typical temperature was between 450 and 460°C. During the transition to the norox raw meal it can been seen that the temperature reduces and has stabilised around 410°C. Although not quite the same temperature reducing as the initial trial, this is conclusive of the energy efficiency that is achieved with the use of Norox.

The table below shows the typical composition of the raw meal with pfa and with Norox.

	As received	
	%	%
Limestone	74.5	76.8
PFA	15.6	0
Norox	0	4.4
Sand	9.2	16.5
Iron	0.7	2.3
Sum	100	100

The increase in the use of sand as a raw material is due to the Norox being very much higher in alumina content and lower in silica content than the pfa.

Following the success of the above trials, Padeswood Works will be submitting a permit variation to NRW for the permanent use of Norox. Whilst the application is being written we propose to continue to use the material and are asking for approval from NRW for this. As mentioned previously, extractive stack testing is currently scheduled for week commencing 5th September and if approval is given to continue to use Norox, the site can have a complete set of data for review in quarter 4 this year.