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BRE Client Report

Testing of physical and chemical properties of a generic sample of natural pozzolan against tests in BS EN 450-1

Prepared for: EMC Cement

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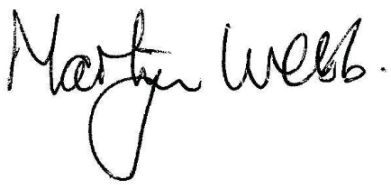
Signature 

Executive Summary

BRE was commissioned in February 2017 to independently undertake physical and chemical testing of a single bulk sample of one generic natural pozzolan using the performance tests referred to in BS EN 450-1 (fly ash for concrete). The objective of the work was to establish whether the material complies with this standard.

1) Where there are upper or lower limiting values specified in BS EN 450-1, the material complied with all these limits.

2) In addition, the material has a reactive silica content that exceeds the requirements (lower limit) given for pozzolanic materials in the standard for Common Cements (EN 197-1).

3) Supporting testing has confirmed that the material supplied by the client is consistent with its claimed origin as a natural pozzolana having a volcanic origin.

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Table of Contents

1 Introduction

BRE has been commissioned by EMC Cement to undertake physical and chemical testing of a bulk sample of a generic natural pozzolan. The material's performance has been assessed in tests referred to in BS EN 450-1 [1] and also, the supplementary tests listed in Section 2.2. The material assessed was selected by the client and is understood to comprise natural pozzolan(s) of a volcanic or sedimentary nature.

BRE was required to independently generate chemical and physical characterisation data for the generic sample of this natural pozzolanic material (using tests detailed in BS EN 450-1) to establish whether it complies with this standard.

2 Description of the project

2.1 General approach and material provided

The chemical and physical testing has been carried out by an external laboratory under the direction of BRE to characterise a sub- sample of the generic pozzolan (which was sampled and sent to BRE by the client). This testing was carried out to benchmark the physical and chemical properties of the material against those in/referred to in BS EN 450-1. BRE's assessment has also included additional testing (a full oxide analysis using XRF- (x-ray fluorescence) and a visual assessment). The material was also viewed with a scanning electron microscope (SEM) to verify that the material supplied by the client is consistent with its claimed origin as a natural pozzolan.

One bulk sample (provided by the client) was assessed. Brief information on the material is provided in Table 1.

Table 1: Details of the bulk sample of pozzolan provided to BRE

Client's sample marking	Date received at BRE (and sub-sample references)	Approx. mass of sample provided by client (kg)	Approx. mass of sub-sample submitted by BRE to laboratory for testing (kg)	BRE visual assessment
LLA-EC-9559255 316912278-01	14th February 2017 (BRE 106756) (P107550)	14.50	3.56	Pale grey powder

The client had specifically requested a testing program built upon BS EN 450-1 requirements and including the specific determinations listed under Section 2.2 of this report.

This report is provided by BRE for use by the client in accordance with the BRE Terms and Conditions. It relates to the bulk sample provided. It does not include advocating use of the pozzolan more generally or guaranteeing the continued performance of the material with external bodies.

2.2 Test methods

The chemical and physical characterisation tests to BS EN 450-1 were sub-contracted (under the project management of the author of this BRE report), to an external laboratory. The testing laboratory is in the UK, is UKAS accredited and works to British technical excellence standards.

The following test methods have been applied by the laboratory to the representative sub-sample (sampled by Dr Andrew Dunster):

- Chemical tests referred to in BS EN 450-1 for:
  - Free CaO [1]
  - Loss on ignition [2]
  - Sum of contents of SiO_2, Al_2O_3 and Fe_2O_3 [2]
  - Total content of alkalis [2]
  - Reactive SiO_2 (in accordance with EN 197-1, Section 3.2) [3]
  - SO_3 [2]
  - Cl^- [2]
  - Reactive CaO [3]
  - MgO (EN 196-2) [2]
  - Soluble phosphate (Annex C of BS EN 450-1) [1]

- Physical tests referred to in BS EN 450 for:
  - Activity Index (7, 28 and 90 days) [4]
  - Initial setting time [6]
  - Fineness (sieving) [5]
  - Soundness [6]
  - Particle density [7]
  - Water requirement [1]

- A full oxide analysis using XRF

3 Findings

3.1 Results of chemical and physical tests

Table 2 shows the results of chemical and physical tests. Where there are upper or lower limiting values specified in BS EN 450, the material complied with these limits.

- Upper limit values (free CaO, loss on ignition, total content of alkalies, sulfate, chloride, reactive CaO, MgO, soluble phosphate, initial setting time, fineness, soundness, water requirement.
- Lower limit values (reactive silica, activity index).
- The material complied with Category A for loss on ignition and Category S for fineness.

Table 3 shows supporting data (e.g. water volumes used for the water demand test, actual setting times) in support of the data included in Table 2.

The following tests referred to in BS EN 450-1 (BS EN 450 Part 1: Fly ash for concrete: Definition, specifications and conformity criteria)	Test method applied	Other comments (if any)	Limit (BS EN 450)	BS EN 450	Test result: Sample P107550	Pass or fail
Free CaO	EN 451-1		2.6% max	Upper limit value	0.26	P
Loss on ignition	EN196-2	Ignition time of 1 hour	5.0% Cat A 7.0% Cat B	Upper limit value	4.96	P
Sum of contents of SiO_2, Al_2O_3 and Fe_2O_3	EN 196-2	Modified as indicated in 5.2.1	65% min	Lower limit value	82.96	P
Total content of alkalis	EN 196-2		5.5% max	Upper limit value	5.28	P
Reactive SiO_2 (shall be analysed in accordance with EN 197-1, section 3.2)	EN197-1, section 3.2		22% min	Lower limit value	51.04	P
SO_3	EN 196-2		3.5% max	Upper limit value	0.14	p
Cl-	EN 196-2		0.10% max	Upper limit value	0.02	p
Reactive CaO	EN 197-1: 2011, section 3.1		11% as react. CaO	Upper limit value	8.19	p
MgO (EN 196-2)	EN 196-2		4.5% max	Upper limit value	0.55	p
Soluble phosphate (Annex C of BS EN 450-1)	Annex C of BS EN 450-1		110 mg/kg max	Upper limit value	31.27	p
Activity Index (7 days)	EN 196-1	Intermediate test at 7 days age carried out (not required by BS EN 450-1)	none specified	limit value not defined	71.8	n/a
Activity Index (28 days)	EN 196-1		70% min	Lower limit value	89	p
Activity Index (90 days)	EN 196-1		80% min	Lower limit value	96	p
Initial setting time (PC reference)	EN 196-3		mins (none specified)		160	n/a
Initial setting time (Test mix)	EN 196-3		mins (none specified)		200	n/a
Initial setting time (multiple)	EN 196-3		2.0 max	Upper limit value	1.3	p
Fineness (sieving)	EN 451-2 (wet sieving) or EN 933-10 (air jet sieving)	As available to lab	45% CAT N 13% CAT S	Upper limit value	5.87	Pass (Cat S)
Soundness	EN 196-3	Determined. However, determination not required by standard as free lime < 1.0%	11 mm	Upper limit value	1.0	p
Particle density	EN 1097-7		none specified	Declared	2360	n/a
Water requirement	Annex B of BS EN 450-1		97% max	Upper limit value	94.7	p
A full oxide analysis using XRF		See Table 4.				

Table 2: Test methods and results

Table 3: Supporting data for water demand and strength activity tests

Property	Parameter	Result
Water demand	Water in 30% pozzolan mix (cm^3)	213
	Flow of 30% pozzolan mix (mm)	182
	Water requirement (wt %)	94.7
Strength (7 days)	Strength of PC control (7 days, N/mm^2)	45.1
	Strength of PC pozzolan mix (7 days, N/mm^2)	32.4
	Activity index (7 days, %)	71.8
Strength (28 days)	Strength of PC control (28 days, N/mm^2)	54.4
	Strength of pozzolan mix (28 days, N/mm^2)	48.4
	Activity index (28 days, %)	89
Strength (90 days)	Strength of PC control (90 days, N/mm^2)	64.3
	Strength of pozzolan mix (90 days, N/mm^2)	62.0
	Activity index (90 days, %)	96

3.2 Oxide analysis (XRF)

Table shows the results of a full oxide analysis using XRF. The results for major oxides (CaO, SiO_2, Al_2O_3, Fe_2O_3), are consistent with other published data for oxide analysis of natural pozzolans derived from volcanic glasses (for example [8])

Table 4: Oxide analysis of pozzolan

	wt%
Total CaO	4.43
SiO_2	66.36
Al_2O_3	14.58
Fe_2O_3	2.02
Na_2O	2.62
K_2O	4.04
MgO	5.28
Total P_2O_5	0.55
SO_3	0.14
Sum	100.02

3.3 Verification of sample identity

BRE (as part of their own due diligence) has independently verified the characteristics of a sub-sample (taken from the bulk sample of the material provided by the client) using Scanning Electron Microscopy (SEM). We can confirm that the appearance of the sample was consistent with it having undergone a grinding process. The sample contained a high proportion of amorphous (glassy) material with spherical particles consistent with a volcanic origin, formed during the ejection of lava from a vent, whilst the grains displaying conchoidal (brittle) fracturing are fragments of the walls of glassy bubbles of lava. This is consistent with the material being a processed product derived from a volcanic ash.

3.4 Results in the context of BS EN 197-1

Clause 5.2.3.1 of BS EN 197-1: 2011[3] indicates that the reactive silicon dioxide content of a pozzolanic material conforming with the standard shall be not less than 25.0 % by mass. According to Clause 5.2.3.2, natural pozzolanas are usually materials of volcanic origin or sedimentary rocks with suitable chemical and mineralogical composition and shall conform to 5.2.3.1. *We can confirm that the reactive silicon dioxide content of the sample provided (51.04 %), exceeds the minimum requirement of 25 % specified for pozzolanic materials in BS EN 197-1.*

4 Conclusion and recommendations

1) A single bulk sample of generic material understood to be a natural pozzolan has been provided to BRE by the client. BRE has characterised this using physical and chemical testing and compared the results with limits given in the standard for fly ash, BS EN 450-1.

2) Where there are upper or lower limiting values specified in BS EN 450, the material complied with all these limits.

3) The material also has a reactive silica content that exceeds the requirements (lower limit) given for pozzolanic materials in the standard for Common Cements (EN 197-1).

4) BRE's own due diligence confirms that the material supplied is consistent with its claimed origin as a natural pozzolana from a volcanic origin.

5 References

[1] BS EN 450 Part 1: Fly ash for concrete: Definition, specifications and conformity criteria.

[2] EN 196-2: 2013 Method of testing cement. Chemical analysis of cement.

[3] EN 197-1: 2011. Cement Part 1: Composition, specifications and conformity criteria for common cements.

[4] EN196-1: 2016. Methods of testing cement. Determination of strength.

[5] EN 451-2: 1995 Method of testing fly ash. Determination of fineness by wet sieving.

[6] EN196-3: 2016. Methods of testing cement. Determination of setting times and soundness.

[7] EN 1097-7: 2008. Tests for mechanical and physical properties of aggregates. Determination of the particle density of filler. Pyknometer method.

[8] Chapter 10 of: Concrete Admixtures Handbook, Properties, Science and Technology. Second Edition. VS Ramachandran (ed). Noyes Publications, (USA). 1995.

Appendix A Images

Figure A1: The material as received.

Figure A2: A sub-sample of the material on white paper sheet.