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Powering up pozzolans

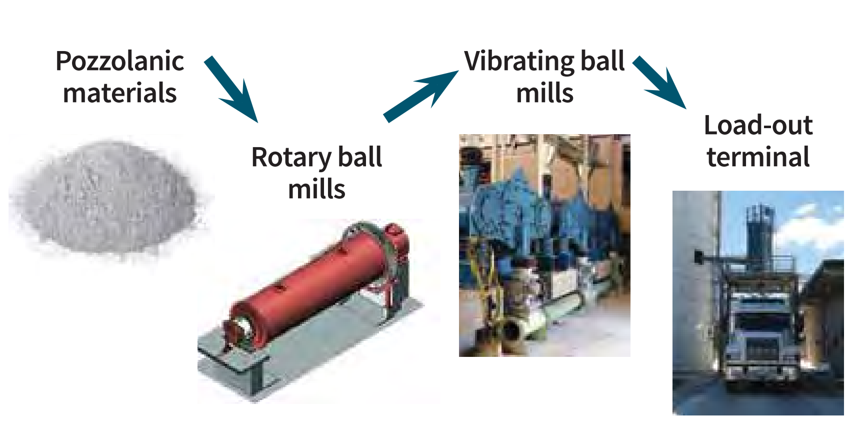
The use of blended cements including pozzolans can make a significant contribution to reducing CO_2 emissions and new technology is able to increase the substitution rate of pozzolans while improving concrete durability. EMC Technology uses a low-energy, all-electric mechanical activation process to improve the performance of pozzolans.

Over 90 per cent of CO_2 emissions released by cement production come from a combination of the natural release of imbedded carbon in the limestone raw material as it is being heated to 1450˚C in the clinker production process. Therefore, reducing process emissions of cement production hinges upon reducing the amount of clinker in cement, according to the Battelle Memorial Institute's report "Toward a Sustainable Cement Industry".

The substitution of clinker by supplementary cementitious materials (SCMs) is one way of reducing CO_2 emissions from cement production. EMC Technology manufactures SCMs from globally-abundant natural (volcanic) pozzolans and therefore, can substitute up to 70 per cent of ordinary Portland cement (OPC). This compares to a 15-20 per cent substitution rate for a similar performance if the volcanic pozzolan has not been subjected to EMC Technology.

Raw materials other than volcanic ash can also be used: fly ash has similar chemical characteristics to volcanic ash.

Figure 1: EMC process flow



Focus on volcanic ash

While a range of raw materials can be used, EMC focuses on volcanic ash because it is different from other SCMs such as fly ash and ground granulated blastfurnace slag (GGBS):

- It is the result of naturally-occurring volcanic eruptions in the world, while fly ash and GGBS are byproducts of coal-fired power plant and steel mill operations, respectively – leading sources of CO_2 emissions.
- A total of ~70tnt of volcanic ash has been deposited in the past 2.5m years, and only from very large eruptions (ref eg Bristol University/Smithsonian Institution – www.bgs.ac.uk/vogripa/view/controller.cfc?method=lameve). Thus, although significant volumes have been lost, eg fallen into the oceans, volcanic ash production is expected to be sufficiently abundant to be considered a permanent solution.
- In contrast, annual production of fly ash and GGBS is each counted in hundreds of millions tonnes and in decline. Therefore they cannot offer a long-term solution.
- The exceptional durability features of high-level volcanic ash use has been demonstrated over 2000 years by way of the famous construction works executed by Roman Empire engineers and builders.

The use of EMC-based concrete helps to reduce CO_2 emissions in road construction

Process overview

Widely-patented EMC Technology uses a low-energy, all-electric, two-step mechanical activation process:

Table 1: summary of chemical and physical tests according to EN 450-1, performed by BRE						
Ranking	**Test method applied**	**Comments**	**Limit (BS EN 450)**	**BS EN 450 limit value**	**Result**	**Pass/ fail**
Free CaO	EN 451-1		2.6% max	Upper	0.26	P
Loss on ignition	EN 196-2	Ignition time: 1h	5.0% Cat A 7.0% Cat B	Upper	4.96	P
Sum of contents of SiO_2, Al_2O_3 and Fe_2O_3	EN 196-2		65% min	Lower	82.96	P
Total content of alkalis	EN 196-2		5.5% max	Upper	5.28	P
Reactive SiO_2	EN 197-1, section 3.2		22% min	Lower	51.04	P
SO_3	EN 196-2		3.5% max	Upper	0.14	P
Cl-	EN 196-2		0.10% max	Upper	0.02	P
Reactive CaO	EN 197-1: 2011, section 3.1		11% as react. CaO	Upper	8.19	P
MgO (EN 196-2)	EN 196-2		4.5% max	Upper	0.55	P
Soluble phosphate	Annex C of BS EN 450-1		110 mg/kg max	Upper	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	Not defined	71.8	n/a
Activity Index (28 days)	EN 196-1		70% min	Lower	89	P
Activity Index (90 days)	EN 196-1		80% min	Lower	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	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	5.87	"Pass (Cat S)"
Soundness	EN 196-3	Determined. However, determination not required by standard as free lime < 1.0%	11 mm	Upper	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	94.7	P
A full oxide analysis using XRF		See Table 2				

- Step 1 – crushed and dried natural pozzolans are processed in rotary ball mills to achieve the required particle size distribution of the material
- Step 2 – the material is then processed in specially-configured vibrating mills. The specially-configured vibrating ball mills impart highly-intensive surface impacts that create defects in the form of sub-micro cracks and dislocations on the surface of pozzolan particles. The energy in the form of various lattice defects, accumulated during the mechanical processing, leads to significant increase of its surface chemical reactivity or even chemical transformations. The result is the vastly-improved chemical reactivity of the pozzolanic particles, which increases the OPC replacement opportunity in concrete production from typically 15-20 per cent to around 70 per cent.

The process uses ~120kWh of renewable electric energy per tonne of EMC output, considerably lower than over 1000kWh/t of OPC.

Characteristics of EMC-processed natural pozzolans

EMC-processed pozzolans comply with ASTM C618, EN 450-1, EN 196-1, BS 8615-1 and BS 8500-1 and 2 requirements for pozzolanic additives in concrete. Tables 1 and 2 present the average data on pozzolan composition and performance according to EN 450-1 requirements. Amended versions of BS 8500-1 and 2 allow 55 per cent replacement of OPC in concrete by fly ash and natural pozzolans.

Concrete strength performance

Table 3 shows the strength performance of a wide range of concrete mix designs for industrial applications, using EMC pozzolan concrete. It includes typical

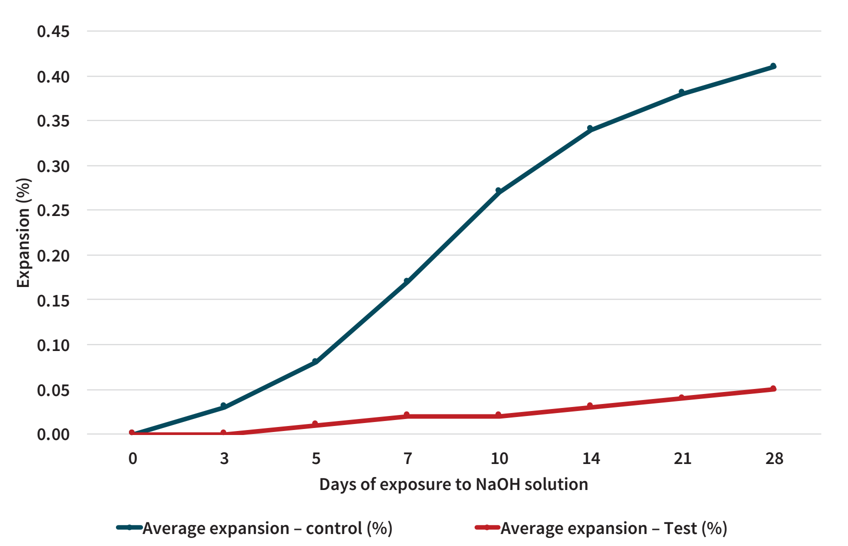
Table 2: oxide analysis using XRF	
Oxide	**Content (wt %)**
Total CaO	4.43
SiO_2	66.36
Al_2O_3	14.58
Fe_2O_3	2.02
Na_2O	2.62
K_2O	4.04
MgO	5.28
Total P_2O_5	0.55
SO_3	0.14
Total	**100.02**

The laying of pavement on the IH-10, Texas, USA, using EMC Technology

Table 3: compressive strength development for different EMC-POZZ (CemPozz) concrete mix designs

Parameter	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6	Mix 7
Cementitious content (kg/m³)	273	273	273	265	249	249	243
CemPozz content (kg/m³)	136	150	150	93	125	149	146
CemPozz content (wt %)	50	55	55	35	50	60	60
Water content (kg/m³)	191	136	158	106	137	132	148
Water-to-cementitious content	0.70	0.50	0.58	0.40	0.55	0.53	0.61
Coarse aggregates – 1* limestone (kg/m³)	1097	1097	1097	1127	1038	1068	1038
Fine aggregates (kg/m³)	742	823	848	827	919	854	825
Air entrainment (ml/m³)	0	0	0	155	155	155	116
Water reducer (ml/m³)	0	696	1005	580	657	657	464
Slump (cm)	21.6	14.0	16.5	4.4	15.2	13.3	17.1
Compressive strength (MPa)							
7 days	9.8	15.9	12.7	25.6	14.6	15.2	12.7
28 days	19.9	27.6	24.7	33.8	26.2	26.0	23.6
56 days	24.9	34.4	30.4	36.8	31.2	31.4	29.5

Figure 2: alkali-silica resistance testing shows a reduction in deleterious expansion in mortar containing 50 per cent EMC pozzolan and 50 per cent OPC/CEM I – tests performed according to ASTM C1260 and C1567



ready-mix concrete with a slump of over 12.5cm, as well as zero slump concrete used in paving projects. In terms of 28-day strength, EMC-based concretes show improved performance and reduce the production risks for contractors.

Sulphate and alkali-silica resistance

In addition, EMC pozzzolans have a significant impact on the mitigation of

Table 4: sulphate resistance performance – expansion according to ASTM C 1012 (%)

Term	Expansion OPC (%)	Expansion 50% E-POZZ (%)
30 days	0.007	0.000
60 days	0.013	0.000
90 days	0.100	0.010
180 days	0.290	0.013

concrete sulphate resistance (see Table 4) and alkali-silica resistance (see Figure 2).

Self-healing concrete

Furthermore, EMC concretes have self-healing capabilities. Continued pozzolanic reaction leads to the formation of additional volumes of C-S-H gel, which fills in the available space and therefore, eliminates cracks.

The Texas Department of Transportation reports that in highway paving jobs it noted a 50 per cent reduction of drying shrinkage cracks due to concrete self-healing.

EMC Technology applied in USA

EMC Technology is commercially proven, with several million cubic metres of concrete poured in Texas, USA. In these projects EMC's fly ash-based product accounts for 50-60 per cent of total cementitious content.

Leading customers have included Webber (Ferrovial) and Oldcastle (CRH), while key end-users include the Federal Highways Commission and the Texas Department of Transportation, which placed the EMC product on the same level as GGBS.

"The adoption of SCMs processed using EMC Technology not only reduces direct CO_2 emissions by up to 70 per cent but, as shown previously, also results in a concrete with significantly-enhanced durability.This provides lifecycle emissions savings that are increasingly important to contractors and end-users."

In Texas and Pennsylvania, EMC Technology was validated using fly ash as the raw material, while the California Department of Transportation (Caltrans) validation was carried out with volcanic ash as the two have very similar chemical compositions and comply with ASTM C618. EMC Cement has also been used on large infrastructure projects.

Carbon reduction potential

The adoption of SCMs processed using EMC Technology not only reduces direct CO_2 emissions by up to 70 per cent but, as shown previously, also results in a concrete with significantly-enhanced durability. This provides lifecycle emissions savings that are increasingly important to contractors and end-users.

Accordingly, widespread adoption of EMC Technology has the potential to reduce cement industry carbon emissions to the level set out in the most recent (October 2018) IPCC report: 45 per cent below the 2010 level by 2030 as well as the recent EU announcement that aims to reduce CO_2 emissions by 50-55 per cent, compared to 1990 levels, by 2030. ■

The pouring of several million cubic metres of concrete including EMC pozzolans in the USA showed that EMC Technology is a commercially-proven solution