

The low-carbon cement bet

Cementos Argos has developed a low-carbon cement using alkaline activation technology to formulate hybrid cements. This type of green cement allows the increased use of supplementary cementitious materials activated with additives which significantly reduces the clinker content and, therefore, CO₂ emissions.

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Supplementary cementitious materials (SCMs) are natural mineral sources such as calcined clays and volcanic rocks¹ or industry byproducts such as vitreous blastfurnace slags and fly ash.² Low-carbon cements are a development priority for Cementos Argos as the company seeks to minimise the clinker content of cement and hence, reduce CO₂ emissions. By using alkaline activation technology with additives, the company has been able to increase the use of SCMs like slags, fly ash and natural pozzolans, which allows for significant reductions in clinker.

Low CO₂ emission cements, also known as hybrid cements, have been successfully manufactured and commercialised at Cementos Argos' facilities due to extensive research into alkaline activation over the last few years. Initially, the objective was to produce cements without clinker. Although this is feasible at laboratory scale, the technical team at Cementos Argos discovered that mixing the chemical activator with clinker and the SCMs improves the cement's performance, leading to new concepts in hybrid cements.

After validating this concept in laboratories at the Argos Innovation Center, industrial trials were carried out in vertical and ball mills at several different cement plants. Following successful results, full industrial-scale

low-CO₂ emissions hybrid cement manufacturing was implemented. The hybrid cements showed a very positive performance and were assessed by Argos' quality control and technical teams with customer testing in the field.

Cementos Argos continues to develop this technology with the aim of increasing the use of SCMs, such as fly ash, natural pozzolans and others to reduce dependence on blastfurnace slag, which is an increasingly scarce material due to the high demand worldwide.

Experimental procedure

The aim of this research was to create a general use cement with a lower clinker content and higher additive content. The SCMs used in this study were granulated blastfurnace slag (GBS) from Japan and natural pozzolan (NP) from Central America.

The experimental procedure began

To activate the SCM correctly, additives are fed into the process using an accurate dosage system



by characterising each raw material using X-ray fluorescence (XRF) and X-ray diffraction (XRD) analysis and standards including the Slag Activity Index (ASTM C989) and the Strength Activity Index with Portland cement (ASTM C311). Also, alkaline activation with analytical reagent-grade sodium hydroxide (NaOH) was performed to assess the potential of each material to generate strength. The XRD pattern of the slag showed that it exhibits a glassy structure, unlike that of pozzolan, where greater crystallinity is evident.

Binary mixtures of the supplementary cementitious materials GBS and NP were made to seek the best synergy between them when activated with additives. With the best slag-to-pozzolan ratio, a general

Table 1: raw materials analysis results using XRF

Parameter	Clinker	Blastfurnace slag	Natural pozzolan
SiO ₂ (%)	20.30	33.48	54.53
Al ₂ O ₃ (%)	5.20	10.82	16.05
Fe ₂ O ₃ (%)	3.50	1.50	8.13
CaO (%)	64.70	41.27	9.15
MgO (%)	0.90	7.27	1.92
SO ₃ (%)	2.00	2.44	0.14
Na ₂ O (%)	0.20	0.61	2.56
LOI	0.40	1.18	4.51

use cement was formulated, maintaining a particle size distribution similar to the reference cement and 97 per cent passing mesh 325.

Results and discussion

XRF chemical analysis

The XRF analysis results are shown in Table 1. The GBS has a promising composition of calcium, silica and aluminium, in terms of activation. As for the natural pozzolan, a high silica content and low calcination losses are evident.

XRD analysis

In terms of the XRD patterns, the halo between $20\text{--}35^\circ 2\theta$ is evident in the GBS diffractogram, which is proof of the vitreous phase presence (see Figure 1). In turn, the diffractogram of the NP denotes the presence of crystalline phases such as anorthite sodium, diopside potassium and some quartz, with low amorphous phase content (see Figure 2).

Strength

Slag Activity Index (ASTM C989)

The slag activity was evaluated by determining the compressive strength of Portland cement mortars and corresponding mortars made with the same mass of a 50-50 combination of slag and Portland cement. The GBS fulfils the ASTM C989 standard (≥ 75 per cent).

Figure 1: XRD diffractogram of blastfurnace slag

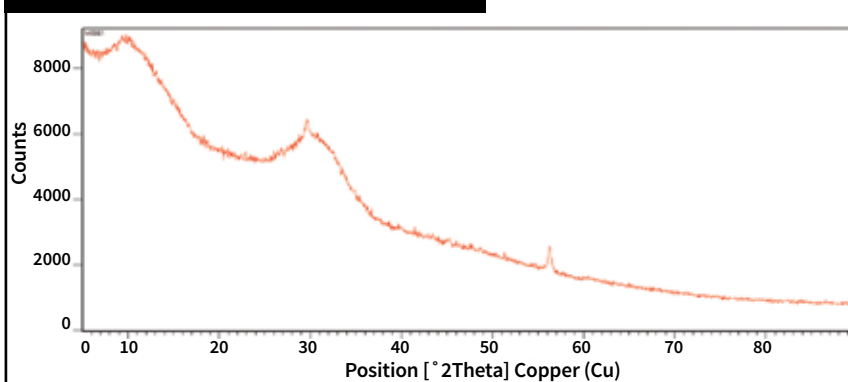
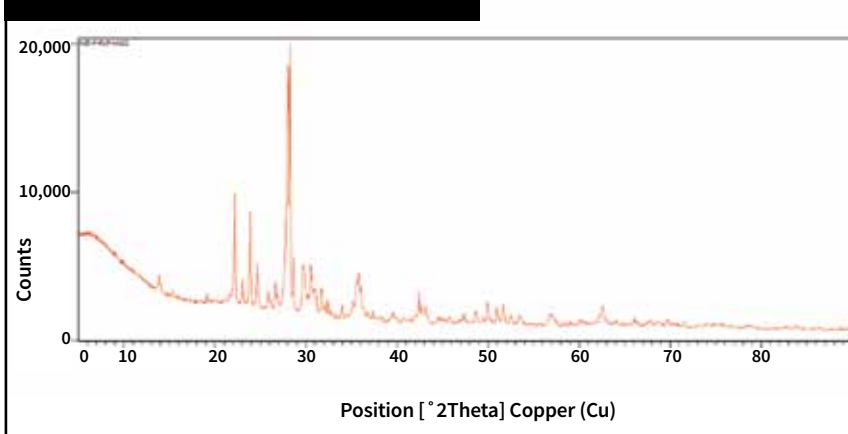


Figure 2: XRD diffractogram of natural pozzolan



Strength Activity Index with Portland cement (ASTM C311)

The potential of the NP was evaluated

by determining the compressive strength of Portland cement mortars and corresponding mortars made with the same

Table 2: Slag Activity Index (ASTM C989)

	Age (days)	w/c ratio	Strength (MPa)	ASTM C989 (%)
Reference cement	7	48.50	38.07	–
	28	48.50	43.87	
Reference cement + slag	7	49.00	29.93	78.61
	28	49.00	42.41	96.67

Table 3: Strength Activity Index with Portland cement (ASTM C311)

	Age (days)	w/c ratio	Strength (MPa)	ASTM C311 (%)
Reference cement	7	48.50	29.43	–
	28	48.50	45.51	
Reference cement + slag	7	49.00	23.03	78.30
	28	49.00	35.54	78.10

Figure 3: compressive strengths of activated slag pastes as a function of the activator concentration (cured 25°C – seven days)

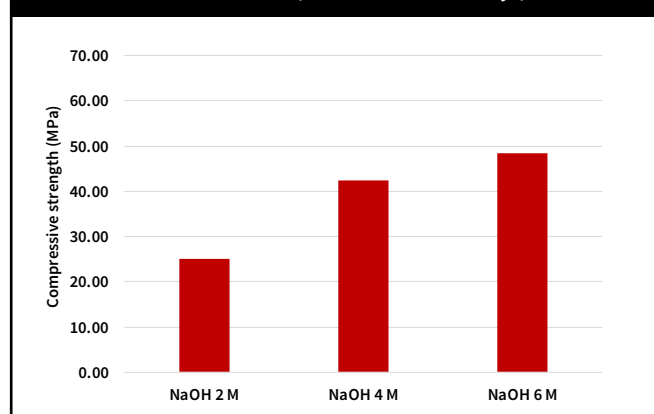
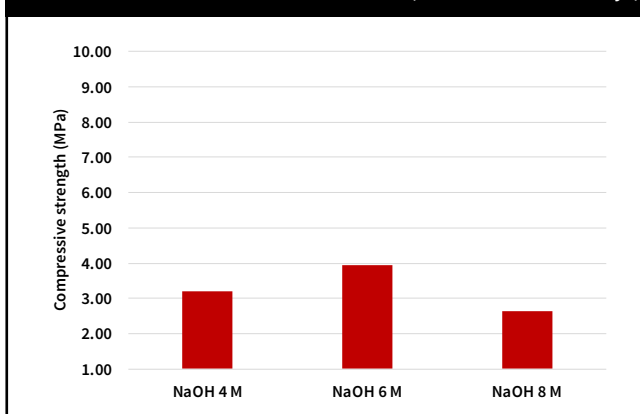


Figure 4: compressive strengths of activated natural pozzolan pastes as a function of the activator concentration (cured 25°C – seven days)



mass of 80-20 combinations of Portland cement and natural pozzolan. The pozzolan fulfils ASTM C311 standard (≥ 75 per cent).

Alkaline activation

The experimental conditions for alkaline activations are summarised in Figures 3 and 4. According to these findings the mechanical strength of the slag is near to 50MPa. In contrast to the alkaline activator of natural pozzolan, it exhibited very low strength (less than 4MPa).

Mechanical strength cement

With the best GBS to NP ratio, general use cement was formulated, keeping a particle size distribution similar to that of the reference cement (97 per cent passing mesh 325in). Two hybrid cement formulations fulfilled the ASTM C150 standard despite a low clinker content of between 18-23 per cent compared to the reference cement.

Life cycle analysis (LCA)

With a life cycle analysis, the main environmental impacts at all stages are identified: from raw materials extraction and processing to production and packaging. Once the main impacts are identified, working on strategies to reduce emissions can be spotted and implemented.

Conclusions

Research into chemically activated SCMs and their potential to reduce the clinker content of cement and CO₂ emissions has led to the following conclusions:

- The formulation of low-carbon cements is feasible. This type of cement focuses on green solutions to increase the use of SCMs that are activated chemically and achieve significant reductions in clinker and CO₂ emissions.

Figure 5: compressive strengths of activated slag and pozzolan pastes as a function of the activator concentration

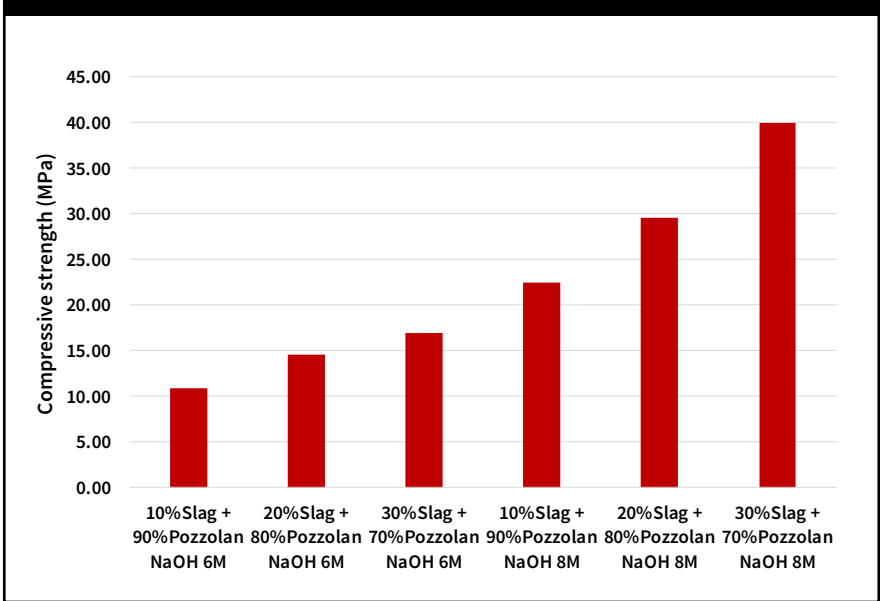
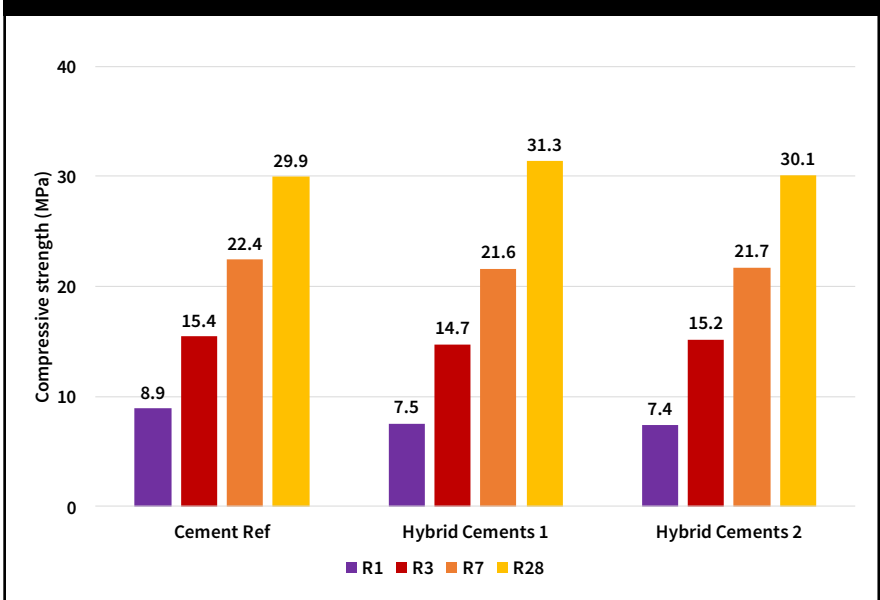


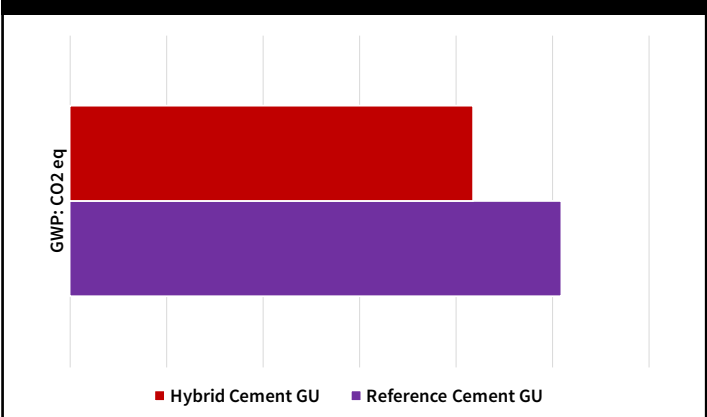
Figure 6: compressive strengths of hybrid cement vs reference cement (trial test)



- The composition and amorphicity of SCMs, and the pH of the activator have a considerable impact on the formulation of hybrid cements.
- Hybrid cements are another alternative to reducing the GWP (global warming potential) indicator and reflect

Cementos Argos' commitment to mitigating climate change. ■

Figure 7: calculation of GWP of hybrid cement vs reference cement (trial test)

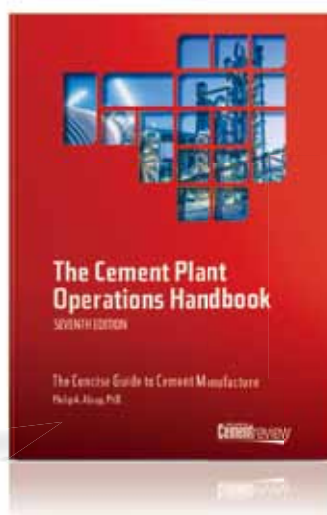


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