The role of additives in Latin American low-clinker cements

The replacement of clinker by supplementary cementitious materials (SCMs) is currently one of the cement industry's most effective approaches to reducing embodied carbon, and Latin America has been a leader in this field. As cement companies in the region continue making commitments to further reduce CO_2 emissions, GCP Applied Technologies has been working with some producers to develop and supply strength-enhancing additives designed to allow ambitious levels of clinker replacement.

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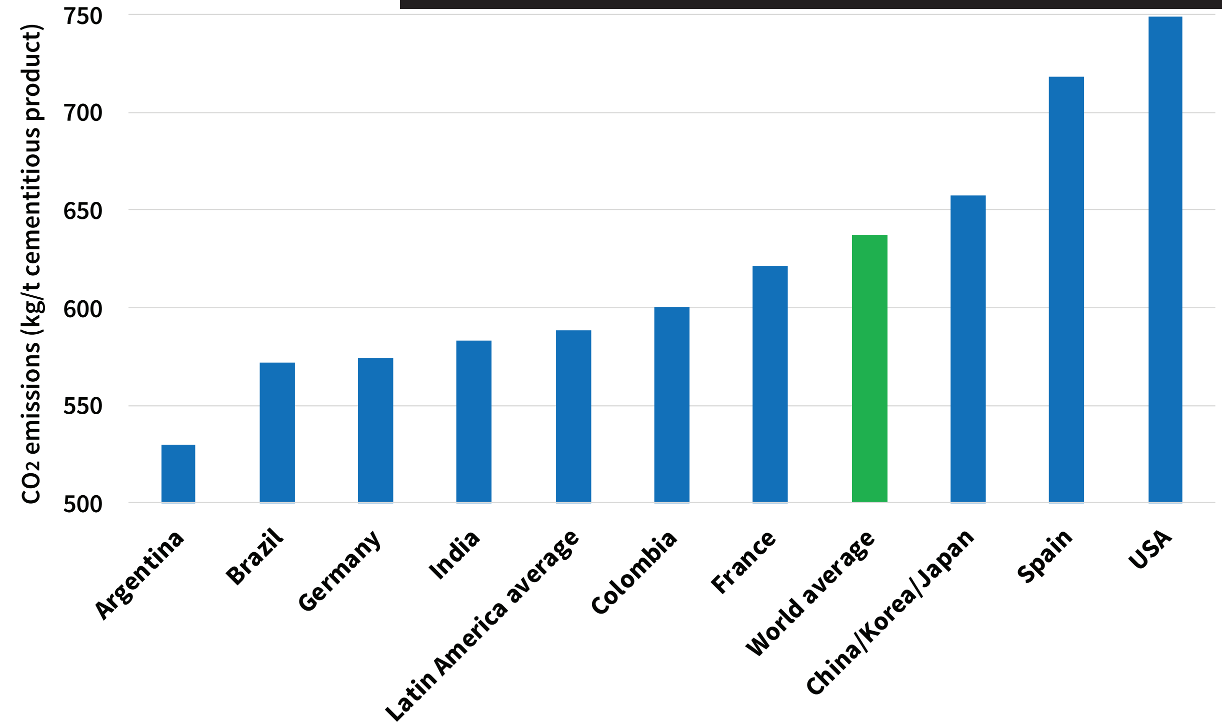
Figure 1: net CO_2 emissions of cement for selected countries and regions[5]



The demand for built infrastructure in developing countries will require significant increases in cement production in upcoming decades. As a result, cement-related CO_2 emissions, which are under increasing scrutiny for their contribution to climate change, are projected to increase by 260 per cent over the 1990-2050 period.[1] To transform cement manufacturing into a more sustainable business with less climate impact in a timely manner constitutes a great challenge for the world. The Cement Sustainability Initiative[2] has established targets for worldwide average carbon emissions from cement production of 520kg CO_2/t of cement by 2030 and 370kgCO_2/t of cement by 2050.

According to a United Nations study,[3] concrete based on Portland cement will continue to dominate the market in the foreseeable future due to economies of scale, levels of process optimisation, availability of raw materials and market confidence. To fully eliminate the carbon footprint of concrete will likely require costly investment in carbon capture and storage over the next 20-30 years.

However, in the shorter term there are two key areas that can deliver substantial CO_2 reductions:

1. increased use of supplementary cementitious materials (SCMs) as partial replacements for Portland cement clinker
2. more efficient use of Portland cement clinker in concrete.[4]

The increased use of SCMs has proven to be a valid solution, but the approach brings some important challenges for cement manufacturers, including changes in the performance of cement, the availability of suitable SCMs, limitations of standards and market acceptance. Perhaps the most important technical issue is reduced strength development, although

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this depends on the amount of clinker replaced and type of SCM used.

Latin America and SCM incorporation

Latin America has been a leader in the incorporation of high levels of SCMs into cement. This is reflected in the results of a recent study[5] showing that several Latin American countries have among the lowest levels of embodied CO_2 per tonne of cement in the world (see Figure 1). Although there is currently no carbon tax or other financial incentive to reduce CO_2 emissions in Latin America, several cement companies in the region have made strong commitments to further reduce their CO_2 emissions. As part of this effort, GCP Applied Technologies has been working with some cement producers to develop and supply strength-enhancing additives designed to allow high levels of clinker replacement.

Chemical additives have been used for over 80 years to improve the grinding process and the performance of finished cement. Today, chemical additives are allowing the cement industry to reduce the embodied carbon in cement and achieve ambitious environmental objectives. To facilitate this approach, the additive industry is now focussing on developing new high-performance chemical additives to facilitate even greater cement clinker reductions.[6] Additives act by catalysing the cement hydration process and increasing strength development, which then allows for more replacement of clinker by SCMs without decreasing strength.[7] These additives also help to optimise the grinding process to increase throughput and reduce grinding energy, further reducing CO_2 emissions.[8]

Each country in Latin America maintains its own standards and specifications for the manufacture and performance of cement, and there are different overall approaches. For example, Brazil uses a traditional approach based on composition: for each cement type there are allowable percentage ranges for different components.[9] On the other hand, Colombia uses a performance-based approach, in which there are no compositional limitations but rather performance specifications for each type of cement depending on its application.[10] The traditional model guarantees a more standardised cement for the concrete plant since all the technological control is done by the cement companies, but there are more limitations on the contents and combinations of mineral additions. With a performance-based approach, it is possible to utilise higher levels of SCMs as long as the minimum performance prescribed for each type of cement is maintained – but this requires greater technological control on the concrete side.

Presented below are two case studies from countries with different approaches to cement specification, which are both targeting an ambitious reduction of the clinker factor.

Table 1: case study 1 results– Brazilian producer field trial of GCP OPTEVA additive*

Cement sample	Blaine (cm²/g)	7 days (MPa)	28 days (MPa)	Mill output (tph)
Reference	4097	40.9	51.3	30.0
With OPTEVA	3992	41.9	55.8	34.0

**Strength measured in GCP laboratory*

Case study 1: Brazil

A Brazilian producer wished to increase the slag content of its cement. GCP suggested a cement additive that would allow the company to reach its objectives. As Table 1 shows, the proposed OPTEVA® additive increased the strength of the producer's current cement product made with 10 per cent limestone and 15 per cent slag. This allowed the cement manufacturer to increase the slag content by eight per cent, reducing its clinker factor from 71 to 63 per cent. This resulted in an emission reductions of 9000tpa of CO_2 and economic savings of approximately BRL500,000 (US$104,160) per year.

The chemical action of the OPTEVA additive increases the rate of hydration of cement and also improves grinding efficiency. This results in increased output, lower grinding costs, and improved cement performance and characteristics.

Case study 2: Colombia

A producer in Colombia was aiming to produce a portfolio of low-carbon cements incorporating relatively high levels of SCMs. GCP was contacted to develop an additive to help overcome some of the negative impacts of the SCMs such as lower strength development. GCP helped the plant map out possible scenarios available with the use of quality improving cement additives and four cements were designed with different clinker factors and SCM types (see Table 2). A screening of several GCP additives was then carried out in a GCP laboratory and the plant was able to select the product with the performance characteristics that best met its needs.

The effect of the selected OPTEVA product on the strength development of the cements is summarised in Table 3. The strength of all four cements increased at all ages in the presence of the GCP additive, effectively allowing the customer to increase clinker replacement levels without loss of performance. Cement 2 contains an additional 15 per cent slag, and 14 per cent less clinker compared to Cement 1 and, as a result, the early strength of Cement 2 is lower. With the use of the OPTEVA additive, Cement 2 gives similar strengths at one day and three days, and greater strength at 28 days compared to Cement 1. This allows

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the cement producer to achieve the same cement performance while using 14 per cent less clinker and equates to savings of 72,000tpa of CO_2.

Similarly, Cement 3 has a further eight per cent clinker reduction compared to Cement 2, with a corresponding further decrease in early strength development. With the use of the OPTEVA additive, Cement 3 gives similar strengths at one day and three days, and greater strength at 28 days compared to Cement 2. Consequently, the Colombian producer is able to achieve the same cement performance while using eight per cent less clinker, equating to CO_2 savings of 41,000tpa.

Cement 4 has very similar clinker content as Cement 3 but replaces five per cent of a higher quality SCM (slag) with a lower-performing SCM (natural pozzolan), resulting in lower strength development at all ages. As with the previous comparisons, this change is also effectively overcome by the use of the OPTEVA additive with Cement 4.

In summary, the increased performance provided by the GCP quality improving additive gives the producer the flexibility to increase the SCM content (and decrease the clinker content), or to replace a higher performing SCM with a lower performing SCM without loss of performance. These changes result in lower CO_2 emissions and financial savings for the cement producer.

Conclusion

The need to reduce CO_2 emissions is a global reality. The use of cements with low embodied carbon intensity, with performance characteristics that meet (but do not exceed) concrete design specifications, is a key aspect of sustainable construction.

The replacement of clinker by SCMs is currently one of the most effective approaches to reducing embodied carbon, and cement producers in Latin America are global leaders in this area. GCP is contributing to this effort by developing high-performance cement additives designed to allow high levels of clinker replacement while maintaining cement quality and performance. ■

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Table 2: cement compositions from case study 2, Colombia

Sample ID	Clinker (wt%)	Gypsum (wt%)	Limestone (wt%)	Slag (wt%)	Pozzolan (wt%)
Cement 1	64	4	32	–	–
Cement 2	50	3	32	15	–
Cement 3	42	3	34	21	–
Cement 4	43	3	33	16	5

Table 3: compressive strength results from case study 2, Colombia

Cement sample	1 day (MPa)	Δ (Mpa)	3 days (MPa)	Δ (Mpa)	28 days (MPa)	Δ (Mpa)
Cement 1 (blank)	10.9		19.1		31.7	
Cement 1 with OPTEVA	**13.0**	**+2.1**	**23.4**	**+4.3**	**34.7**	**+2.9**
Cement 2 (blank)	7.4		14.8		28.5	
Cement 2 with OPTEVA	**9.1**	**+1.6**	**19.0**	**+4.2**	**34.1**	**+5.6**
Cement 3 (blank)	5.7		11.7		25.5	
Cement 3 with OPTEVA	**6.8**	**+1.1**	**14.6**	**+3.0**	**31.6**	**+6.2**
Cement 4 (blank)	4.4		9.5		22.7	
Cement 4 with OPTEVA	**5.6**	**+1.1**	**11.6**	**+2.1**	**28.3**	**+5.7**