CLINKER SUBSTITUTION IN THE CEMENT INDUSTRY

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Frequently Asked Questions

Low-carbon cements, and in particular the substitution of clinker in cements, are currently discussed by stakeholders. Yet, this debate is particularly complex, and sometimes subject to unsubstantiated claims that lack a detailed understanding of the issue. This FAQ document intends to shed light on the topic and provide a clear overview of the opportunities and challenges related to clinker substitution.

What is clinker and why is the cement industry trying to use less clinker?

Clinker is the main constituent of cement. It is essentially a mix of limestone and other minerals that have been heated in a kiln at a temperature of approximately 1450°C and transformed by heat into complex reactive minerals. Once it is produced, the clinker is finely ground and mixed with gypsum and normally with alternative constituents (raw materials or by-products) to make cement[1].

Producing clinker is CO2-intensive. When limestone is converted to clinker, CO2 coming from the carbonates of the limestone is released (these emissions are known as process emissions, and amount for about two thirds of the total emissions from cement manufacturing). Furthermore, a substantial amount of heat coming from the combustion of different fuels is needed to start and sustain the chemical reactions, leading to further CO2 emissions (these emissions are known as combustion emissions and amount for about one third of total emissions).

Given the significance of CO2 emissions related to clinker production, the cement sector is constantly looking at ways to minimise and optimise clinker use.

Is lowering the clinker-to-cement ratio the only way to decarbonise cement production?

No. As identified in CEMBUREAU's carbon neutrality roadmap, the decarbonisation of the industry will necessitate a combination of different levers, which include improving the thermal energy of kilns; reducing reliance on fossil fuels and switching to cleaner alternatives to reduce combustion emissions; lowering the clinker-to-cement ratio; and deploying carbon capture to tackle process emissions.

It is important to stress that each of these decarbonisation levers have their own challenges: carbon capture requires a strong value chain and significant investments together with a significant increase of (electrical) energy; reducing fossil fuels use requires the availability of lower-CO2 alternative fuels and sustainable biomass; and the availability of traditional clinker substitutes is not evenly distributed across the EU and set to be limited in the mid-term, causing significant scalability issues.

The geographical location of cement kilns will also greatly influence the type of decarbonisation investments that a given plant will make. For instance, a plant located in an industrial area may have better access to clinker substitutes; or a plant located next to the North Sea may opt for carbon capture due to the proximity of CO2 storage sites.

[1] For a comprehensive description of the clinker, cement and concrete manufacturing processes, please see CEMBUREAU's document 'The Story of Cement Manufacture', January 2021

CEMBUREAU
55 Rue d'Arlon – 1040 Brussels - Tel : +32 2 234 10 11
secretariat@cembureau.eu – www.cembureau.eu

From a technical perspective, how does one lower the clinker content of cement?

Lowering the clinker-to-cement ratio requires the use of Supplementary Cementitious Materials (SCMs). SCMs have been used by the cement sector for a long time. They contribute to the cement and concrete performance and are also used to produce cements and concretes that can exhibit properties for dedicated applications.

The most frequently used SCMs in the EU are fly ash (a by-product of the coal-fired power plants) and granulated blast furnace slag (a by-product from the steel industry) – as far as their use both allows to reduce CO2 emissions and for a circular approach using secondary materials from other industries.

Other constituents including limestone, natural pozzolanas (siliceous and aluminous materials) as well as calcined clay are available and suitable as alternative SCM to slag and fly ash.

Recycled concrete fines, coming from the Construction and Demolition Waste separation and treatment are also a promising SCM.

In addition, some other materials are being investigated for suitability in cement-making, such as by-products of aluminium and glass production.

This sounds like an easy way to reduce emissions in the short term. Are there any limitations?

Yes, there are significant challenges related to clinker substitution. These relate to:

- The availability of SCMs: with the decarbonisation of the steel and energy sectors, granulated blast furnace slag and fly ash inevitably become less available over time. Based on external sources, CEMBUREAU assumes that:
    - Slag consumption in Europe will decline from approximately 13 million tonnes in 2020 (8% of cement content) to a maximum of 4 million tonnes by 2050 (less than 2% of cement content).
    - Fly ash consumption in Europe will decline from approximately 3 million tonnes in 2020 (2% of cement content) to less than 1 million tonnes by 2050 (less than 1% of cement content).

The EU cement sector is therefore constantly on the lookout for new sources for these SCMs (e.g. recuperation from landfills) as well as alternative SCMs (calcined clay, recycled concrete fines, natural pozzolans…). CEMBUREAU has contracted a specific study, looking at the availabilities of SCMs and alternative raw materials in Europe[2]. Some other sources indicate similar, but not equal challenges on the availability of the materials.

- The properties of the SCMs: cements containing SCMs have different properties and characteristics, therefore their use must be assessed case by case depending on the final application and environmental conditions. Potential new SCMs have to be tested (in terms of their chemical sustainability for cement production, hydraulic and pozzolanic properties, durability, sustainability) to ensure that the cement, and ultimately concrete preserves its strength and durability. Not all potential SCMs could replace clinker without risks on the durability and strength of concrete used or without specific provisions (concrete cover, concrete mix design and execution). A sizable amount of clinker per ton of cement will always be needed, with the amount of SCMs used depending on their individual properties and qualities.

[2] For more information, please see study Status and prospects of Alternative Raw Materials in the European Cement Sector (ECRA, 2022) as well as the related Q&A, and the recording of CEMBUREAU event on the topic, 2023.

- The environmental, health and safety aspects of new SCMs, which are often by-products from other industries, have also to be evaluated in order to maintain quality and safety levels of products.

Have some cement companies managed to produce very low-clinker cements, and are these products scalable today?

Both traditional EU cement suppliers as well as other operators have successfully produced very low-clinker cements. This was done mainly through specific partnerships with steelmakers to have privileged access to a high quality of granulated blast furnace slag, allowing for a very low clinker-to-cement ratio and significantly reduced CO2 emissions.

However, it is factually incorrect to claim that such solutions are scalable today. As mentioned above, the availability of SCMs causes significant scalability issues, and such very low-clinker cements could not meet the EU cement demand (for instance, one of the prominent low-clinker cement operators reports a global production around 2.4 million tonnes, against an annual EU demand of 170-180 million tonnes of cement).

Does using a lower clinker cement imply a lower CO2 concrete or a lower CO2 construction?

Not necessarily, and for several reasons:

- The quantity of embedded CO2 in concrete depends on the amount of cement used per cubic metre of concrete. For instance, using low-clinker cements may lead to a situation whereby more cement is used per cubic metre of concrete, to preserve concrete's strength and durability. This, in turn, means that the CO2 impact of concrete in buildings will be similar or even higher than when using a higher clinker cement.
- Low-clinker materials not always lead to low carbon constructions. A complete analysis, not only of the material, but also of the structure, must be undertaken. In many cases, the best way to reduce the carbon footprint of constructions is designing slender structures, so that the amount of concrete used is low, thus reducing the impacts. However, a highly efficient use of concrete usually requires a high-performance concrete with a high content, not only of cement, but also of clinker. In these cases, the clinker content of concrete per m^3 is high and so is its carbon footprint. However, the carbon footprint of the structure is low because the amount of concrete used in the structure is very low.

Does reducing the clinker content impact the performance of cement and concrete?

The clinker content of cement and the type of SCM used influences the performance of cement. Based on that, the strength and durability of concrete (e.g., protection of reinforcement corrosion, impermeability, frost resistance, resistance against chemical attack) are impacted. These impacts may be at least partially compensated by adjusting other parameters in structural design (e.g., concrete cover), concrete mix design (e.g., adjusting water-to-cement ratio) or execution (placing and curing of concrete).

In fact, cement standards (EN 197) are themselves articulated around the clinker content of cements as well as the type of constituents. A sizable amount of clinker per ton of cement will always be needed, with the amount of SCMs used depending on their individual properties and qualities, as follows:

- CEM I Portland cement (>95% clinker)
- CEM II Portland-composite cement (50-94% clinker)
- CEM III Blast furnace cement (5-64% clinker)
- CEM IV Pozzolanic cement (45-89% clinker)
- CEM V Composite cement (20-64% clinker)
- CEM VI Composite cement (35-49% clinker)

Some people are claiming that cement standards are an obstacle to low-clinker cements in the EU, and that the EU cement industry is opposed to any change of these. Is this true?

Both statements are incorrect.

As mentioned above, cement standards already allow for low-clinker cements, and these are being used on the EU market today. As part of the so-called 'Construction Products Regulation acquis' process, these cement standards – which have proven their efficiency and are being replicated worldwide – will be reviewed in the coming years to further support the deployment of low-carbon cements.

As far as the industry's position, EU cement suppliers have actually taken the lead by supporting a non-harmonised route to speed up the way to have the new standards EN 197-5 (Portland-composite cement CEM II/C-M and Composite cement CEM VI) and EN 197-6 (Cement with recycled building materials) available for the placement of new low-carbon cements in the EU market.

As part of the upcoming revision of cement standards, CEMBUREAU is supporting the adoption of a dual approach keeping the current system whilst introducing in parallel a complementary, more performance-based system. Such a dual approach should further facilitate the standardisation of new low-carbon products, whilst ensuring the safety and reliability of cements put on the European market (please see CEMBUREAU position paper "A new momentum for standardisation", October 2023).

What is the current clinker-to-cement ratio in Europe? Why is it higher than in some non-European countries?

The clinker-to-cement ratio in the EU was of 77.3% in 2021 (*GCCA, Getting the numbers right database*), down 0.6% as compared to 2020.

Some countries are indeed performing below this level, but it is important to keep in mind the following points when making international comparisons:

- Certain countries have access to a considerable amount of clinker substitutes (typically, China and India where fly ash is abundant due to the importance of the coal-fired power generation and metallurgical sectors).
- Some countries outside EU27 achieve statistically a low clinker-to-cement ratio, but as expressed above, tend to use more quantities of cement per cubic meter of concrete, with a negative CO_2 outcome.
- Conversely, certain regions tend to favour high-clinker cements due to the need of their construction market (e.g. adaptation to seismic conditions).

What are the EU cement industry's objectives when it comes to lowering the clinker-to-cement ratio?

As part of its Carbon Neutrality Roadmap, CEMBUREAU aims to reach a level of 75% clinker content in cement by 2030 (which corresponds to a reduction of 5 million tonnes of natural raw materials used for the EU cement production per year) and to 65% by 2050 (reduction of 20 million tonnes of natural raw materials per year). CEMBUREAU is currently in the process of reviewing its roadmap and will update the different decarbonisation levers, including the lowering of the clinker-to-cement ratio.

Is the EU cement industry incentivised to reduce the clinker-to-cement ratio? Would a review of the EU ETS benchmark rules help?

The EU industry is strongly incentivised to reduce the clinker-to-cement ratio through the existing EU regulatory framework:

- As clinker is CO2 intensive, cement companies are naturally incentivised to reduce emissions through the EU Emission Trading Scheme (ETS) and reduce their carbon costs, which account for a major share of global cement production costs. These incentives will further increase as free allocation is planned to be gradually phased-out with the introduction of the EU Carbon Border Adjustment Mechanism (CBAM).
- The EU Taxonomy requirements use a 'best-in-class' clinker-to-cement ratio of 65%, combined with low emission thresholds, to define the activity as sustainable for green investments purposes.

With regards to the ETS benchmark, CEMBUREAU firmly believes that a review is unnecessary in light of these strong incentives. EU legislation should not force the sector to go for one certain decarbonisation route (lowering clinker-to-cement) as opposed to the other levers for emissions reductions in the cement industry, e.g., use of biomass fuels, use of renewable energy, increase of energy efficiency, carbon capture, etc. Especially as the scalability of the first option is questionable. In this respect, it is important that the ETS remains technologically neutral, leaving the possibility to producers to choose which decarbonisation route suits their specific position.

What policy measures could support the lowering of the clinker-to-cement ratio?

As mentioned above, the key obstacles behind lowering the clinker-to-cement ratio lie with the limited availability of SCMs and with the complex interaction between clinker, cement and concrete. CEMBUREAU therefore believes that:

- Waste landfilling should be either banned across the EU or highly taxed by Member States and the export of waste outside of the EU should be minimised. EU and national policies should allow for the opening and restoration of old landfills which could be sources of traditional SCMs.
- An EU-wide harmonised model for separate waste collection should be set up to simplify waste management, improve efficiency of resource flows and ensure better access to secondary materials for business. Furthermore, cooperation should be enhanced to further investigate materials coming from Construction and Demolition Wastes to be used as new constituents.
- The EU cement standards should be reviewed at speed under the EU CPR Acquis and kept updated to accommodate new SCMs. Please see CEMBUREAU position paper "A new momentum for standardisation" for more information.
- Member States must take the necessary measures to adopt the new low-carbon cements in their Structural Codes and national technical legislation as well as adopt public procurement measures to encourage the use of this new generation of low-carbon materials.

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