THE USE AND AVAILABILITY OF ALTERNATIVE CEMENTITIOUS MATERIALS

Clinker is the fundamental component of cement that confers it some of its most important properties, mainly strength. Clinker can be complemented with blended materials that enhance some of these properties, in particular, durability. Clinker substitution is one of the actions included in the resource efficiency route to achieve the objective of reducing the cement carbon footprint by 32% in 2050 using conventional technologies.

Clinker can be blended with a range of common cementitious -natural and alternative- materials, including pozzolans, finely ground limestone and waste materials or industrial by-products. The clinker-to-cement ratio (percentage of clinker compared to other non-clinker, components) has also an impact on the properties of cement, enhancing their workability and durability.

The use of other natural or alternative materials in cement and the reduction of the clinker-to-cement ratio means lower emissions and lower energy use. According to the European Environmental Product Declaration of cement, the Global Warming Potential can be reduced from 898 kg CO_{2eq}/t_{cement} for CEM I to 738 kg CO_{2eq}/t_{cement} (CEM II), or even to 479 kg CO_{2eq}/t_{cement} for CEM III, showing the potential of cementitious materials in reducing CO_2 footprint of cement and cement-based products.

Types of cement are defined in a European harmonised standard (EN 197-1). Type CEM I contains almost 100% clinker but the subsequent types, CEM II, III, IV, and V, increase the amounts of different natural or alternative materials. In addition to clinker, only 9 constituents are currently allowed to produce blended cements. Constituents of cement are required to be reactive -pozzolanic and hydraulic properties- and are subjected to health and environmental restrictions, both to assure performance and safety of the five main types of common cements. EN 197-1 has been revised introducing a new range of compositions allowing further reductions of CO_2 footprint, providing simultaneously the possibility of using a greater number of additions combining different reactive blended materials.

Currently, the most natural or alternative constituents used are fly ash, finely ground limestone, and blast furnace slag, but projections of decarbonising scenarios will affect the availability of some alternative materials derived from industrial processes. Closure of coal-fired power plants are expected in Europe by 2030. Shifting steel production from primary blast furnace to secondary electric arc furnace may reduce the supply of granulated blast furnace slag in a mid-long term. Other constituents, such as natural pozzolana or silica fume, not affected by decarbonising policies, are only available at the local level. Therefore, the cement sector is working to develop the appropriate framework in which research and pre-normative tests to use alternative blended materials can be undertaken.

Carbon footprint reduction is included in the commitment of the cement industry with Sustainability where the quality of cement is a key aspect. Performance, durability as well as health and safety (H&S) are the drivers to select and use new cementitious materials for future blended cements.

Sustainable Development and Circular Economy Policies lead us to focus on providing higher performance and durable cements and cement-based products with less impact and the use of fewer resources. The idea is simple: reduce clinker in cement and increase performance and durability of concrete per unit of the structural unit. A balance among performance, durability and CO_2 content in cement, concrete and other cement-based products shall be calibrated depending on the intended use of each material.

Availability

The availability of alternative materials may be considered under different perspectives. For example, granulation technologies in blast furnace slag, local availability of mineral resources or local presence of industries supplying the waste or by-product materials are well-known aspects. Nevertheless, new parameters have to be considered. For instance, the accessibility to alternative materials in sufficient quantities and within an acceptable transport distance or the guarantee of supply in a future Low Carbon Economy.

In this respect, mineral thermally activated materials, such as calcined clay, are well-known and widely spread across Europe. The challenge may be linked not only to H&S aspects but also to the balance between its embedded CO_2 during its production phase in a decarbonised economy, and the allocation of these emissions to cement. To what extent this allocation may offset the advantages of the high rate of clinker substitution in severe decarbonised scenarios, is subjected to further research.

Health and Safety

Assessment of H&S and environmental aspects are important prerequisites to consider during standardisation processes to keep the high level of safety of cement and cement-based products that the sector has guaranteed so far.

Performance

CO_2 footprint of clinker used in cement is regulated by the Emissions Trading Scheme and limited by the benchmark. The cement sector is making a great effort to take clinker production to the edge of its current technological limit to reduce, as much as possible, its CO_2 content. However, further efforts may be made on the side of cement and cement-based products (as concrete), providing the same level of performance and durability as now. This can be achieved by using both, new, reactive constituents and new grinding technologies Performance of existing and new blended cements may be improved by optimising the particle size distributions of the different constituents, which will require high-performance grinders and separate grinding of each component.

Conclusions

Availability of cement blending materials remains critical, in terms of quantity, quality and environmental/H&S impacts. Availability of blast furnace slag, fly ash and third part by-products affected by decarbonising scenarios are expected to decline.

Pre-normative studies, testing and standardisation process are a time-consuming process. The future availability of current blended materials and shifts in industrial processes affected by decarbonisation context have led cement sector efforts to identify and to develop new cement blended materials with a clear time frame and a flexible approach. Calcined clays minerals, among others, are a promising candidate, and ongoing research is expected to provide critical information on their performance and durability.

In the same low carbon context, similar benefits may be obtained from constituents less used today (silica fume or burnt shale) but they are available only at the local level. Another line of research is the consideration of including new blending materials such electric arc furnace slags, bauxite, residue and tailings from mining operations in a context of industrial symbiosis, with extensive testing on mechanical, durability and H&S aspects. Targeted R+D+I actions are crucial in addressing the challenges that will allow the use of alternative blending materials, such as improving hydraulic or pozzolanic properties.

The use of currently available constituents as limestone or new mineral constituents such low-grade clays can remain or even increase when used in new ternary cements either because they will not be affected, at least significantly, by the long term decarbonisation scenarios, or by using new constituents such as calcined clay or thermally activated minerals.