THE “SUSTAINABILITY” OF CEMENT AND CONCRETE

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Sumário:

There are two main ways in which the global CO_2-footprint of concrete can be reduced without reducing its usefulness as a construction material. The first approach, which in principle should also be the easiest to apply, is to use the most CO_2-efficient concrete for any given structural application. For example, it has been shown that optimal CO_2-efficiency in terms of concrete compressive strength usually occurs around 50-70 MPa, which is higher than the average concrete strengths used routinely in most countries. Thus, there are significant CO_2 savings to be made by this approach, and the techniques are already well known.

The second approach, which is the main subject of this presentation, is to reduce the average CO_2-footprint of hydraulic binders while maintaining equivalent performance in concrete. One obvious approach to achieving this end is to improve the energy-efficiency of the PCC manufacturing process. The current best available technology (BAT) uses only about 3GJ of primary energy per tonne of clinker produced, while the global average today is believed to be about 4GJ/t, suggesting that average energy efficiency can probably be improved by up to about 25% by converting all cement plants to BAT. Of course, this should occur slowly anyway, for purely economic reasons, as old plants are decommissioned. Realistically, there are good theoretical reasons to believe that the current BAT values are unlikely to be reduced much by investing further in R&D on the conventional manufacturing process; it looks like we have probably reached a point of diminishing returns in that area. But CO_2 emissions can also be reduced by changing the fuel mix even at constant energy-efficiency. Most cement plants burn coals and cokes, which are amongst the most CO_2-intensive of fuels, so the use of alternative fuels has the potential to help. The most attractive approach from an economic viewpoint is to use waste fuels for which the high burning-zone temperature in the cement kiln, coupled with a modern preheater kiln system’s ability to efficiently scrub the exhaust emissions of many toxic dusts and gases, often provides a very safe and effective disposal method. Biomass-derived fuels are also a good option. But whether or not such approaches are able to reduce total CO_2 emissions depends very much on how the CO_2 emissions are accounted for when such fuels are burned. It is currently believed that the alternative fuel approach will be an important factor in reducing the industry’s environmental impact. However, the use of high substitution levels of waste fuels can also result in a reduction in the quality of the PCC produced, so there may well be serious practical limits to what can actually be achieved in this respect.

Because PCC is very rich in calcium, and the main source of that calcium is limestone (calcium carbonate) which contains about 44% “fossil” CO_2 by mass, the CO_2 emissions associated with the manufacture of PCC in an energy-efficient (BAT) modern kiln system are about 60% attributable to the decarbonation of the raw materials in the kiln, and such emissions cannot be reduced at all by improving energy efficiency. But they can be reduced simply by replacing more PCC with SCMs, as long as the SCMs used have lower carbon footprints than the PCC replaced at equivalent performance. The SCMs most commonly used today vary from materials which are inherently hydraulic binders, such as ground granulated blastfurnace slags (GGBFS), to pozzolanic materials that react with the lime produced during OPC hydration (such as pulverized fuel ash or “fly ash” (PFA)) and natural pozzolans, to ground limestones that have only very limited capacity to react with Portland cements but nevertheless can act as effective fillers by improving the rheology of fresh concrete. All of these approaches are

already well known and are to a large extent already allowed for in existing concrete standards. However, the quantities of SCMs available worldwide of suitable quality do not currently appear to be sufficient to meet the projected demand.

So, even if all of the above approaches to reducing the CO_2 footprint of hydraulic binders (increased energy efficiency, use of alternative fuels, and increased levels of PCC replacement by SCMs) are pushed to their maximum practical limits based on our current technical understanding and the supply of suitable raw materials, the global cement industry will only be about half-way to meeting the CO_2 emissions targets proposed in the International Energy Agency's "Blue Map" scenario, which is based on limiting atmospheric CO_2 levels to 450ppm in 2050 (and which in turn is assumed to give a less than 3°C increase in global mean temperatures).[1] The IEA's analysis assumes that the existing technical processes for CO_2 capture and sequestration (CCS) will have to be applied to the cement industry, but since this approach is very expensive and also rather unattractive due to the need to stock the excess CO_2 underground in pressurized reservoirs, it is in the interests of the industry to continue to look for novel alternative approaches which could be more cost-effective than simply applying the standard CCS approach developed for all CO_2-emitting industries.

Amongst the alternative approaches currently under investigation, the most widely publicized is that of alkali-activation (often called "geopolymerization"), a method by which the low reactivity of many common pozzolanic materials may to some extent be compensated by activation with concentrated basic alkali metal solutions. Another approach is to make cements (e.g. Lafarge's "Aether"™ cements) based on "BCSAF" clinkers – i.e. clinkers based essentially on belite, calcium sulfoaluminate and calcium aluminoferrite. Such clinkers can be made in conventional PCC kilns, (which is advantageous in terms of reduced capital investment), with CO_2 emissions 25-30% lower than those of PCC for similar hydraulic performance. Other approaches currently under study include the manufacture of calcium silicate cements by autoclave processes, and the manufacture of cements based on reactive calcium carbonates. In the longer term, binders based on raw materials with no fossil CO_2 content, such as magnesium silicates, might become a promising alternative approach, as they can, at least in theory, produce truly "carbon neutral" binders.[2]

The development of novel hydraulic binder technologies is a long and slow process because cement science is not yet an exact science. The cement manufacturing and cement hydration processes both involve many different steps, and many of the fundamental chemical and physical processes that lie between the extraction of raw materials and the final properties of the resulting concrete structures (which must have a service life of at least several decades) are as yet too poorly understood for accurate modeling. Thus, a lot of the research and development work needed to develop such alternative binders is necessarily empirical, which makes it both very slow and very expensive. Nevertheless, it seems very likely that some of the novel systems currently under investigation will have the potential, well before 2050, to replace the currently-envisaged CCS approach at a lower total cost to society for the CO_2 emissions avoided.

[1] International Energy Agency, "Energy Technology Perspectives 2010, Scenario and Strategies to 2050", International Energy Agency, (2010), Paris, ISBN: 978-92-64-08597-8.

[2] Gartner, E., Macphee, D., (2011). A physico-chemical basis for novel cementitious binders, Cement and Concrete Research, 41: 736-749.