Progress through the ranks

Lawrie Evans and Mark Mutter, JAMCEM Consulting, present an environmental ranking of cements.

It is becoming increasingly evident that global warming is a generational challenge. There may still be head in the sand politicians attempting to ignore the warnings, but the mass of scientific data is now pointing to the conclusion that the challenge to reduce CO_2 emissions is critical to our future climate. The 'Big Four' major sources of CO_2 now standing in the dock are transport, power generation, steel, and cement. Transport is making substantial moves to electrification, but any attempt to increase fuel costs and reduce usage meets an immediate adverse reaction. Look no further than the 'gilets jaunes' in France. Power generation is also rapidly pursuing a route to renewable sources, leaving steel and cement as the two major sources without a clear route for substantial reductions in CO_2 emissions.

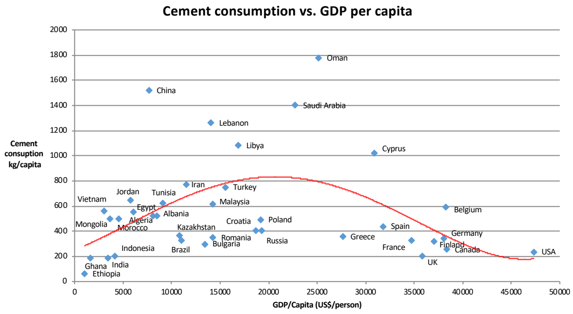


Figure 1. Cement consumption kilogram/capita vs GDP/capita.

Also, cement in its current form is not going away in a hurry. Predictions are that the global peak of cement production is still in the future, and is likely to be 12% higher than current volumes. This is supported by the curve shown in Figure 1, in which there are many countries – notably India and almost the entire continent of Africa – on the growing left-hand side of the climb to peak cement consumption per capita.

The portland cement recipe requires the decarbonation of calcium carbonate and a large amount of heat for the process, both of which imply the evolution of CO_2. Many alternative cements to the portland recipe, with lower CO_2 footprints, have been proposed but have yet to make a significant dent in the dominance of portland cements in both pure and additions formats. With a global cement capacity approaching 6 billion t and with a conservative asset valuation of US$150/annual tonne, total cement global assets are worth approximately US$900 billion, and this will not be sacrificed or replaced easily.

Developmental steps

So what are the regulating authorities and the cement industry doing? The actions can be divided conveniently into developmental and major evolutionary steps.

The industry developmental steps include the following:

- Reducing fuel and power consumption.
- Reducing clinker content of cement.
- Moves to alternative fuels, especially those with a significant biomass content.

For the authorities, the major action has been the introduction of carbon trading, most significantly in Europe but with other schemes emerging in many regions around the world. Unfortunately, carbon trading has tended to become more significant as a financial tool, rather than as a driver of change. For every forward step in reducing specific emissions, such as in Europe, there have been other setbacks, such as in Egypt, where the change from natural gas/oil to coal/petcoke has adversely impacted specific CO_2 emissions.

More evolutionary steps include the following:

- Several routes to capture and dispose of CO_2 from modified kiln processes. However, current costings indicate a trading cost of over US$100/t for CO_2 before breakeven is achieved.
- Using CO_2 in concrete (i.e. Solidia) with current developments directed at the precast industry.
- The most advanced thinking with the current cement recipe is to source heat for the kiln process from diverse sources, i.e. hydrogen, 100% biomass, and electrification. But the issue of CO_2 from calcium carbonate remains.
- Other cement recipes remain in development but have yet to be produced in significant volumes.

What is clear is that the impact of these initiatives is rarely clear to cement consumers and the general public. Most often, references to 'green' cements are made with little or no justification or quantification.

Environmental rankings

One potential idea that could drive cement producers to focus more on reducing CO_2 is that of giving cements a clear environmental ranking, such that consumers and the general public can understand the CO_2 generated in the manufacture of cement. This would influence customer behaviour and, therefore, the revenue streams of the cement producers. The measures of kilogram of CO_2/tonne of clinker or cement are certainly useful, but what is not clear is how much of any improvement in this measure is due to the production of lower strength cements. As the vast majority of cement is used for the strength it can produce in concrete and mortar applications, the parameter proposed for ranking has to take both CO_2 emissions and the resultant strength of the produced mortar/concrete into account. The CO_2 factor would be that attached to the original clinker source and the percentage content in a given cement. Where cement from grinding plants uses outsourced clinker, it is proposed that the clinker(s) used are ranked for kilogram CO_2/tonne of clinker, in order to correctly assign a ranking to the cement produced by that grinding plant.

The compressive strength parameter would be defined as that achieved at 28 days, which is the parameter generally used for the majority of concrete designs. Thus, kilogram of CO_2/ tonne of cement/MPa of 28 day mortar strength using EN standard testing methods would become the standard environmental performance for cements. EN standards for compressive strengths have been selected as the standard in most widespread use. There are also well-known conversion factors that can allow strengths obtained from other standards to be converted to EN standards.

It is further proposed that the kilogram of CO_2/tonne of cement/MPa parameter should be classified in a similar manner to those of domestic appliances, such as washing machines and televisions etc., and be ranked in bands from A+++ to F. This would allow more clarity in labelling. As well as CO_2 from the kiln process, any emissions from slag and flyash driers, and from artificial pozzolan calciners etc., should be included in the CO_2 measure for the ranking.

There are several counter arguments to this type of environmental ranking. These include the following:

- 28 day strength is not the only consideration, for e.g. precast customers.
- Mortar strength performance is not always replicated in concrete applications.
- CO_2 emissions from the production of slag and flyash are not included.
- The CO_2 emitted from power generation and used on the plant or from any captive power generation installed at a plant is not included.
- The ranking takes no account of the minimum cement requirement in many concrete specifications.

No ranking method can entirely eliminate discussion as to the exact measures to be used, but the relatively simple ranking that has been adopted for domestic appliances, using methods largely initiated by the European Union, has led to a virtuous circle of development. This means that even A+++ ranking is not sufficiently good to include current best practice. Today, it is difficult to imagine a customer buying an E ranked washing machine and who, given equal price, would buy a B ranked machine over an A++ ranked.

Products and rankings

As an example of cement environmental ranking, a typical CEM I 52.5N in Europe has a kilogram of CO_2/tonne of cement of 828, for a 28 day compressive strength of 63 MPa. By dividing the 828 by 63, a ranking of 13.2 is produced. By comparison, an average CEM II/A-L 42.5N, with a lower clinker content than the CEM I, has a kilogram of CO_2/tonne of cement of 747 for a 28 day compressive strength of 53 MPa. This produces a ranking of 14.1 – apparently inferior in ranking to the CEM I.

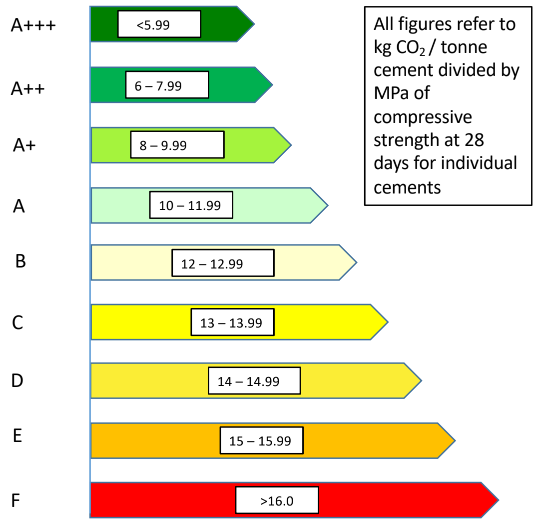


Figure 2. Proposed environmental rankings for cements.

Table 1. Cement types and kilogram CO_2/tonne of cement/MPa compressive strength at 28 days for a typical European cement plant.

Cement type	Kilogram of CO_2/tonne of cement/MPa at 28 day strength	Kilogram of CO_2/tonne of cement
CEM I 52.5N	12.9	794
CEM II/A-LL 42.5R	13.4	700
CEM II/A-LL 32.5R	13.4	649
CEM II/B-LL 32.5R	15.7	573
CEM IV/A-V 32.5R	12.2	571

Why is this the case? The major part of the explanation is usually to be found in the cement grinding system, where the softer limestone in the CEM II is preferentially ground over the clinker. With poor separators, this leaves a higher proportion of clinker insufficiently ground to contribute to strength development in mortar and concrete. By comparison, cements with flyash, slag, and pozzolanic additions give significantly better results, as the additions are active in developing strength, especially at ages of 28 days and beyond. However, even in this case it is important that preferential grinding and poor separators do not rob the cement of any potential strength development.

As an illustration of this point, figures for the range of products from a typical European plant are shown in Table 1.

It can be seen that there is a significant range of data for kilograms of CO_2/tonne of cement/MPa compressive strength at 28 days. And this is not necessarily in the expected direction, as shown by the more conventional kilogram of CO_2/tonne of cement data. However, flyash cement (CEM IV/A-V 32.5R) is clearly the best performer on both counts.

Overall, the suggested ranges for the overall environmental ranking of cements are shown in Figure 2. These ranges cover most cements produced.

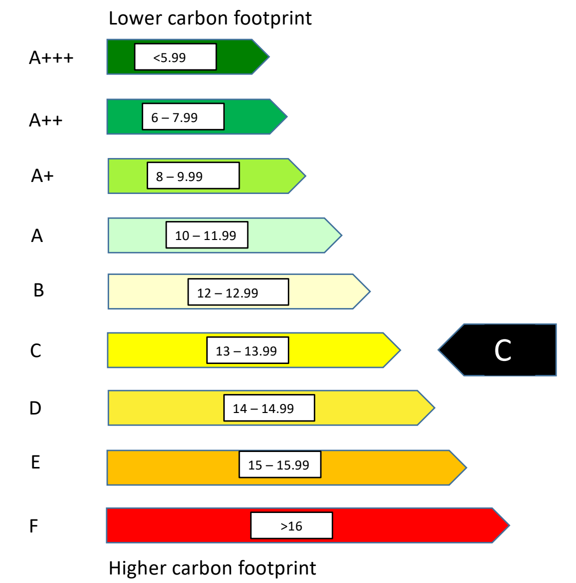
The overall result for a given cement is the classification shown in Figure 3. In this case, it is for the CEM II/A-LL 32.5R in the plant example given in Table 1.

The result is clearly labelled as a 'C' classified cement. Customers can also evaluate competing cements for their environmental ranking and make decisions based on the rankings.

Conclusion

Two additional measures would also help the cement industry to progress to a lower carbon footprint. The European standards (EN 197-1) are generally recognised as offering the widest choice of recipes for a given cement strength. There are several major national standards that do not offer such clarity and freedom, and these need to be revised to allow the more effective use of additions. Also, as previously stated, the issue of minimum cement content in concrete has to be addressed in parallel with any attempt to rank cements. Worldwide standards for the minimum cement content in concrete vary widely and there are many expert opinions suggesting that a critical review of these standards is urgently required. This review could significantly reduce the amount of cement used in many concretes.

Moving the cement industry to a more CO_2 friendly future will follow many routes, but by ranking cements in the manner proposed, the efforts of manufacturers to progress in fuel consumption reduction, biomass utilisation, improved grinding, and the better use of active additions can be seen clearly by customers, government bodies, environmentalists, and the wider public. ■



CEM II/A-LL 32.5R 13.4 Kg CO_2 / t cement / MPa strength 28days

Figure 3. Example of environmental labelling for cements.

About the authors

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