Tony Sheridan, DB Group, discusses the benefits of low-carbon cement alternatives and why they may be the answer to improving the strength, durability, and hygiene of the material.

Rewriting the rules on cement

All environments weaken concrete surfaces over time, especially harsh ones, but a recent study shows that low-carbon cement could provide an answer to improving strength and durability. Concrete made using an ultra-low carbon cement (in this case, Cemfree) could be a more sensible alternative to conventional concrete – and help save the planet. Concrete is one of the most commonly used materials used in construction – for good reason. It is economical, sets at ambient temperature, is easy to use and it can be cast into almost any shape.

Figure 1. Cemfree was chosen due to its weather, chemical and road salt resistant properties for the M25 Woodford Viaduct hardstanding recently.

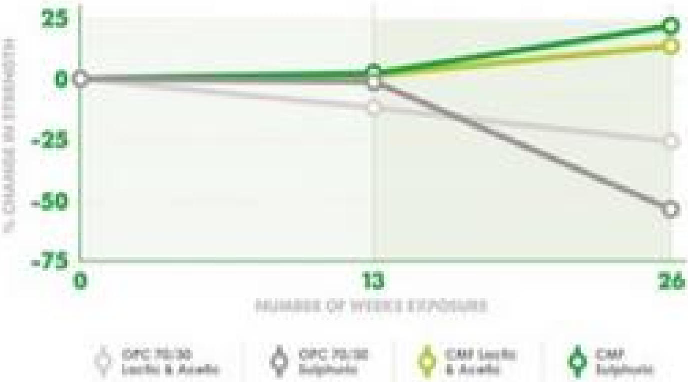

Figure 2. Effect of acid on Cemfree strength gain.

But in nearly every case, concrete is routinely exposed to highly demanding environments – whether it be through traffic or weathering, or through contact with acidic and alkaline chemicals – man-made or environmental – all of which take a heavy toll on concrete surfaces.

Structures made using a conventional cement-based concrete mix are very likely to deteriorate prematurely. But just how prematurely? The DB Group technical team investigated this, and the results proved to be more surprising than anticipated.

Concrete is made using a mix of water, fine sand and coarse aggregates which are held together using a binder. Ordinary Portland Cement (OPC) is the binder commonly used in concrete. However, OPC is susceptible to acids commonly found in harsh environments which react with it, causing premature failure. To help improve its durability, some concrete suppliers replace up to 70% of the OPC with ground granulated blast-furnace slag (GGBS).

Cemfree is an alternative to OPC. It is a proprietary alkali-activated cementitious material (AACM) that activates waste materials such as Ground Granulated Blast-furnace Slag (GGBS) and Pulverised Fly Ash (PFA) to create a binder. Its different chemical composition means that it has a naturally higher resistance to acids found in chemically aggressive environments.

To find out how the durability of concrete made using Cemfree compared with a conventional concrete mix, DB Group recently commissioned a 26-week laboratory-based accelerated degradation test.

To enable the comparison, two sets of concrete samples were prepared. One set was based on the most durable version of OPC used in harsh environments – a mix of 70% GGBS, 30% OPC. The other set was made using Cemfree low carbon cement.

Laboratory tests involved fully and partially submerging the samples for a

Table 1. Results of the of the compressive strength test.

Mix	Compressive strength after 28 days [MPa]	Acid in which sample was submerged	Compressive strength after 26 weeks [MPa]	Percentage increase/ decrease in strength
OPC70/30	68.1	Lactic and acetic	51.7	-24.1
OPC70/30	68.1	Sulfuric	32.0	-53.1
CMF	31.8	Lactic and acetic	36.3	14.2
CMF	31.8	Sulfuric	38.9	22.3

Figure 3. OPC after sulphuric acid test showing deterioration.

Figure 4. Cemfree low-carbon cement after sulphuric acid test, showing a lot less deterioration.

Figure 5. Formwork being stripped on Cemfree wall prior to use on A14 major roadway in Cambridgeshire later this year.

total of 26 weeks in three different acids: lactic, acetic and sulfuric. The results made for interesting reading (Figure 2 and Table 1).

Loss of strength

The most notable difference to emerge from the tests concerned changes in the samples' compressive strength. Compressive strength is a measure of the ability of the concrete to carry loads without cracking or failing. The tests showed that the OPC sample submerged in sulfuric acid exhibited a 53% decrease in strength after 26 weeks, while the OPC sample submerged in lactic and acetic acid showed a decrease in strength of over 24% in the same time period.

By comparison, the Cemfree samples submerged in the same acids showed an increase in compressive strength of up to 22% over the same test period.

Table 1 shows the results of the compressive strength test in detail.

Loss of mass

The tests also showed that both the samples submerged in sulfuric acid showed signs that material had been dissolved. However, there was a significant difference in the amount of material dissolved: the Cemfree sample suffered a minor loss of 14 g of material, while the OPC sample exhibited a much greater loss of 225 g of material.

Change in appearance

After 26 weeks, the appearance of both samples had been affected by their submersion. However, discolouration was worse on the OPC samples and, significantly, mould growth was present.

These results show that the type of binder used has an impact on the material resistance and durability of concrete. In particular, the low carbon cement mix showed an improved resistance to organic acids, even gaining strength in this environment. The tests demonstrate that concrete made with Cemfree can provide a durable alternative to OPC concrete.

Environmental benefits

In addition to its durability benefits, there are major environmental benefits to using low carbon cement such as Cemfree. Structures built using Cemfree will have less embodied CO_2 compared to one constructed using OPC-based concrete. That is because the production of 1 t of OPC releases almost 1 t of CO_2 into the atmosphere. By comparison, low carbon cement is made from waste materials and its carbon footprint is ultra-low.

If concrete made with Cemfree was poured in place of OPC concrete, in addition to being durable, Cemfree concrete would have up to 80% less embodied CO_2, which would be beneficial for both the longevity of surfaces, as well as the environment.

The OPC alternative is also batched, delivered and placed in the same way as an OPC concrete.

Conclusions

Low carbon cement is becoming a viable choice for demanding environments such as high vehicle and foot traffic areas, tidal defenses, major roadways and peripherals, runways, agricultural precast and other rural applications, and industrial environments.

Cemfree has been used in various applications, from Harwich's tidal sea defense for the Environment Agency to developments such as the Thames Tideway project, eco-home builds in environmentally sensitive areas, and, for the first time in this application, Cemfree is being commercially used on the A14 major road development by Highways England (Figure 5). ■

About the author

Tony Sheridan (B.Sc. Civ Eng. MBA), Group Commercial Manager, DB Group, has nearly 20 years of construction industry experience. A civil engineering graduate of University College Dublin, he worked as a structural design engineer before completing his MBA and going on to work in several UK commercial and general management roles in the ready-mix concrete industry.

Figure 6. Durability of Cemfree was key to being used for tidal sea defence in Woodbridge, Suffolk.

Figure 7. Cemfree kerbing.