Figure 1: CEM 0 trial with a concrete without aggregate. This semi-dry paste was laid in a 100mm layer.

> The focus of our research programmes is to use secondary materials that have no current market value and are being sent to landfill. This brings an additional environmental benefit of reducing the need for landfill sites.

Introducing Cem-Zero

The term 'Cem-Zero' (CEM 0) is used in research programmes at Coventry University to describe the powders that are being developed to replace Portland cement (PC) in concrete. These powders are made entirely of secondary minerals that are dried and ground as necessary and then pre-blended so the user may add them to a concrete using existing plant. Peter Claisse and Esmaiel Ganjian of the Construction Materials Applied Research Group at Coventry University provide the details.

The key benefits obtained from the use of PC since it was invented almost 200 years ago have been high strength and rapid strength gain. The theory behind the development of CEM 0 is to maximise these properties as far as possible and then to target applications where they are not critical. Thus CEM 0 is typically intended for use in soil stabilisation, controlled low-strength materials, unreinforced concrete, paving and building blocks, and footings rather than beams and columns.

The name Cem-Zero is intended to correspond to the various other cement types such as CEM I, CEM II, etc, which are currently used in BS EN 197[1]. It is hoped that as the work progresses, this extra category could be considered for inclusion in this Standard. CEM 0 is not intended for use in combination with PC; it should just be mixed with water and aggregate to make concrete.

Benefits

The environmental benefits of reducing the use of PC will be well known to readers of *Concrete*. The focus of our research programmes is to use secondary materials that have no current market value and are being sent to landfill. This brings an additional environmental benefit of reducing the need for landfill sites. It also brings an economic benefit and, if the saving on disposal costs is maximised, it is possible to produce 'negative cost concrete'.

Current alternatives

The usual methods used to produce low-strength concrete are either to use normal PC with a high water/cement ratio or, for very low-strength applications, to use foam in a mortar. PC is too valuable a resource to be used in these ways.

Some hydraulically bound materials for road construction contain no PC; however, the authors are not aware of any pre-blended powders being produced for this.

Cenin (*www.cenin.co.uk/cement.php*) is a CEM 0 that is made by reprocessing steel slag and could be used without PC; however, it is normally used in combination with cement.

Materials

Most of the material combinations used in our programmes depend for their hydraulic properties on one of two basic reactions:

- The pozzolan–alkali reaction that was exploited by the Romans by burning limestone and mixing the resulting lime with either volcanic ash or ground clay tiles or bricks. In current use in concrete, fly ash reacts with the lime produced by the hydration of PC. In our research programmes fly ash is generally minimised because it already has a market. Run of station ash (ROSA) is used because it is often freely available as it is not suitable for use in structural concretes. Waste industrial alkalis such as kiln dusts are used as activators.
- The sulfate–slag reaction. This has been known about for a long time. Super-sulfated cement made from ground-granulated blast-furnace slag (GGBS) and gypsum was popular during much of the 20th century, only disappearing from used in the UK due to a relatively poor shelf life. In our research programmes, the use of GGBS is minimised due to its existing market. Many of the concretes contain ground basic oxygen slag (BOS) from steel production. Waste gypsum is freely available from a number of sources[2]. A CEM 0 produced in this way could cause unwanted sulfate reactions if blended with PC, so it would be necessary to make sure that users did not confuse a CEM 0 with a traditional cement replacement material such as fly ash.

Test methods

There is an abundance of published literature about the use of different secondary materials in concrete[3]. In this literature it is generally agreed that compressive strength is an

Figure 2: Cores from trial of roller-compacted concrete with CEM 0 and crushed concrete aggregate used in a car park.

important property to measure but, beyond that, a considerable range of different tests are used. The strategy for the CEM 0 programme is to target specific applications and select the tests to suit. Thus, for example, in the work on waste containment, the tests focused on transport properties but expansive reactions such as sulfate attack were not considered because they would not reduce the effectiveness of the containment[4].

One particular test that should be used with great caution is the so-called 'rapid chloride permeability test' in ASTM C1202[5]. This test is not suitable for comparing pozzolanic mixes with other types because the pozzolanic reaction depletes the charge carriers and gives an unrealistically low value for charge passing[6].

Larger-scale site trials yield very useful information. For example, our trials have shown very clearly that pre-blending powders is the only method that will make most secondary materials acceptable for use in industry. Concrete batching plants do not have sufficient silos to store the individual components.

Programme methodology

There are a number of mathematical methods available to optimise the strength obtained with combinations of different materials. Artificial neural networks based on material proportions have been used by many authors and also in our programmes[7]. The limitation with these methods is, however, that they can be used to develop optimised concretes for particular samples of materials but the models they produce will then fail when new batches are obtained if they are not identical.

It is a feature of secondary materials that they often vary considerably from one batch to the next and some streams may even disappear completely due to plant closures etc, and need to be replaced with others. Our more recent programmes have therefore focused on measured properties of the materials, specifically the oxide percentages from X-ray fluorescence (XRF), to see if these can be used as predictors for strength. The authors are starting by using the oxide data in published papers to build a model to predict strength. If this proves inadequate, we shall include other measurements such as infra-red spectroscopy.

Production

A CEM 0 production plant would basically consist of facilities to receive secondary materials from local sources, dry and grind them as necessary and blend them in optimised proportions. However, to overcome variations in the materials it would be necessary to use in-line analysis such as XRF on them and then to adjust the blending proportions to compensate. The aim of the research is to provide a model to calculate the adjustment and ensure that the blend is continually optimised.

Example of a CEM 0

In a recent research programme[8] 100 tonnes of a CEM 0 were produced, which contained 15% plasterboard-derived recycled gypsum, 5% bypass dust and 80% basic oxygen slag. Two site trials were carried out with this material. It was used without aggregate (Figure 1), achieving a strength of 30MPa. Given that the CEM 0 was produced entirely from materials that would otherwise have gone to landfill, the use of a concrete without aggregate was economically justified. In the second trial, crushed concrete aggregate was used and a semi-dry mix was made. The cores (Figure 2) gave strengths of 10MPa.

Concluding remarks

The term CEM 0 is used to designate a blended powder, which can be used to make concrete with no Portland cement. Experience has shown that a pre-blended material is most likely to be acceptable to the industry. We have demonstrated that strengths of up to 30MPa can be achieved with CEM 0 concretes. ●

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