Sustainability briefing

Cementitious materials

In the context of the need to consider whole life performance and the interdependence of operational and embodied carbon dioxide (ECO_2), there is increasing pressure on structural engineers to specify materials in a manner that minimises environmental impacts even if those materials are abundant. This briefing note seeks to give guidance on how this can be achieved with cements and combinations whilst avoiding unforeseen consequences which lead to a less sustainable outcome. Cements are single powders supplied to concrete producers containing, for example, Portland cement and fly ash. Combinations are formed where concrete producers mix Portland cement with, for example, fly ash in a concrete mixer.

Background

The materials commonly used with Portland Cement are ground granulated blastfurnace (ggbs), siliceous fly ash, silica fume (all industrial by-products from other industries) and limestone. Durability of concretes can be improved by the use of these materials and this benefit is recognised in codes of practice. Common proportions of ggbs, fly ash, silica fume and limestone fines used in UK-produced combinations are 50%, 30%, 10% and 6-10% by mass of total cementitious content respectively, and the use of these pre-dated the current sustainability agenda due to cost and performance credentials.

For most applications and construction scenarios, BS 8500-1[1] allows considerable specification flexibility in terms of cement or combination type used. Permitted Portland cement replacement ranges, by mass, are 6-10% (silica fume), 6-20% (limestone), 6-55% (fly ash) and 6-80% (ggbs). The British Standard table A.6 in BS 8500-1:2006 provides details of the cement and combination types recommended for UK structures where selected exposure classes, intended working life and nominal cover to normal reinforcement have been identified.

The British Standard does not give specific guidance on the relative merits of cements and combinations in terms of their associated performance (apart from that relating to exposure) and environmental impacts. This briefing provides initial guidance on these matters.

CONCRETE	Concrete type	ECO_2 ($kgCO_2/m^3$)		
		CEM1 concrete	30% fly ash concrete	50% GGBS concrete
Blinding, mass fill, strip footings, mass foundations	GEN1 70mm	173	124	98
Trench foundations	GEN1 120mm	184	142	109
Reinforced foundations	RC30 70mm	318	266	201
Ground floors	RC35 70mm	315	261	187
Structural: *in situ* floors, superstructure, walls, basements	RC40 70mm	372	317	236
High strength concrete	RC50 70mm	436	356	275

Table 1 ECO_2 for different concretes (Data source: www.concretecentre.com)

Embodied carbon and recycled content

Use of fly ash, ggbs and silica fume, by-products/waste from other industries, contributes to the recycled content of the final concrete. Also their use will directly reduce the ECO_2 of the final concrete. Table 1 shows the ECO_2 for different concretes based on UK production. (Note CEM1 is the designation for 100% Portland Cement).

When designating or designing concrete to BS 8500-1:2006, close attention should be given to all of the strength classes and cement/combination types permitted for selected minimum working lives, exposure classes and nominal covers to normal reinforcement. Giving preference to options with low recommended minimum cement contents and permitted cement/combination types with the highest levels of Portland cement replacement will directly reduce values of ECO_2 of the concrete and increase recycled contents.

It is important to note that ECO_2 or recycled content values for concrete should not be considered or specified in isolation. Adopting holistic approaches to sustainability-related decision making is always advisable, given the significant impact of cement/combination type and content on a range of key concrete properties given below.

Early strength development/heat development

For a given value of 28 day strength, concrete containing additions such as fly ash and ggbs will exhibit lower relative early age strengths and lower heat development, than those containing Portland cement only. This is because concrete's early strength is dependent, primarily, on its Portland cement content. However it is likely that some level of additions will be possible in most cases.

Recognised routes to address low early strength gain for low ECO_2 concretes are available. To help reduce formwork striking times, for instance, technologies such as accelerating admixtures can be combined with increased insulating effectiveness of formwork and accelerated application of curing.

Equally, established methods[2,3,4] for more accurately determining *in situ* early age concrete strengths and/or formwork striking times are available. These include the use of maturity methods using site specific or predicted input data; on site cured or temperature-matched test cubes; and penetration, pull-out or break-off tests.

Contractors are able to erect concrete structures, such as framed buildings, conventionally (to programme and budget) using low ECO_2 concrete mixes. Indeed, using the established assessment techniques described above, innovative construction teams are presently erecting high rise structures year round using average to high Portland cement replacement levels with additions such as fly ash and ggbs. In the UK further details may be sourced from CONSTRUCT and British Ready Mixed Concrete Association members.

Reduced heat development is an advantage for large cross section elements and can be achieved through the use ggbs, fly ash, limestone fines or silica fume thus reducing thermal gradients and the risk of cracking.

Colour

The surface colour of concrete is dominated by its finest particles, which typically includes the cement/combination and sand particles smaller than around 63µm. The colour of Portland cement varies, according to the materials from which it is manufactured. The incorporation of additions such as fly ash, ggbs and micro silica also has a major influence. Ggbs is off-white in colour (see Fig 1) and substantially lighter than Portland cement due to its low

1 Pale off white finish of GGBS

2 Dark grey finish of fly ash

iron content. Fly ash is dark grey in colour (see Fig 2), resulting from a combination of iron compounds present and carbon residues left after the coal is burned as part of its manufacturing process, the shade depending on the source of coal and the process plant used.

Where structural aesthetics are critical, the impact of cement/combination type on concrete colour may dominate over restrictions due to local availability or requirement for ECO_2 content. Further guidance[5,6] on cement/combination type and concrete colour is available in the literature.

Availability

Fly ash and ggbs are widely available in the UK and transport distances from the point of production to the point of use are similar to that for Portland cement. At ready-mixed concrete plants producers typically stock Portland cement and either ggbs or fly ash. Limestone fines and silica fume may also be available in a percentage of ready-mixed concrete plants, or be made available given sufficient notice, but will not always be available at all locations. As such, overly prescriptive specifications that dictate a firm requirement for fly ash, ggbs, limestone fines or silica fume may not lead to economical and/or more sustainable solutions. Instead, the recommended approach is to prepare specifications that allow flexibility and choice in terms of materials, with, perhaps, caveats added to state justified material preferences. Advice is given in the recently published 4th edition of the *UK National Structural Concrete Specification*[7]. Beyond the UK, advice with respect to availability should be sought from relevant trade associations or local concrete producers.

References

1 BS 8500-1:2006 *Concrete – Complementary British Standard to BS EN 206-1. Part 1: Method of specifying and guidance for the specifier,* BSI
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4 *Formwork striking times – criteria, prediction and methods of assessment*, *CIRIA Report 136*, TA Harrison, 1995.
5 *Architectural Insitu Concrete*, RIBA Publishing, ISBN 978 1 85946 259 1, David Bennett, 2007
6 *Plain formed concrete finishes, Technical report 52*, The Concrete Society, 1999
7 *CONSTRUCT, National Structural Concrete Specification for Building Construction* 4th edition, April 2010, The Concrete Centre, available at: http://www.construct.org.uk/bpg/NSCS_V4.pdf

Further Information

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Issue No. 18