Admixtures and sustainable concrete

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Introduction

Admixtures are defined in EN 934-2:2012 as: 'material added during the mixing process of concrete in a quantity not more than 5% by mass of the cement content of the concrete, to modify the properties of the mix in the fresh and/or hardened state'.

They are normally liquids and act on the surface of particles in the mix. This differentiates them from "additions" such as ground granulated blastfurnace slag (GGBS), pulverized fly ash (PFA) and limestone fines which are powders that can be added at the concrete plant to produce a blended cement or obtained as a pre-blended

Sustainability

Admixtures can reduce the embodied carbon content (ECO_2) of concrete, despite having a relatively high ECO_2 themselves when compared on a tonne-for-tonne basis. Admixtures are used in very small dosages compared to most other ingredients, and as such they typically contribute less than 1% to the total ECO_2 of concrete, while allowing the overall cement content to be reduced. Under BS EN ISO 14044 constituents contributing less than 1% of the impacts can be ignored, and this would apply to most cases of admixture usage. This reduction in the ECO_2 of concrete can be achieved whilst maintaining, and, in most cases further enhancing, the properties of the concrete. In the hardened state, for the same cement content, admixtures can significantly improve the durability of the concrete for a range of aggressive environments, thus extending the maintenance-free service life.

In the UK, the Cement Admixtures Association (CAA)[2] estimates that current admixture use already saves about 600,000 tonnes of ECO_2 per annum and this could be significantly increased by further mix optimisation. This estimate is based on typical dosage rates for admixtures (Table 1). In certain specialist applications such as very high strength concrete, these dosages may be exceeded.

The admixture manufacturing process has undergone an environmental inventory, enabling six Environmental Product Declarations (EPDs) to be produced covering over 80% of admixture production in the European Union. These EPDs are freely available to download from the CAA website[2] along with other environmental and sustainability information.

A safe solution

Although admixtures are composed of a wide range of raw materials, they are not generally toxic and indeed most of them have been individually assessed for use in concrete in contact with drinking water by the UK's national water regulators. The assessment covers toxicology of the individual substances in the admixture and leaching tests from concrete. The migration of the substances is often below the detection limit and always well below the maximum tolerable concentration (MTC) at the tap according to European directives.

New regulatory requirements for admixtures in concrete in contact with drinking water (and on release of dangerous substances) currently being drafted by the European Commission, will eventually appear in EN 934 part 1.

Table 1: Typical UK use and dosage rate for admixtures (CAA, 2011)

Admixture type to EN 934-2	Proportion of total admixture sales %	Average dosage % by weight of cement
Superplasticizers	45	0.70*
Normal plasticizers	34	0.45
Accelerating	2	1.65
Retarding	2	0.45
Air entraining (AEA)	4	0.20
All other concrete admixtures	13	

*Dosage based on 40% solution. Some superplasticizers will be sold at greater dilution with a correspondingly higher dose

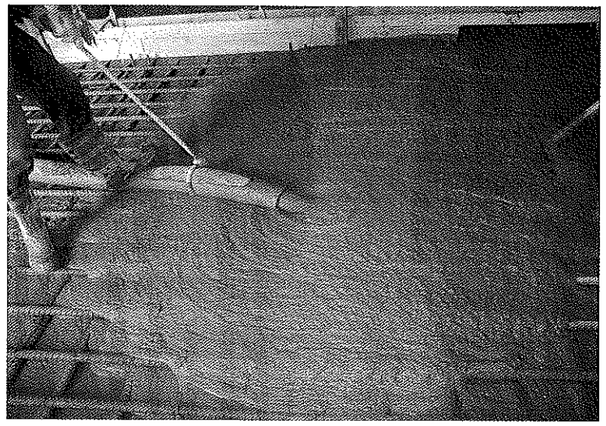

Figure 1 **A saving in ECO_2 for reinforced concrete of up to 10-15% may be achieved if admixtures are used**

Concrete for different exposure conditions

When specifying concrete to BS EN 206-1 and BS 8500 parts 1 and 2, consideration needs to be given to the environmental conditions to which the concrete will be exposed. The five main exposure classes defined in BS 8500 are listed here. Each class has a number of sub-categories depending upon the severity of exposure:

- XC Exposure class for risk of corrosion induced by carbonation
- XD Exposure class for risk of corrosion induced by chlorides other than from sea water
- XS Exposure class for risk of corrosion induced by chlorides from sea water
- XF Exposure classes for freeze/thaw attack
- XA Exposure classes for chemical attack

Depending upon the exposure condition and the cover, BS 8500 will define a minimum cement content, maximum water/cement ratio and possibly required strength to give the desired design life.

The use of water-reducing or superplasticising admixtures enables a given strength and/or water/cement ratio to be achieved with lower cement content (subject to achieving the minimum cement content). The correct use of admixtures can reduce the ECO_2 of the concrete, while maintaining or enhancing the long-term durability performance of the concrete.

Some examples

Example 1

Strength requirement: C32/40, Exposure: XC3/4, Cover: 35mm+Δcdev
From BS8500-1 Table A.4 the minimum cement content is 260 kg/m³ with a maximum water/cement ratio of 0.65.

For a range of cement types, with or without limestone, fly ash or GGBS:
a) The benefit of incorporating a normal water-reducing admixture (WRA) is to enable a reduction in cement content by about 30 kg/m³, giving a 5-8% saving in ECO_2 for reinforced concrete.
b)The benefit of incorporating a high-range water-reducing admixture (HRWRA) is a potential further reduction of around 30kg/m³. This total reduction cannot be realised for all cement types as the cement content cannot be reduced below the 260 kg/m³ minimum. A saving in ECO^2 for reinforced concrete of 10-15% can be achieved (Figure 1).

Example 2

Exposure: XS1, Cover: 35mm+Δcdev.
Normally a resistance to chloride ingress requirement will mean there is sufficient strength to meet the engineer's structural requirement. For normal or high quality aggregates, a strength of C40/50 will be readily achieved by a concrete meeting the BS8500-1 Table A.4 XS1 exposure requirement, where the minimum cement content is 360 kg/m³ with a maximum water/cement ratio of 0.45.

For a range of cements (as in Example 1):
a)The use of a WRA gives a potential cement reduction of around 40 kg/m³, but this is not realisable for all cements because it would reduce the cement content below the 360 kg/m³ minimum. A saving in ECO_2 for reinforced concrete of 1- 8% can be achieved.
b) Using a HRWRA will not give any further savings because the minimum cement content can be achieved with WRA. In this example, as the specified maximum water/cement ratio is 0.45, there are occasions where the water/cement ratio is higher than specified due to the available aggregates, or where a higher level of consistence is required. In these cases a HRWRA may be usefully incorporated to further reduce the cement content, and therefore the ECO_2, as long as all the other criteria such as minimum cement content and/or maximum water cement ratio are still complied with.

Further information

A range of guidance is freely available to download from the CAA website[2]. This includes Admixture Technical Sheets for the following admixture types:

- Normal water-reducing/plasticizing admixtures (WRA)
- High-range water-reducing/superplasticizing admixtures (HRWRA)
- Retarding
- Accelerating
- Air-entraining
- Water resisting (waterproofing)
- Corrosion inhibiting
- Polymer dispersion admixtures
- Pumping aids
- Self-compacting concrete
- Precast, semi-dry concrete
- Shrinkage reducing admixtures
- Anti-washout/underwater admixtures
- Truck washwater admixtures
- Viscosity modifying/segregation-resisting admixtures

Additional information is also available from the CAA via a series of Admixture Information Sheets, and Environmental Sheets as well as other guidance documents on the use of admixtures.

Guidance for specification

It is unusual for the structural engineer to specify admixtures in any detail for there is scarcely the need. On occasions where there is a need, the expertise required goes beyond what is covered in this article. For the vast majority of cases the simple guidance is that the use of admixtures should be permitted in the specification.

References

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Figure 1
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