the Sign of Quality

Admixture Technical Sheet – ATS 2

Superplasticising / High range water reducing

1 Function

High range water reducing (HRWRA) /Superplasticising admixtures are synthetic, water-soluble organic chemicals, usually polymers, which significantly reduce the amount of water required to achieve a given consistency in plastic concrete. This effect can be utilised in two ways:

To reduce water content to achieve increased strength and reduced permeability / improved durability
To achieve increased workability at the same water content

With a slightly higher admixture dosage, both these effects can often be achieved in the same mix.

When high range water reducing admixtures are used to increase the workability or consistence of the concrete they are usually termed 'Superplasticising admixtures' but these names are frequently interchanged.

High range water reducing admixtures function in a similar way to 'Normal Water Reducing Admixtures' (see AS1) but are more powerful in their cement dispersing action and can be used at higher dose without unwanted side effects such as air entrainment or retardation of set.

2 Standards

This class of admixture is covered by the requirements of BS EN 934 Part 2: Concrete admixtures – Definitions requirements, conformity, marking and labelling. The specific requirements are stipulated in Tables 3.1 and 3.1.

All CAA manufacturers CE mark their products to show they conform to this standard.

3 Materials

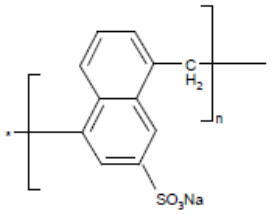
High range water reducing admixtures are typically based on:

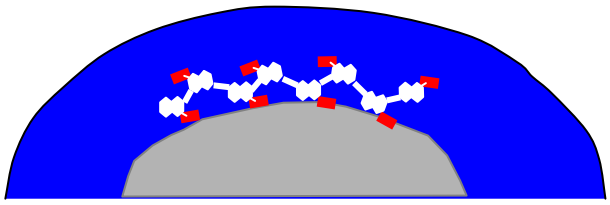
Salts of Sulphonated Naphthalene Formaldehyde Condensate (SNF) and variants
The sodium salt of Sulphonated Melamine Formaldehyde Condensate (SMF)
PolyCarboxylates including Esters and Ethers and other copolymer derivatives (PCE)

These are often blended formulations or mixtures with other water reducing components or additives to give admixtures with carefully targeted properties, notably balancing water reduction with workability retention. Some different chemical type blends however may be incompatible. eg SNF and PCE.

4 Mechanism

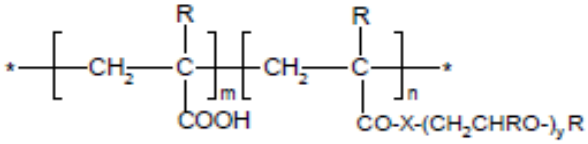
Most HRWRAs work in a very similar way to normal water reducing admixtures. They dissociate in water to give negative charges on the **SO3** group or **COO** group for example. Some of these are adsorbed onto the positive sites on the cement particles, others form an outer negative charge round the grain lowering the inter-particle attraction by an electrostatic mechanism and producing a more uniform dispersion of cement grains. This reduces the amount of water needed to achieve a given paste viscosity. A typical example is Sulphonated Naphthalene Formaldehyde Condensate

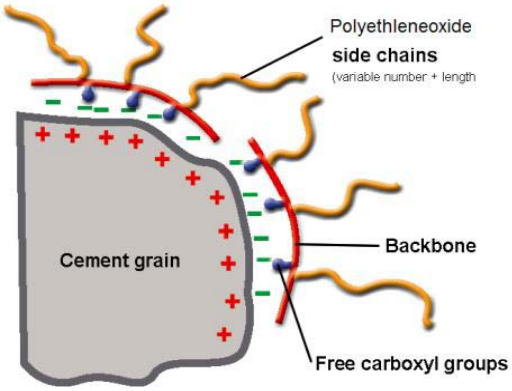




The most recently developed products; the PolyCarboxylate Ethers and Esters additionally work by steric hinderence resulting from the hydrophilic polyether pendent chains which are grafted onto a polyacrylic acid backbone. In total there exists a complex family of PCE products all having influence on rheology, water reduction, workability retention and concrete performance. The user is thus particularly advised to consult the manufacturer before use.

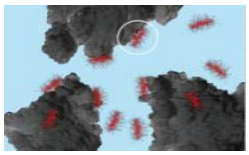
An example of a simple polycarboxylate ester containing polyether side chains;



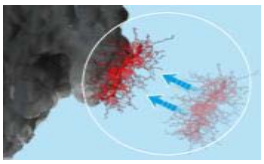


The modes of action of the new Polycarboxylate Ether (PCE) based superplasticer effects can be observed below:

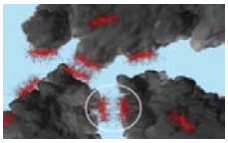
Adsorption of the polymer on the cement grain



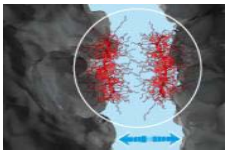
Water reduction effect



Improved workability due to steric hindrance



steric effect



5 Use

5.1 Dosage

The Naphthalene and Melamine types of superplasticiser / HRWRA are typically used in the range 0.7 to 2.5% by weight of cement and give water reductions of 16 to 30%.

The PolyCarboxylate Ethers are more powerful and/or efficient and are used at 0.3 to 1.5% by weight of cement to typically give 20 to over 40% water reduction.

The water contribution from a superplasticiser can be allowed for, wherever necessary, in the calculation and determination of the w/c ratio of the concrete mix. The water content in the admixture can be obtained from the manufacturer but is typically in the range 60% to 80%.

5.2 Admixture Selection

The different types of superplasticiser / HRWRA each have specific characteristics which make them particularly appropriate for certain jobs although they will all give good performance for the majority of applications. The following comments are very general guidelines and should not be regarded as inclusive or exclusive of the admixture type. Always discuss specific requirements with the supplier.

Naphthalenes (SNF): Good water reduction and strength development with reasonable workability retention for most applications. Currently a very cost effective all round superplasticiser. Can sometimes give problems with air entrapment and poor surface finish.

Melamines: (SMF): Good early strength development at low temperatures, excellent surface finish. Good with very cohesive mixes. However there can be rapid loss of workability, especially at elevated temperatures. Prone to bleed and segregation in low cohesion mixes.

PolyCarboxylate Ethers/Esters (PCE): As a water reducer they can give maximum water reduction and early strength development. As a superplasticiser they give excellent fluidity and flow retention. Their properties can be tailored by modification of the polymer backbone, added functional groups and the copolymer side chains to give specific properties for particular applications. They can give good water reduction at a very low dose and hence very little retardation, which makes them very effective where retardation is a problem, eg floors. They can be relatively expensive compared to the other types, especially on a cost per litre basis but cost in use combined with enhanced performance is often attractive. This high performance can sometimes make them more sensitive to small variations in the consistence of other mix materials, batching sequence or batching accuracy etc. PolyCarboxylate Ether/Ester use has increased rapidly over the last 10 years. They are now widely used in precast plants and are the preferred superplasticiser type used in the production of concrete with a target consistence level greater than S3, for example, self-compacting concrete is almost exclusively produced using this superplasticiser type.

The wide range of blended and optimised systems available within this category of admixture means that an individual product may have the combinations of, or enhancement of, the features detailed above so manufacturer's advice should always be sought for critical jobs. The development in PCE technology has made it possible to tailor make products for specific applications/performance requirements.

5.3 Cement Type

Superplasticising / HRWRA can be used with all types of Portland cement including those covered by EN 197-1 and with alternative binders blended with CEM I cement.

Factors such as air entrainment, mix cohesion, water reduction and stiffening time may be slightly affected when admixtures are used with blended cements.

Different admixture chemistries respond differently to different cement sources and qualities (all of which are unique). Some admixtures give a more or less robust response to variations in cement chemistry.

5.4 Yield

Where water reduction is used, there will be a reduction in the volume of cement paste and hence in the yield. With HRWRA, this can be quite large and must be taken into account in calculating mix yield.

5.5 Overdosing

The amount of water reduction or increase in consistence (workability) will normally increase with increased dosage. Any dosage that is significantly in excess of that intended (overdosing) can, in certain circumstances, result in mix segregation, retardation and/or a degree of air entrainment. The higher the intended dosage within the manufacturers stated range, the more significant will be the effect of any overdosing.

For non retarding HRWRA, the retardation is unlikely to be more than 24 hours even at considerable overdose but extra curing is advisable to prevent the surface drying out before setting and re-vibration up to the time of initial set will help to prevent plastic settlement cracking.

6 Effects on properties of concrete

6.1 Strength

When HRWRA are used, the compressive strength of concrete is increased as a direct result of the lower water/cement ratio. BS EN 934-2 requires an increase in compressive strength over the equivalent plain concrete mix of at least 140% after 1 and 115% after 28 days, when used as a high range water reducer.

When superplasticising admixtures are used to increase workability at equal water content, the compressive strength is generally similar to that of the equivalent plain concrete mix.

Typical results for a 330 Kg/m^3 cement content mix with CEM I cement and a Naphthalene and a PCE based admixture are shown below:

	Control	Naphthalene Superplasticised	Naphthalene **Water Reduced**	**Control**	**PCE Water Reduced**
Dose lit / 100 kg cement	0.0	1.0	1.0	0.0	0.5
W/C	0.55	0.55	0.44	0.66	0.53
Slump mm	75	220	75	135	165
Strength at 1 day N/mm^2	16.0	14.0	32.0	14.4	24.3
Strength at 28 days N/mm^2	49.0	48.0	60.0	39.0	60.5

6.2 Consistency

Where no change is made to the water cement ratio, superplasticising admixtures significantly increase workability, typically the slump will be more than 120 mm higher than the value for a plain concrete of equal water content. At higher dosages, the concrete can be made flowing or even self-compacting but in both these cases, care is needed over mix design or the mix may be subject to significant bleed and segregation. This is normally achieved by increasing the proportion of sand and or adding other fine fillers.

6.3 Slump loss

The rate of consistence loss of concrete containing a HRWRA is generally similar to or greater than that of the equivalent plain concrete mix of the same initial consistence but there are significant variations between HRWRA types with respect to rate of loss. However the advent of slump retaining Superplasticer has enabled concrete to provide prolonged working life without negative effect on early or ultimate strength development.

Where slump retention is required over a longer period, the admixture should be used to increase initial consistence. The concrete will then maintain a high level of consistence for longer after mixing and will still have the structural properties of the plain concrete. Again, there are considerable differences in workability retention between the different types of superplasticiser with polycarboxylate

ethers/esters, Vinyl Copolymer and modified naphthalenes typically giving the best results. Some types are formulated to enhance this property.

6.4 Setting time
The setting time of the concrete containing non retarding HRWRA is normally within 90 minutes of the equivalent plain mix at equal consistence and in most cases will be less than 45 minutes longer. Some types may even slightly accelerate the set.

6.5 Air entrainment
BS EN 934-2 requires that any increase in air content shall not be more than 2% by volume, over that obtained from the reference mix, and most types of HRWRA easily meet this requirement. Some types may even reduce the level of air and this can result in a less cohesive mix, which may be more prone to bleed and segregation or may leave the mix feeling harsh and difficult to handle.

With some types of HRWRA it may be difficult to entrain air with a good, well spaced bubble structure. Where this is a requirement for freeze thaw resistance, the admixture supplier should be consulted for advice on the selection or HRWRA and or Air Entraining agent.

6.6 Bleeding
In certain circumstances and when used to increase consistence (workability), some types of HRWRA may reduce the level of air and this can result in a less cohesive mix that may be more prone to bleeding and segregation or may feel harsh. Some superplasticisers are formulated to have enhanced cohesion and can produce an essentially bleed free mix with excellent handling properties.

Increasing the proportion of sand and or adding other fine fillers may be necessary in order to avoid bleeding, especially in high workability mixes.

Viscosity modifying agents (VMA) can also be used to overcome bleed, segregation and harshness issues. These agents are polymers or blends which increase the viscosity of cement paste and thereby keep coarse aggregates in suspension in high workability mixes. Some agents can retard concrete set and / or entrain excess air. They can improve pumping characteristics and sometimes anti-washout properties. It is always recommended to seek manufacturer's advice before selection.
Further advice can also be found on ATS sheets 13 and 18.

6.7 Heat of hydration
The maximum rise in temperature of concrete is unaffected by the presence of a HRWRA when no other mix design changes are made. If the cement content is reduced the maximum temperature rise is reduced in direct relation to the cement reduction made.

6.8 Volume deformation
Creep and drying shrinkage are slightly reduced from that of plain concrete when these admixtures are used as a HRWRA but may slightly increase when being used as a superplasticiser. The best reductions in drying shrinkage are obtained if a combination of water and cement reduction can be achieved. In this situation, shrinkage may be reduced by 20% or slightly more.

6.9 Durability
When used to reduce the water content of the mix normal water reducing admixtures enhance the durability of the concrete by improving both the density and impermeability.
With an increasing emphasis on durability, many concrete specifications now call for water/cement ratios of below 0.40 and HRWRA are one of the best ways to achieve this.

Typical durability test results are shown below:
NB workability, aggregate type and cement source differed between sets of mixes and so factors like strength should not be compared between the sets.

	Admixture	**Cement content**	**W/C**	**28-day strength**	**Test Result**

		kg/m3		MPa	
Pressure Permeability	Control	350	0.52	45	5×10^{-11} m/s
	Naphthalene	350	0.40	59	6×10^{-13} m/s
Chloride Diffusion	Control	375	0.50	49	28×10^{-12} m^2/s
	Naphthalene	360	0.40	63	8×10^{-12} m^2/s
Accelerated Carbonation	Control	350	0.54	41	14 mm
	Naphthalene	350	0.43	58	3 mm

6.10 Sustainability

Most admixtures have a potentially significant part to play in sustainability of buildings and structures, comprising

- A reduction in primary cement clinker use
- Enabling reuse of recycled materials
- Reduction of waste
- Improving the durability of concrete structures

Admixtures can reduce the embodied carbon content (ECO_2) of concrete. Because admixtures are used in such small dosages compared to most other ingredients, they typically contribute less than 1% to the total ECO_2 of concrete while allowing the overall cement content which is the main contributor of ECO_2 to be reduced. Under BS EN ISO 14044, constituents like admixtures that contributing less than 1% of the total impact can be ignored in the environmental calculation. When using admixtures, this reduction in the total ECO_2 of concrete can be achieved whilst maintaining and, in most cases, further enhancing the properties of the concrete.

7 Health and Safety of Admixtures

Most admixtures are non hazardous and pose no abnormal health and safety risk but as with all forms of chemical it is essential that the material safety data sheets are read and understood before use. Risk assessments should be conducted to ensure all users are provided with a safe means of use and relevant PPE.

8 Other information

Other CAA information sheets are available including Environmental Product Declarations, use of admixtures in drinking water applications, sustainability, storage and dispensing. These are available at www.admixtures.org.uk under the ‘Publications’ tab.