CEMENT ADMIXTURES ASSOCIATION
38a Tilehouse Green Lane, Knowle, West Midlands B93 9EY
Tel/Fax: 01564 776362
www.admixtures.org.uk

SECRETARY: JOHN DRANSFIELD

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, which significantly reduce the amount of water needed to achieve a given consistence in plastic concrete. This effect can be utilised in two ways:

To reduce water content for increased strength and reduced permeability / improved durability
As a cement dispersant at the same water content to increase consistence and workability

With a slightly higher admixture dosage, both these effects can 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 Materials

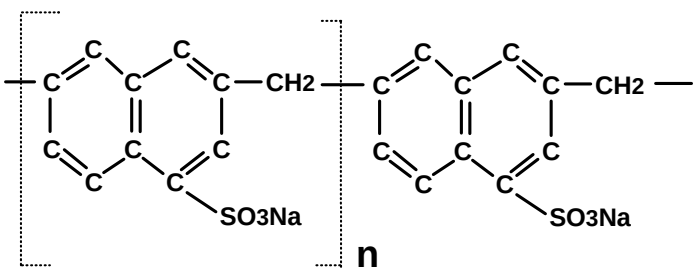
High range water reducing admixtures are normally based on:

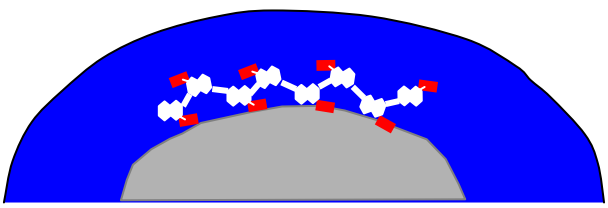
Salts of Sulphonated Naphthalene Formaldehyde Condensate.
The sodium salt of Sulphonated Melamine Formaldehyde Condensate.
Derivatives of Vinyl Copolymers and Aminosulphonic Formaldehyde Condensates.
Derivatives of PolyCarboxylate Ethers.

These are often blended with each other or with 'normal water reducing admixtures' to give admixtures with carefully targeted properties.

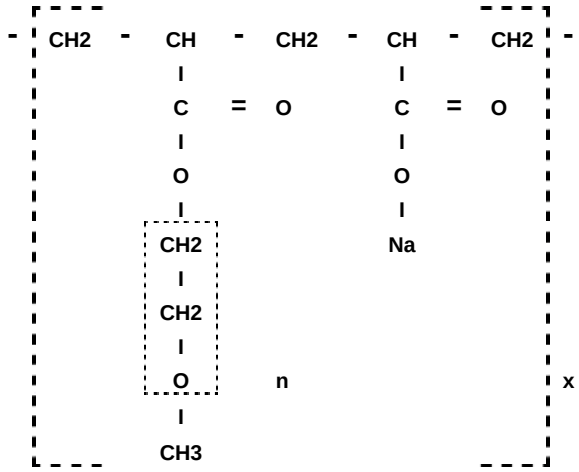
3 Mechanism

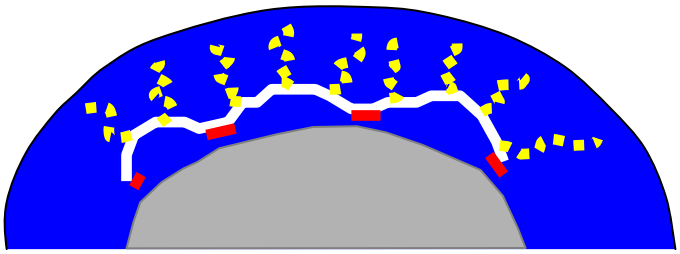
Most HRWRA work in a very similar way to normal water reducing admixtures. They dissociate in water to give negative charges on the **SO3** group. Some of these are adsorbed onto the positive sites on the cement particles, others form an outer negative charge round the grain lowering the inter-particle 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





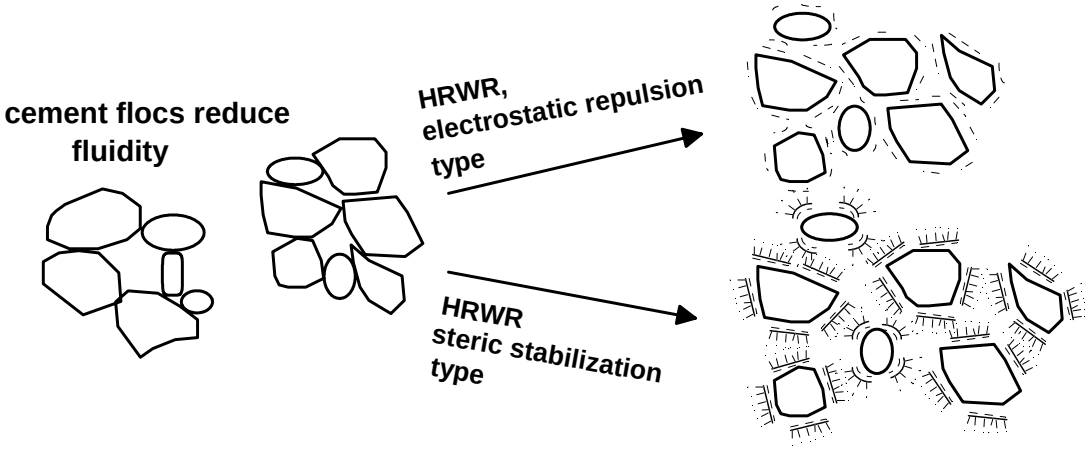
The most recently developed products; the PolyCarboxylate Ethers are thought to work by steric stabilisation, resulting from the hydrophilic polyether pendent chains which are grafted onto a polyacrylic acid backbone.





The difference in dispersion of the cement and subsequent stabilisation between the polycarboxylate ether types and the electrostatic repulsion types can be compared.

.



4 Use

4.1 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 are used at 0.3 to 1.0% by weight of cement to typically give 20 to over 40% water reduction.

Even at the highest superplasticiser dosages, the amount of water being added to the mix by the admixture is relatively small. It can usually be ignored with respect to W/C. The effect on W/C is less than 0.01 in most mixes and in the worst possible case should not go above 0.02.

4.2 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: 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: Good early strength development at low temperatures, excellent surface finish. Good with very cohesive mixes. Can loose workability quickly, especially at elevated temperatures. Prone to bleed and segregation in low cohesion mixes.

PolyCarboxylate Ethers: 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 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 as an all round superplasticiser compared to the other types, especially if compared on a cost per litre basis but this is offset by their enhanced performance. This high performance can make them less forgiving of small variations in consistence of mix materials, batching etc. PolyCarboxylate Ether use has increased rapidly over the last 10 years. They are now widely used in precast plants and are the principle superplasticiser type used in the production of self-compacting concrete.

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.

4.3 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 and stiffening time may be slightly affected when admixtures are used with blended cements.

4.4 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.

4.5 Overdosing

The amount of water reduction or gain in consistence will increase with increasing dose. 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.

5 Effects on properties of concrete

5.1 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 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 based admixture are shown below:

	Control	Superplasticised	High Range Water Reduced
Dose lit / 100 kg cement	0.0	1.0	1.0
W/C	0.55	0.55	0.44
Slump mm	75	220	75
Strength at 1 day N/mm^2	16.0	14.0	32.0
Strength at 28 days N/mm^2	49.0	48.0	60.0

5.2 Consistence
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.

5.3 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.

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 consistence retention between the different types of superplasticiser with polycarboxylate ethers, Vinyl Copolymer and modified naphthalenes typically giving the best results. Some types are formulated to enhance this property.

5.4 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.

When superplasticised with a non-retarding type, there may be 2 to 3 hours extension of set but again, this depends on the type used and on the dose. In some cases retardation will be less than 60 minutes.

5.5 Air entrainment
BS EN 934-2 requires that any increase in air content shall not be more than 2% by volume 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 bleeding, and segregation or may leave the mix feeling harsh and difficult to handle.

Superplasticised, high workability mixes tend to destabilise the air so that it will rarely be above that of a control mix without admixture.

With some types of HRWRA, especially naphthalenes, it is difficult to entrain air with a good, well spaced bubble structure. Where this is a requirement for freeze thaw resistance, other types generally give a better bubble structure.

5.6 Bleeding
As noted above, 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.

5.7 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.

5.8 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.

5.10 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 kg/m3**	**W/C**	**28-day strength MPa**	**Test Result**
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