



CEMENT ADMIXTURES ASSOCIATION

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the Sign of Quality

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Admixture Sheet – ATS 11

Polymer dispersion admixtures

1 Function

Polymer dispersion admixtures are aqueous dispersions of elastomeric / thermoplastic synthetic polymers which will form a continuous film under the conditions of use when sufficient water is lost from the system. Bituminous products, two pack systems that can form films through cross linking, or redispersable powder polymers are not included in this section.

Concrete modified with polymer dispersion is known as Polymer Cement Concrete (PCC).

Polymer dispersions :

- Reduce the permeability of concrete, improving durability.
- Give a more reliable bond to base concrete and to reinforcing steel.
- Increase toughness, resistance to abrasion / dusting and freeze - thaw action.

The reduced permeability of PCC gives improved resistance to many chemicals and the ingress of chlorides. Thinner sections / decreased reinforcement cover can be used without compromising durability. These properties make it suitable for bridge deck overlays, roads, sea wall defences, concrete repairs, precast products, industrial floors etc.

For economic reasons applications are usually restricted to thin section concrete e.g. concrete up to about 75 mm in thickness. Polymer dispersions are also widely used in screeds, mortars, renders, and grouts.

2 Materials

The principal generic polymer types in use are:

Polyacrylate (polyacrylic ester)	PAE
Styrene acrylate (styrene acrylic ester)	SA
Styrene butadiene rubber	SBR

Each type can be tuned by the manufacturer to give a wide spectrum of overlapping properties regarding the rheology of the wet concrete mix and the mechanical properties of the hardened concrete. PAE is the best choice for colour retention in white concrete, and SBR for maximum acid / alkali resistance. However as stated on Page 11 of Concrete Society Technical Report No 39 (Polymers in Concrete) "The engineer should only specify the performance he requires from the polymer modified mortar or concrete. Specifying a generic polymer type will not assist towards obtaining the most suitable product - - - -"

The polymers are supplied as aqueous dispersions which have the appearance of milk. They are usually supplied by the manufacturers as low viscosity liquids with a total solids content in the order of 50% by weight of the polymer dispersion. The polymer particles in the dispersion have a particle size in the order of 0.2 microns (200 nanometres). The specific gravity of the dispersions is between 1.00 and 1.06 g/cc.

Polymer dispersions are used in many industries, but dispersions for use with cement are stabilised by the manufacturer in order to prevent the cement causing premature coagulation of the dispersion.

3 Mechanism

These products function in 4 ways:

They reduce the required water : cement ratio for a given consistency or give extra fluidity if the water : cement ratio of the unmodified mix is maintained.

As water is lost from the concrete the polymer particles coalesce together to form an interpenetrating network of strands and films within the cementitious matrix. This network partially blocks the capillaries and partially bridges the microcracks. Hence permeability is reduced and crack propagation is limited.

The polymer improves the adhesion of the cementitious paste to the aggregate.

The drying out rate of the concrete is reduced and this leads to better hydration of the cement.

4 Use

4.1 Dosage

Typical dose rate is 10 - 30 litres of a 50 % solids dispersion per 100 kg of cement

4.2 Temperature

Polymer dispersions should be stored between 5°C and 35°C and mixed before use. If diluted and then stored for more than a few days extra biocide should be added.

PCC should preferably be placed within the following guide climate limits :

Temperature	7 to 28°C
Humidity	50 to 100 % RH
Wind	Less than 20 mph

4.3 Mixing

A forced action mixer is preferred and essential if the mix is of low workability. Tools and all equipment should be cleaned with water as soon as is practical after use as the polymer is very difficult to remove once it film forms. The time interval between use and cleaning should not normally exceed 1 hour and it facilitates cleaning if the tools and equipment are kept damp during this time interval.

4.4 Overdosing

Overdosing will reduce the compressive strength, make the PCC difficult to finish, delay the setting / hardening and increase creep.

4.5 Curing

Damp curing of PCC should begin immediately after finishing and be continued for 2 days, followed by at least 3 days dry curing. If, when in use, the PCC is to be continuously immersed in water, it must first be dry cured in order to bring about the necessary coalescence / film formation of the polymer particles.

5 Effects on the properties of concrete

5.1 Strength

PCC does not require a high compressive strength to achieve good durability. In fact high compressive strength may detract from other desirable properties e.g. crack resistance and compatibility with weak backgrounds.

Increasing the dose rate of the polymer dispersion above 20 litres of a 50% solids dispersion per 100 kg of cement may decrease the compressive strength, but will give higher values for flexural, tensile and impact strength.

Two important properties of polymer dispersions are the minimum film forming temperature (MFFT) of the dispersion and the glass transition temperature (Tg) of the polymer in the dispersion.

The MFFT is the minimum temperature at which the polymer particles in the dispersion can coalesce together to form a continuous film, when the dispersion is dried out.

The T_g is usually expressed as the midpoint of the temperature range at which the polymer from the dispersion suddenly becomes much stiffer on cooling.

The T_g and MFFT are largely controlled by the ratios of the monomers in the polymer. For example by increasing the styrene : butadiene ratio when making SBR a “harder” polymer is produced having a higher T_g and MFFT

If other factors remain constant, the higher the T_g of the polymer and the higher the MFFT of the polymer dispersion, the higher the compressive strength of the PCC. However if the polymer dispersion does not film form under the conditions of use then the main advantages from using a polymer dispersion will be lost.

For a typical polymer dispersion having a mid point glass transition temperature of minus 6^oC and a minimum film forming temperature of below 1^oC, the combined effect of lower water : cement, higher air content and the polymer is to reduce the 28 day compressive strength by about 10 % (compared with an unmodified control made to a similar mix consistency) for a dosage rate of 20 litres of a 50 % wt /wt polymer dispersion per 100 kg of cement. However the same polymer dispersion will give significant improvements to the tensile, flexural, bond, impact strength and abrasion resistance. Regarding mortars, where more test results are available, a guide to possible improvements from the above polymer and dosage rate is as follows (taking 100 as the value for the unmodified mortar) :

Tensile strength	175
Flexural strength	150
Tensile bond strength to concrete	250
Impact	250
Abrasion	500

By using a harder polymer e.g. one with a T_g of 20^oC and a MFFT of 25^oC the 28 day compressive strength of the PCC can be expected to be equal or slightly higher than the unmodified control. Such hard polymers will not impart good strain capacity to the PCC and might not film form under the conditions of use.

5.2 Workability

Where no change is made to the water : cement ratio, polymer dispersions increase the workability.

5.3 Slump loss

In mixes where the ability of the polymer dispersion to reduce the required water : cement ratio is utilised, the rate of slump loss will be increased. Where the water : cement ratio is not reduced, the allowable time between mixing and placing will usually be extended.

5.4 Setting / placement time

To maximise the improvement to hardened concrete by the use of polymer dispersions, the water : cement ratio is usually kept as low as possible consistent with adequate workability. Under these conditions the setting and placement time compared with an unmodified control of similar mix consistency is usually reduced. The placement time of such a PCC mix at 20^oC is often reduced to below 1 hour.

If the water : cement ratio is not reduced compared with an unmodified control then the setting time / placement time will usually be extended.

5.5 Air entrainment

Polymer dispersions, even those containing an antifoam, usually increase air entrainment. An air content of 2 to 5% in concrete modified with polymer dispersions is typical.

5.6 Bleeding

Polymer dispersions reduce bleeding, due to increased air entrainment and /or their ability to reduce the required water / cement ratio. This means that less water is available at the surface of the concrete to replace that lost by evaporation. Consequently such concrete must be adequately cured and the curing should start within 1 hour of placing the concrete to avoid surface cracking.

5.7 Volume deformation

The early drying shrinkage of mixes modified with polymer dispersion is lower than that of unmodified mixes of the same workability. However the ultimate drying shrinkage of both modified and unmodified mixes is similar.

There is conflicting data on the creep behaviour of PCC, but it is logical to expect that the creep of concrete containing soft polymers will be slightly increased.

5.8 Durability

The durability of PCC is significantly higher than that of unmodified concrete, largely because of its lower permeability and higher tensile strength. PCC has been in wide use since the 1960's and the experience gained has established a high level of confidence.