Learning Text

Part 4

Admixtures, Additives and Water

Contents

Introduction

This learning text considers the subjects of admixtures, additives and water, with each of the materials being considered in turn. A glossary of terminology and bibliography are included. The final section of this learning text is self-assessment questions and answers.

The use of admixtures to enhance the properties of mortar, renders and screeds has taken place for many centuries.

The ancient Chinese were known to have used black grain molasses; the Romans used animal fat, milk and blood in their mortars. It is probable that the early use commenced when workmen found that the addition of a particular substance to a mortar mix enhanced the fresh properties.

The use of admixtures by ancient civilisations was thus based on practical experience and observation not on an understanding of chemical theory.

Admixtures can be divided into three categories:

- Active materials are those which react chemically with a component within the cementitious material.

- Surface active admixtures (surfactants). These are generally split into two components (one positively charged and the other negatively charged) and react with the air - water - solid material interface within the mortar thereby resulting in orientation and adsorption. (Orientation means that the particles all face or point in the same direction, adsorption means a concentration of molecules gathering or being deposited on the surface of a solid material see Figure 1).

- Passive or inert admixtures. These do not change their form but have a physical effect such as light absorption and reflection as in the case of pigments.

It should also be noted that some admixtures are multi functional, this means that the addition of the admixture to a mix results in more than one property of the mix being affected (e.g. a water reducing air entrainer).

Water Reducing/Plasticizing Admixtures

This group of admixtures which are surface active (surfactants) posses the ability to disperse or deflocculate the cement particles within the mix, some water reducers/plasticizers are based on detergents. When these are incorporated into a mortar mix the admixture particles are adsorbed onto the surface of the cement particles and the negatively charged tails protrude. These repel each other, as illustrated diagrammatically in Figure 1. (You may recall from your school days experiments with magnets; that like charges repel and unlike charges attract.) The repulsion of the like charges results in a powerful deflocculating action and hence a more uniform distribution of the cement particles throughout the mix; this action also frees some of the water trapped by the flocculation of the cement particles as shown in Figure 2. This has a lubricating effect on the mix components and results in an increase in the level of consistence (workability), (a plasticizing effect). Where this is not desired the quantity of added water can be reduced (a water reducing effect), leading to an increase in the compressive strength of the mix.

A third way that this type of admixture can be used is to reduce the water content but keep the strength constant by reducing the cement content (an environmental benefit, the less cement that is used the less raw materials and fuel for production that are consumed).

The actual water reduction achieved by the use of this type of admixture depends upon the individual mix composition; typical water reductions are in the range 7.5 - 12.5%.

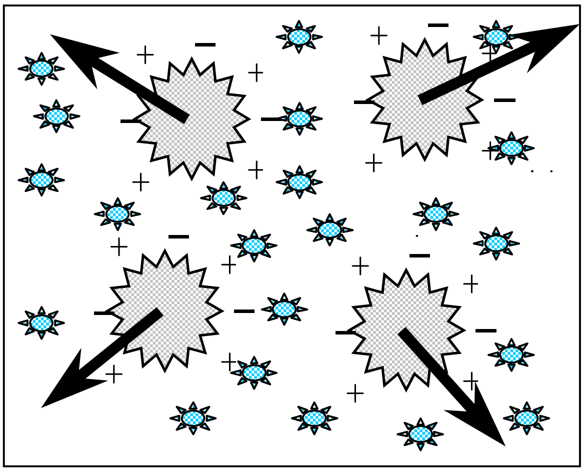

Figure 1: The effect of a water reducing admixture on the dispersion of cement particles

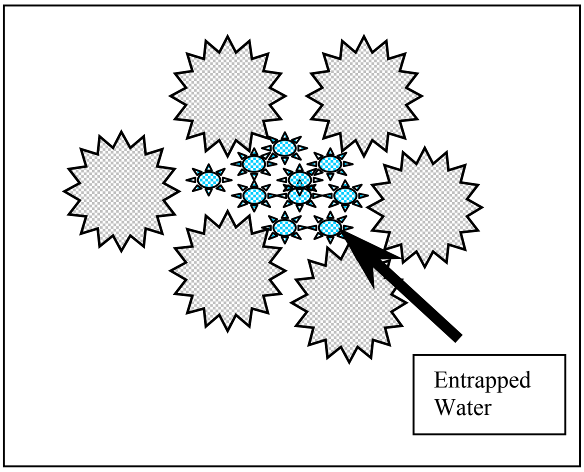

Figure 2: Flocculating cement particles trapping the mix water

Water reducing admixtures are based on modified lignosulfonic acid derivatives, hydroxycarboxylic acids or hydroxylated polymers.

It is important to remember that the addition of an admixture can have secondary effects, which may be beneficial or detrimental. Water reducing/plasticizing admixtures normally entrain small quantities of air, overdosing may lead to retardation of the hydration mechanism and or excessive entrainment of air. In addition to the single function water reducing/plasticizing admixture, multi function admixtures such as water reducing/air entrainers, water reducing/retarders and water reducing/accelerators are available.

Superplasticizers

These materials are sometimes described as high range water reducers. The first generation of superplasticizers were commercially launched in the early 1960's and had an effective working life of less than one hour, the current generation of superplasticizers can be effective for periods of up to four hours. Superplasticizers were first used in the United Kingdom in 1973. The original application of superplasticizers was for the production of flowing concrete, they now have far wider applications including the production of high strength and/or early drying screed mixes. When used as a water reducer typical water reductions compared to a control mix can be in the order of 30%. Superplasticizers can be used in the same three ways as a conventional plasticizer:

- to impart a high level of consistence (beyond that obtainable with a conventional plasticizer)

- to permit a large water reduction to be made beyond the limits of normal plasticizing admixtures
- to achieve economic and environmental benefits (e.g. reduction of the cement content) whilst maintaining performance

The mode of action of superplasticizers is similar to conventional plasticizers, the admixture particles are adsorbed onto the cement particles, causing them to become mutually repulsive and thus having a dispersing effect.

The materials used to manufacture superplasticizers include:

- Naphthalene Formaldehyde (introduced in Japan 1963)
- Melamine formaldehyde condensates (introduced in Germany in 1964)
- Modified lignosulfonate
- Synthetic polymers

Air Entraining Admixtures

Previously, it has been stated that the Romans used animal fat, milk and blood in their construction. No one can be absolutely sure of the reasons for this but, it was probably to improve the level of consistence of the material in the fresh or plastic state.

Air entraining admixtures are surfactants, they act at the air-water interface in cement paste, resulting in the stabilisation of air entrapped during the mixing process in the form of very small separate bubbles. The addition of the admixture to the mix lowers the surface tension of the water thereby assisting in the formation of bubbles. It is important to distinguish between entrapped air and entrained air. Entrapped air normally exists in the form of relatively large air voids, which are not dispersed uniformly throughout the mix, entrained air exists in the form of minute disconnected bubbles (0.02 - 1.0mm in size) well distributed throughout the mix. To achieve an increase in durability the air-entrained bubbles have not only to be of the correct size, but also correctly spaced.

The resistance of hardened mortar to the destructive effects of frost damage (freezing and thawing) is significantly improved by the use of intentionally entrained air (improved durability). As the water in the hardened mortar paste freezes, it causes pressure that can rupture the material. The entrained air voids act as reservoirs for the excess water forced into them, thereby relieving pressure and preventing damage to the mortar or screed.

Air entraining admixtures are manufactured from a number of raw materials including:

- Natural wood resins and their sodium salts, for example vinsol resin
- Animal and vegetable fats and oils
- Alkali salts of sulfated and sulfonated organic compounds
- Water soluble soaps

The minute air bubbles present in the fresh mortar mix can be said to act almost like fine particles (the spherical particles behave like small ball bearings and increase the level of consistence) and result in a more cohesive mix with reduced bleeding characteristics being obtained. Air entraining admixtures also have a plasticizing effect and less water is required to achieve the desired consistence. A very important requirement of air entraining admixtures is that the bubbles they entrain are stable. A practice which should never be encouraged, is the addition of detergents (washing up liquid) to mortar mixes. A more cohesive mix will be obtained in the short term, but the bubbles formed are not stable and confer no long-term advantage to the product.

In concretes, the optimum content of air entrainment is approximately 5.5% (this varies with the maximum aggregate size). Mortar mixes are very different and the optimum air entrainment content is approximately 20%. Admixtures designed for plasticising/air entraining mortars should never be used for concrete production, unless they have been specially designed for this purpose.

The quantity of air that is entrained is influenced by a number of factors including: cement content, fineness and type, aggregate grading and fines content, temperature and efficiency of mixing.

Air entrainment does lead to some loss in compressive strength of the mix, because the same quantity of binder is being used to cement a larger volume of mortar.

Air Entraining Plasticizing Admixtures

The European Standard for mortar admixtures BS EN 934-3 states that the incorporation of an air entraining plasticizing admixture improves the plasticity of the mix.

Supplies of fine aggregate (sand) that have a suitable particle size distribution and shape to enable mortars with desirable properties to be made without the addition of a plasticizer are becoming more scarce. Lime has been added to cement mortars for many years to act as a plasticizer so that the required working properties can be obtained; an air entraining plasticizer is an alternative to this. The incorporation of an air entraining plasticizer (a dual function admixture) leads to the formation of small bubbles; these together with the cement particles fill the voids between the coarser fine aggregate particles. A further alternative that may be used is the addition of lime and an air-entraining admixture.

Mortar air entrainer/plasticizers are similar to those used for concrete admixtures (some manufacturers use blends of synthetic surfactants). The air entrainer/plasticizer when added to a mortar mix does not enter into any chemical reaction with the other mix constituents. The setting time and hardening of the mortar mix are not altered, however, there may be some change in the rate of water loss into the masonry units due to better control of "bleeding" as a result of the incorporation of air entrainment.

Retarding Admixtures

Retarding admixtures slow down the rate of setting with cement, there are two principal ways in which they achieve their effect as described in the following text:

- By altering the solubility of the hydrating compounds in the cement, for example gypsum slows down the dissolution of aluminates and therefore retards the setting of cement.

- By reacting with a component to form an impermeable coating (precipitate) on the cement particles thus slowing down the hydration mechanism (Figures 3 and 4).

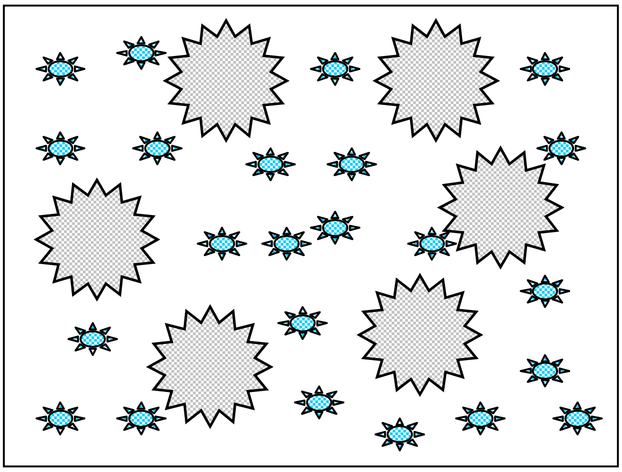

Figure 3: Cement particles free to react with water

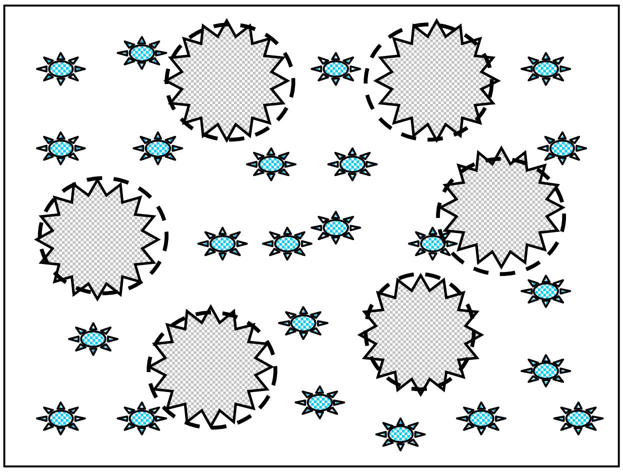

Figure 4: A precipitate on the surface of the cement particle preventing water reaching them

Materials based on the second of these categories are the more widely used and include:

- Unrefined lignosulfonates containing sugars
- Hydroxycarboxylic acids and their salts (i.e. sugars)
- Carbohydrates including sugars
- Gelatin (Sodium Heptonates - animal or fish fats)
- Hydroxylated polymers

An important sub group of retarders are those used in the production of ready to use mortar, they are covered by BS EN 934–3. Their use enables mortar delivered to site to be used for up to seventy- two hours after manufacture. Conventional retarders are used at a high dosage rate in combination with air entraining/plasticizing admixtures. The air entrainment assists in the retention of the level of consistence and the minimisation of bleeding.

The fines content of the fine aggregate can have a significant effect on the working life of the mortar and the dosage of the admixture may have to be altered to take account of varying fines contents.

Absorption of water from the mix by the masonry units starts the stiffening process (hydration) of the mortar. These units can absorb up to 30% of the water component together with a quantity of dissolved retarding admixture.

Accelerating Admixtures

This group of admixtures are not generally used in mortar and screed production, however some proprietary screed mixes incorporate an accelerating admixture. They achieve their effect by increasing the rate of chemical reaction between the Portland cement and water (hydration) within the mix. This is achieved by either increasing the rate of dissolution of the silica and alumina phases of the cement or by dissolving the lime.

An accelerator that was formerly widely used was based on calcium chloride, this was added at a dosage of between 1 and 2% by weight of cement. However, calcium chloride was found to increase the rate of corrosion of embedded metal and now is not permitted to be used where the mortar or screed contains any embedded metal e.g. ties or lathing .

Chloride free accelerators based on triethanolamine, calcium formate and sodium thiocyanate are widely available. However, generally they are not as effective as calcium chloride. The use of accelerators in mortar is unlikely to be beneficial.

Bonding Agents

Bonding agents are used for two main applications:

- To improve adhesion of renders to substrates
- To improve the adhesion of levelling screeds to a concrete base

The incorporation of a bonding agent is sometimes specified for mortar mixes used in brickwork below the damp proof membrane.

Bonding agents are formulated from polymers including:

- Styrene-butadiene polymer (SBR) (sometimes referred to as latex)
- Polyvinyl acetate (PVA)

Care must be taken when using a bonding agent in a mortar mix as some products affect the quantity of air that is entrained. The method of use is that the polymer emulsion, in the form of a milky liquid, replaces approximately half the normal amount of mixing water in a mortar mix. When used as a bonding coat a slurry is made with cement and applied to the substrate or base prior to the render or screed.

Water Repellents

The inclusion of this type of admixture in a mix reduces water absorption and the passage of water through the matrix by capillary action. The admixtures in this group principally act by blocking or lining the capillaries or pores within the matrix. Alternatively, some materials produce a hydrophobic (water repelling) action at the surface of the material. Some publications describe this type of admixture as a permeability reducer.

Water repellent admixtures may be formulated from a variety of compounds including:

- Long chain carboxylic acids
- Calcium, ammonium and butyl stearates
- Acrylic resins

A number of manufacturers produce water repellent admixtures in powdered as well as liquid form.

It should be noted that water repellents applied to the surface of a render may have a limited life, these type of materials only reduce the ingress of water, they do not make the mortar impermeable.

It should be noted that water repellent admixtures are also known as permeability reducers or, incorrectly waterproofers.

Cellulose Ethers

Cellulose ethers are named after, and based on, cellulose one of the most common chemical compounds in organic nature.

There is a broad range of cellulose ethers available including Carboxymethylcellulose, Ethylhydroxyethylcellulose, Hydroxyethylcellulose, Hydroxypropylcellulose, Methylhydroxyethylcellulose and Methylhydroxypropylcellulose.

Cellulose ethers are divided into ionic and nonionic types. The ionic cellulose ethers, e.g. sodium carboxymethylcellulose, contain substituents which are electrically charged. Nonionic cellulose ethers like methylcellulose and hydroxyethylcellulose carry electrically neutral substituents. Both types are available with varying rates of reaction e.g. fast acting, very fast acting and slow release. Very fast acting is required for use in dry silo mortar as there is a very short mixing period.

Upon contact with water the cellulose polymers dissolve through progressive hydration, and thus increases the viscosity of the matrix. The cellulose ethers are more effective if they are dispersed thoroughly throughout the mixture.

Cellulose ethers help improve the product quality and can act as thickeners, water retention agents and help reduce segregation. They are relatively expensive in comparison with general admixtures.

Handling and Storage of Admixtures

Admixtures are complex chemicals and one type may not be compatible with another, therefore admixtures should not be premixed without seeking advice from the manufacturer.

Generally liquid admixtures should be introduced into the mixer by means of automatic dispensing equipment at the same time as the water and aggregates. Liquid admixtures should never be added to dry material.

The quantity of admixture to obtain the desired performance may be quite small and overdosing may result in undesirable effects. Admixture manufacturers data sheets list approximate dosage figures for individual admixtures based on trials they undertake. Field trials should always be undertaken to determine the optimum dosage for the particular mix constituents and proportions.

Admixtures may deteriorate if stored for prolonged periods. Where admixtures have been stored in drums or tanks for periods in excess of twelve months, advice on their use should be sought from the manufacturer. Generally, admixtures should be stored above 0^oC and protected from frost, however some admixtures have depressed freezing points in the range - - 5 to -10^o C. Manufacturers data sheets give further information on the storage facilities/ conditions necessary to maintain the properties of the admixture. They are usually stored in bunded tanks to prevent spillage and provide added protection. In periods of hot weather drums should be stored in shaded conditions.

In dry silo mortar all admixtures are added in powder form. They are batched using smaller more accurate calibrated scales because of the small quantities added per tonne. Generally the admixtures are stored in small hoppers or directly fed into the dry mortar-mixing pan from tonne bags that are in close proximity to the mixer.

Pigments

The colours of objects

In 1666 Sir Isaac Newton made one of his greatest discoveries, namely that white light was made up of many different colours.

Most of you will have seen a rainbow, the colours of a rainbow are visible when sunlight is refracted by water drops and split into its constituent colours. Some of you may recall an experiment from your schooldays in which a disc was painted with all the colours that make up white light (red, orange, yellow, green, blue, indigo, violet), when the disc was revolved rapidly the colour appeared to be greyish-white in colour. When the red segment was covered and the disc rotated a greenish blue colour was obtained.

An object, which is white in daylight, reflects all the different colours of the spectrum. In blue light, therefore, the object appears blue, in red light it appears red. A transparent red filter paper transmits only red light and absorbs the rest of the colours. A rose appears red because it absorbs all the other colours of white light, and therefore would appear black if illuminated by blue or green light. A blue pigment absorbs the red and yellow colours in white light; a yellow pigment absorbs the blue and violet colours in white light. Green is the only colour which neither pigment absorbs; hence when the pigments are mixed, a green colour is obtained. Red, yellow and blue are called primary colours when applied to paints and pigments, any colour can be produced by mixing them. It is therefore true to state that colours are acts of light, if there were no light there would be no colour.

History of pigments

Colour has always been important to human beings, many of the cave paintings of the prehistoric civilisations exhibit a variety of colours. These paintings were achieved by using mineral oxides, charcoal and animal fats. Approximately one hundred and fifty years ago William Perkin began to manufacture synthetic colours and this led to the development of the range of synthetic pigments that are available today.

Characteristics of pigments

BS EN 12878:1999 *Pigments for the colouring of building materials based on cement and/or lime - Specifications and methods of test,* this defines a pigment as:

"A substance, generally in the form of fine particles, which is practically insoluble in the application medium and for which the sole purpose is to colour cement and/or lime based building materials".

Pigments are normally inert materials that do not react with the other constituents in a mortar mix. It is very important that the hydration of the cement is not affected and for this reason the use of materials containing lead or zinc salts should be avoided. It is also important that the pigments are alkali resistant and their colour retention is not impaired in an alkaline environment.

Pigments that are incorporated into building products are frequently exposed to variations in temperature and humidity and it is therefore important that they are environmentally stable and do not change colour.

A further requirement of pigments is that they are "lightfast", this means that the pigment does not decompose when exposed to ultra violet radiation, consequently organic materials are generally unsuitable.

Pigments colour mortar by coating the cement and fine aggregate particles. It is essential that the particles are uniformly distributed throughout the mix. It is important that the particles of pigment are easily mixed. Generally, a pigment addition of 3-7% by mass of cement is required, at additions of over approximately 10% a saturation level is reached and the addition of more pigment has no effect on the intensity of the colour.

A number of pigments are based on oxides and hydroxides of iron and these are used to produce various shades of red, yellow, brown and black. Oxides of chromium are used to produce green colours, compounds of cobalt are used to produce blue colours. Carbon is sometimes used as a black pigment (note; carbon based materials may not retain their colour over a period of time and their use is not recommended) and titanium dioxide as a white pigment. In addition, oxides of aluminium, nickel and antimony are also used, often in combination with other metallic oxides.

Fibres

The use of fibres is not a modern development, analysis of ancient mortars shows that early civilisations used materials like horsehair to improve the mechanical properties of their mortars. A number of materials such as glass, carbon and asbestos have historically been used to produce fibres. Currently, polypropylene fibres are the most common type used in the production of mortars renders and screeds. Polypropylene fibres are manufactured by chemical and mechanical processes to produce fibres, which are either fibrillated, or increasingly of a monofilament type.

Fibrillated fibre is manufactured by extruding molten polypropylene through a slit plate die to form a flat sheet. This sheet is then slit into individual tapes and then passed over a series of razor sharp pins which are set into a revolving barrel called a fibrillator. This breaks the individual tapes into interconnecting fibres. The tapes are then coated to aid dispersion and cut to the required lengths to form irregular fibres rectangular in cross section. Typically, 1kg of 12mm long fibres will contain between 5 and 20 million fibres depending on the type or brand.

Monfilament fibre is manufactured by extruding molten polypropylene through a number of dies (there are usually several thousand individual holes on a circular or rectangular shaped die plate). The fibre produced is usually smooth and round although other shapes can be obtained. The fibre is then coated to aid dispersion and cut into the required lengths. Typically, 1kg of a 12mm thin long fibre will contain between 50 and 450 million fibres depending on the thickness of the fibre.

The incorporation of polypropylene fibres into renders improves the bonding to the backing material, reduces permeability and improves frost resistance. Polypropylene fibres when used in screed mixes can give enhanced resistance to curling, minimise early age cracking and improve abrasion resistance.

A number of fibre manufacturers supply polypropylene fibres in pre packaged water-soluble bags that dissolve when added to the mix. The approximate dosage of polypropylene fibres is $1kg/m^3$. BS EN 14889-2 details the requirements for polymer based fibres.

Water

Water should be clean and free from contaminants deleterious to the setting of mortars, renders and screeds. Where the water is obtained from a public supply it can be assumed that it is free from impurities that would affect the hydration mechanism (either retarding or accelerating) of the cementitious components within the mix.

Increasingly, water that is extracted from boreholes and obtained from recycling systems is used in the production of mortars, renders and screeds. Water that is obtained from boreholes is normally consistent in quality and once it has been tested and found to be of acceptable quality all that is normally required is re-testing at regular intervals. A practice that has been found to be acceptable is to test the water source at six monthly intervals for the first two years of use and then at two yearly intervals.

Where water from recycling systems is used regular quality checks need to be undertaken and quality control procedures implemented to ensure material that may be detrimental to production of the product is not discharged into the recycling system.

The European standard for water suitable for use in concrete is BS EN 1008:2002, Mixing water for concrete - Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete.

British/European Standards

The European standard for admixtures has the overall title, "Admixtures for concrete, mortar and grout" and has been allocated the number EN 934. This standard is composed of a number of parts. Part 3: Admixtures for masonry mortar - Definitions, requirements, conformity and marking and labelling. The standard makes reference to a series of testing standards (BS EN 480: Admixtures for concrete, mortar and grout - Test methods), Part 13: Reference masonry mortar for testing mortar admixtures. BS EN 934-1 was revised in 2008 and a number of general requirements that all admixtures shall conform to were taken from the individual parts of the standard and consolidated within BS EN 934-1, Table 1- General requirements.

Glossary of Terms

Admixture	-	Organic or inorganic material added in small quantities to modify the properties of the mortar in the fresh/hardened state.
Additive	-	A finely divided inorganic material that may be added to mortar in order to improve or achieve special properties. (Note: some confusion exists over the differences between an admixture and an additive, generally additives are materials added to cement to control some property e.g. set controlling gypsum stearate added during the grinding of cement; other parts of the construction industry classify liquid materials as admixtures and solid materials as additives).
Adsorption	-	Adsorption is the adhesion of molecules of gas or liquid, to the surface of a solid or liquid, which it is in contact with.
Air entraining admixture	-	An admixture that allows a controlled quantity of small uniformly distributed air bubbles to be incorporated in a mortar and which remain after hardening.
Air entraining/ plasticizing admixture	-	Admixture that increases consistence, or allows water reduction, by incorporating during mixing a controlled quantity of small uniformly distributed air bubbles, which remain after hardening, (BS EN 934-3). (*Often known simply as air entraining admixtures)*.
Bleeding	-	Separation of water from fresh mortar.
Bonding agent	-	Admixture that improves the bonding properties of the mix
Pigment	-	Material used for imparting various colours to a mortar mix (see further definition in the section on pigments - BS EN 12878).
Plasticizing admixture	-	An admixture which, without affecting the consistency, permits a reduction in water content of a mortar, or which without affecting the water content, increases the flow, or which produces both effects simultaneously. (*These materials are often known as water reducing /plasticizing admixtures)*.
Reinforcement	-	Bars, wires, meshes or fibres added to mortars or materials incorporated within a plaster/render system to improve its mechanical strength. (Only fibres are discussed in this learning text).

Set retarding admixture	-	(also known as retarder) Admixture, which extends the time to commencement of transition of the mix from the plastic to the rigid state. *There is an alternative definition of these materials as follows:* Set retarding admixture for long term retarded masonry mortar: Set retarding admixture as defined in BS EN 934-2 but specifically intended for use in long term retarded mortar incorporating entrained air (BS EN 934-3).
Superplasticizer	-	An admixture, which, without affecting the consistency, permits a high reduction in the water content of a mortar or screed without affecting the water content, increases the flow, or which produces both effects simultaneously.
Waterproofing admixture	-	Admixture that increases the resistance to the penetration of water. (S*ome guides to admixtures state that the term Waterproofing is deprecated and the term Water resisting/ Water repelling should be used*).

Bibliography

BS EN 480	Admixtures for concrete, mortar and grout - Test methods
BS EN 934-1: 2008	Admixtures for concrete, mortar and grout- Part 1: Common requirements.
BS EN 934-2:2001	Admixtures for concrete, mortar and grout. Concrete Admixtures - Definitions, requirements, conformity and marking and labelling
BS EN 934-3: 2003	Admixtures for concrete, mortar and grout . Admixtures for masonry mortar - Definitions, requirements, conformity and marking and labelling
BS EN 934-6:2001	Admixtures for concrete, mortar and grout. Sampling, conformity control and evaluation of conformity.
BS EN 998-1: 2003	Specification for mortar for masonry – Part 1: Rendering and plastering mortar.
BS EN 998-2: 2003	Specification for mortar for masonry – Part 2: Masonry mortar.
BS EN 1008:2002	Mixing water for concrete - Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete.
BS EN 12878:1999	Pigments for the colouring of building materials based on cement and/or lime - Specifications and methods of test
BS EN 13318:2002	Screed material and floor screed material – Properties and requirements for Concrete, mortar and grout.
BS EN 14889-2:2006	Fibres for concrete - Part 2: Polymer fibres- Definitions, specifications and conformity
BS 6100-9:2007	Building and civil engineering – Vocabulary- Part 9: Work with concrete and plaster.

Self-Assessment Questions

1	How do water reducing/plasticizing admixtures achieve their effect?
2	In what decade did superplasticizers become available?
3	What is the number of the European standard for admixtures for mortar?
4	What raw materials are retarders principally based on?
5	What are the two principle benefits obtained from using an air entraining plasticizing admixture?
6	What British Standard is applicable to pigments?
7	Admixtures containing which constituent should not be used when the mortar, render or screed mix is in contact with metal components?
8	What is the typical air content of a plasticized/air entrained mortar?
9	What are the main constituents of bonding agents?
10	What are the five main requirements for a pigment?

Answers to Self Assessment Questions

1	By imparting a negative charge to the surface of the cement particles which then repel each other (deflocculation).
2	1960's.
3	BS EN 934-3.
4	Fatty acids, sugars and starches.
5	The improved plasticity of the mix in the fresh state and the improved durability in the hardened state (resistance to frost attack).
6	BS EN 12878: 1999 Pigments for the colouring of building materials based on cement and or lime. Specifications and methods of test.
7	Calcium chloride.
8	20%.
9	Styrene Butadiene polymer/polyvinyl acetate.
10	Environmental stability, alkali resistant, inert, lightfast, mixable.