mortar industry association

Learning text part 04

mpa essential materials sustainable solutions

Admixtures, Additives and Water

Contents

Health and safety

All mortar mixtures, both wet and dry, are abrasive and alkaline. When working with wet mortar, waterproof or other suitable protective clothing should be worn. Guidance on the use of these materials can be found in MIA data sheet No. 20.

Introduction

This learning text covers admixtures, additives and water. A glossary of terminology and bibliography are included and the final section includes self-assessment questions and answers.

Admixtures have been used for centuries to enhance the properties of mortar, renders and screeds. The ancient Chinese were known to have used black grain molasses while the Romans used animal fat, milk and blood. It is likely early use began when workmen found that the addition of a particular substance to a mortar mix enhanced its fresh properties. Use of admixtures by ancient civilisations was therefore based on practical experience and observation, not on chemical theory.

There are three categories of admixtures:

- Active materials - 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. Some admixtures are multi functional, meaning that their addition to a mix results in more than one property of the mix being affected (eg, a water reducing air entrainer).

Water reducing/ plasticising admixtures

This group of surface active (surfactants) admixtures have the ability to disperse or deflocculate the cement particles within the mix. Some water reducers/plasticisers are based on detergents. When these are incorporated into a mortar mix, 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. 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 or workability. This is a plasticizing effect. Where this is not wanted, the quantity of added water can be reduced, 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. This has an environmental benefit because the less cement used, the less raw materials and fuel for production 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%. Water reducing admixtures are based on modified lignosulfonic acid derivatives, hydroxycarboxylic acids or hydroxylated polymers. The addition of an admixture can have secondary effects, which may be beneficial or detrimental. Water reducing/ plasticising admixtures normally entrain small quantities of air but overdosing may lead to retardation of the hydration mechanism and/or excessive air entrainment. 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.

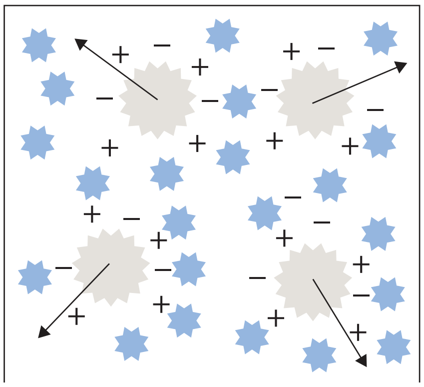

Figure 1: ***The effect of a water reducing admixture on the dispersion of cement particles***

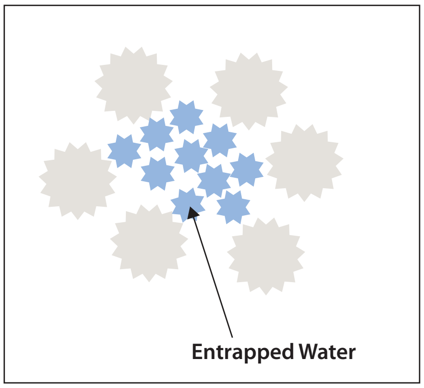

Figure 2: ***Flocculating cement particles trapping the mix water***

Superplasticisers

These materials are sometimes described as high range water reducers. First generation superplasticisers were commercially launched in the early 1960s and had an effective working life of less than one hour. Current generation superplasticisers can be effective for periods of up to four hours. The original application for superplasticisers 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 reductions compared to a control mix can be in the order of 30%. Superplasticisers can be used in the same three ways as a conventional plasticiser:

- to impart a high level of workability, beyond that obtainable with a conventional plasticiser
- to permit large water reductions to be made beyond the limits of normal plasticising admixtures
- to achieve economic and environmental benefits (eg, reduction of cement content) whilst maintaining performance.

The mode of action of superplasticisers is similar to conventional plasticisers with the admixture particles being adsorbed onto the cement particles, causing them to become mutually repulsive and thus having a dispersing effect.

Materials used to manufacture superplasticisers include:

- Naphthalene formaldehyde (introduced in Japan 1963)

- Melamine formaldehyde condensates (introduced in Germany in 1964)
- Modified lignosulfonate
- Synthetic polymers.

Air entraining admixtures

The Romans used animal fat, milk and blood in their construction and while no one can be sure of the reasons for this it was probably to improve the workability of the material in its fresh state. Air entraining admixtures are surfactants and 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 water surface tension, assisting the formation of bubbles.

There is an important difference between entrapped and entrained air. Entrapped air normally exists in the form of relatively large air voids, not dispersed uniformly throughout the mix. Entrained air takes 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 which improves 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 a fresh mortar mix act almost like fine particles. The bubbles behave like small ball bearings and increase workability, resulting in a more cohesive mix with reduced bleeding characteristics. Air entraining admixtures also have a plasticising effect and require less water to achieve the desired workability. A very important requirement for air entraining admixtures is that the bubbles they produce are stable. A practice which should never be encouraged, is the addition to mortar mixes of detergents such as washing-up liquid. In the short term, a more cohesive mix will be obtained 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% although 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.

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 plasticising admixtures

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

Sand supplies are becoming scarce that have a suitable particle size distribution and shape to enable mortars with desirable properties to be made without the addition of a plasticiser. Lime has been added as a plasticiser to cement mortars for many years so that the required working properties can be obtained; air entraining plasticisers provide an alternative. Incorporation of an air entraining plasticiser leads to the formation of small bubbles, which together with the cement particles, fill the voids between the coarser sand particles. A further alternative is the addition of lime and an air-entraining admixture.

Mortar air entrainer/plasticisers are similar to those used for concrete admixtures. The air entrainer/plasticiser when added to a mortar mix does not have a chemical reaction with other mix constituents. The mortar's setting time and hardening are not altered but there may be some change in the rate of water loss into the masonry units due to better control of "bleeding".

Retarding admixtures

Retarding admixtures slowdown the rate of setting with cement. There are two principal ways:

- 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).

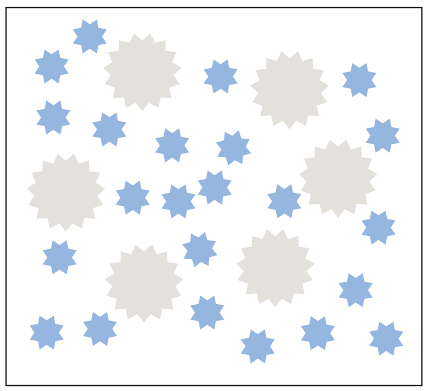

Figure 3: ***Cement particles free to react with water***

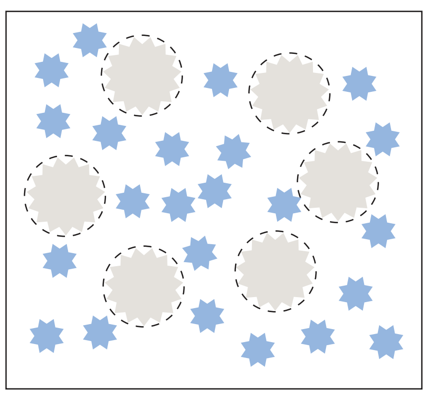

Figure 4: ***A precipitate on the surface of the cement particles preventing water reaching them***

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

- Unrefined lignosulfonates containing sugars
- Hydroxycarboxylic acids and their salts (ie, sugars)
- Carbohydrates including sugars
- Gelatin (Sodium heptonates - animal or fish fats)
- Hydroxylated polymers

An important sub group of retarders is that used in the production of ready-to-use mortar, 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/plasticising admixtures. Air entrainment assists in the retention of workability and the minimisation of bleeding.

Fines content of the sand can have a significant effect on the working life of the mortar and the dosage of the admixture may have to be altered accordingly.

Absorption of water from the mix by the masonry units starts the stiffening process (hydration) of the mortar. 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 although 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 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 eg, ties or lathing .

Chloride-free accelerators based on triethanolamine, calcium formate and sodium thiocyanate are widely available although generally 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 mortar mixes as some products affect the quantity of air that is entrained. In use in a mix, the polymer emulsion, in the form of a milky liquid, replaces approximately half the normal amount of mixing water. When used as a bonding coat, a slurry is made with cement and applied to the substrate or base before the render or screed.

Water repellents

The inclusion of this type of admixture in a mix reduces water absorption and the passage of the liquid 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.

Water repellents applied to the surface of a render may have a limited life as these type of materials only reduce the ingress of water, not make the mortar impermeable.

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, eg, 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 eg, 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 increase the viscosity of the matrix. The cellulose ethers are more effective if they are dispersed thoroughly throughout the mixture. Cellulose ethers help improve 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, so they should not be premixed without seeking advice from the manufacturer.

Liquid admixtures should be introduced into the mixer by means of automatic dispensing equipment at the same time as the water and aggregates. They 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. 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 of over twelve months, advice from the manufacturer on their use should be sought. Admixtures should be stored above 0°C and protected from frost, although some admixtures have freezing points in the range - 5 to -10°C. Manufacturers' data sheets give further information on the storage facilities and conditions necessary to maintain the admixture's properties. Admixtures 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. The admixtures are stored in small hoppers or directly fed into the dry mortar-mixing pan from tonne bags that are stored in close proximity.

Pigments

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

Pigment characteristics

The standard BS EN 12878:2005 Pigments for the colouring of building materials based on cement and/or lime - Specifications and methods of test, 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 is that a pigments is "lightfast", meaning it 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 so it is essential that the particles are uniformly distributed throughout the mix. It is also important that the pigment particles are easily mixed. Generally, a pigment addition of 3-7% by mass of cement is required. At additions of over about 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. Chromium oxides produce green, cobalt compounds blue, titanium dioxide white. Carbon is sometimes used as a black pigment, although carbon-based materials may not retain their colour over a period of time and their use is not recommended. 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 and 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 is the most common fibre 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 is then slit into individual tapes and passed over a series of razor-sharp pins 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 individual pieces depending on the type or brand.

Monofilament fibre is manufactured by extruding molten polypropylene through a number of dies, which usually have several thousand individual holes on a circular or rectangular shaped plate. The fibre produced is usually smooth and round although other shapes can be obtained. It is 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 individual strands depending on the thickness of the fibre.

Incorporation of polypropylene fibres into renders improves the bonding to the backing material, reduces permeability and improves frost resistance. When used in screed mixes, the fibes 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 harmful 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 mortars, renders and screeds. That obtained from boreholes is normally consistent in quality and once tested and found to be of acceptable quality, needs only re-testing at regular intervals. An acceptable practice 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 are needed and quality control procedures implemented to ensure material detrimental to 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 is EN 934, Admixtures for concrete, mortarand grout. This standard has 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 including 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 to which all admixtures shall conform were taken from the individual parts of the standard and consolidated within 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 eg, 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, with which it is in contact.

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/plasticising 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 - 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/plasticising 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).

Superplasticiser
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. (Some guides to admixtures state that the term Waterproofing should not be used and the term Water resisting/ Water repelling should be substituted).

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/plasticising admixtures achieve their effect?

A ______________________________

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2 In what decade did superplasticisers become available?

A ______________________________

3 What is the number of the European standard for admixtures for mortar?

A ______________________________

4 On what raw materials are retarders principally based?

A ______________________________

5 What are the two principle benefits obtained from using an air entraining plasticising admixture?

A ______________________________

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6 What British Standard is applicable to pigments?

A ______________________________

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7 Admixtures containing which constituent should not be used when the mortar, render or screed mix is in contact with metal components?

A ______________________________

8 What is the typical air content of a plasticised/air entrained mortar?

A ______________________________

9 What are the main constituents of bonding agents?

A ______________________________

10 What are the five main requirements for a pigment?

A ______________________________

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 1960s.
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.

MIA Learning Texts include:

1 Introduction to modern mortars
2 Cementitious materials
3 Aggregates
4 Admixtures, additives and water
5 Brick and block production
6 Properties of masonry mortar
7 Production, deleivery and storage of mortar
8 Mortar testing
9 Specifications
10 Quality assurance
11 Construction
12 Properties of rendering mortar
13 Best practice - potential site problems

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The Mortar Industry Association is part of the Mineral Products association, the trade association for the aggregates, asphalt, cement, concrete, dimension stone, lime, mortar and silica sand industries

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There is a real danger of contact dermatitis or serious burns if skin comes into contact with wet mortar. Wear suitable protective clothing and eye protection. Where skin contact occurs either directly or through saturated clothing was immediately with soap and water. For eye contact immediately wash out eyes thoroughly with clean water. If swallowed wash out mouth and drink plenty of water.

The relevant codes of practice, standards and statutory regulations must always be observed.