Lecture 3. Concrete Admixtures

Prepared by:
D.Sc. Fahim Al-Neshawy,

Reviewed by:
Prof. Jouni Punkki

Aalto University School of Engineering
Department of Civil Engineering
A: P.O.Box 12100, FIN-00076 Aalto, Finland
```plaintext
<table>
<thead>
<tr>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture 3. Concrete Admixtures ................................................................</td>
</tr>
<tr>
<td>3.1 Brief history of admixture use ..................................................</td>
</tr>
<tr>
<td>3.2 Admixture standards and types ......................................................</td>
</tr>
<tr>
<td>3.3 Surface-active chemicals (Surfactants) .........................................</td>
</tr>
<tr>
<td>3.3.1 Water-reducing admixtures (Plasticizers) ................................</td>
</tr>
<tr>
<td>3.3.2 High-Range Water-Reducing (Super-plasticizers) - HRWR .............</td>
</tr>
<tr>
<td>3.3.3 Air-entraining admixtures ......................................................</td>
</tr>
<tr>
<td>3.4 Set controlling admixtures .............................................................</td>
</tr>
<tr>
<td>3.4.1 Accelerating admixtures ............................................................</td>
</tr>
<tr>
<td>3.4.2 Retarding admixtures ..................................................................</td>
</tr>
<tr>
<td>3.5 Admixtures for special purposes .....................................................</td>
</tr>
<tr>
<td>3.6 Storing and dispensing (dosing) chemical admixtures .......................</td>
</tr>
<tr>
<td>3.7 References ......................................................................................</td>
</tr>
</tbody>
</table>
```
Admixtures are chemicals, added to concrete, mortar or grout at the time of mixing, to modify the properties, either in the wet state immediately after mixing or after the mix has hardened. They can be a single chemical or a blend of several chemicals and may be supplied as powders but most are aqueous solutions because in this form they are easier to accurately dispense into, and then disperse through the concrete.

The active chemical is typically 35–40% in liquid admixtures but can be as high as 100% (e.g. shrinkage-reducing admixtures) and as low as 2% (e.g. synthetic air-entraining admixtures). In most cases the added water from the admixture is not sufficient to require a correction for water–cement ratio.

Admixtures are usually defined as being added at less than 5% on the cement in the mix but the majority of admixtures are used at less than 2% and the typical range is 0.3–1.5%. This means the active chemicals are usually present at less than 0.5% on cement or 0.02% on concrete weight.

The dosage may be expressed as litres or kg per 100 kg of cement, and cement normally includes any slag, PFA or other binders added at the mixer.

Admixtures are not the same as additives, which are chemicals preblended with the cement or a dry cementitous mix. Neither are they the same as additions, which are added.

### 3.1 Brief history of admixture use [1]

<table>
<thead>
<tr>
<th>Romans</th>
<th>Retarders</th>
<th>Urine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air entrainment</td>
<td>Blood</td>
<td></td>
</tr>
<tr>
<td>Fibres</td>
<td>Straw</td>
<td></td>
</tr>
<tr>
<td>Plasticizers</td>
<td>1932</td>
<td>Patent for sulphonated naphthalene formaldehyde plasticizers (but not available in commercial quantities)</td>
</tr>
<tr>
<td></td>
<td>193?</td>
<td>Lignosulphonates used as plasticizers</td>
</tr>
<tr>
<td></td>
<td>193?</td>
<td>Hydroxycarboxcilic acid salts used as plasticizers and retarders</td>
</tr>
<tr>
<td>Waterproofers</td>
<td>193?</td>
<td>Fatty acids, stearates and oleates</td>
</tr>
<tr>
<td>Air entrainers</td>
<td>1941</td>
<td>Tallow and fatty acid soaps for frost resistance</td>
</tr>
<tr>
<td>Superplasticizers</td>
<td>1963</td>
<td>Sulphonated naphthalene formaldehyde commercially available</td>
</tr>
<tr>
<td></td>
<td>1963</td>
<td>Sulphonated melamine formaldehyde patent and available</td>
</tr>
<tr>
<td></td>
<td>1990–1999</td>
<td>Polycarboxylate ether development and production</td>
</tr>
</tbody>
</table>

---

3.2 Admixture standards and types

Admixture standards in individual European countries were phased out during 2002 and a new European Standard EN 934 introduced, covering all the main types of admixture. This standard is currently divided into five parts. EN 934, covers admixtures for concrete (Part 2), mortar (Part 3), grout (Part 4) and sprayed concrete (Part 5). Part 2, covering concrete admixtures, is probably the most important.

![Diagram of Types of Chemical Admixtures]

**Admixture types covered by EN 934**

- Normal plasticizing / water reducing (WRA) EN 934-2
- Superplasticizing / high range water reducing (HRWRA) EN 934-2
- Retarding & retarding plasticizing EN 934-2
- Accelerating-set and hardening types EN 934-2
- Air entraining EN 934-2
- Water retaining EN 934-2
- Water resisting (waterproofing) EN 934-2
- Retarded ready-to-use mortar admixtures EN 934-3
- Sprayed concrete EN 934-5
- Grout admixtures for prestressing EN 934-4

**Special admixtures:** which include corrosion inhibitors, shrinkage control, alkali-silica reactivity inhibitors, and coloring

**How are the chemical admixtures added to Concrete?**

- Added during mixing (usually to mix water)
- Added to concrete after mixing after transporting to site (before casting)
- Always added in small amounts, <1% by weight of cement
Why use Admixtures?

| Economic benefits (Producer) | – optimised mix design |
| Placing of concrete (Contractor) | – appropriate workability (consistence), compactability, cohesion, setting and strength development |
| Problem Solving (Designer) | – concrete that will meet special needs for placing or performance |
| Durability (Owner) | – Ensuring that concrete fulfils its design requirements for the intended life of the structure |
| Sustainability (Everyone) | – helping to reduce the health and safety aspects of concrete during placing and environmental impact during its life cycle |

3.3 Surface-active chemicals (Surfactants)

The chemical formula of surface-active chemicals consists of a non-polar hydrocarbon chain (water-repelling) with an anionic polar (water-attractive).

![Figure 3-2. Surface active chemicals.](image)

3.3.1 Water-reducing admixtures (Plasticizers)

Plasticizers are the organic or combination of organic and inorganic substances which reduces water content for certain degree of workability, when added in mix.

3.3.1.1 Water-reducing admixtures materials and mechanism in concrete

The basic products consisting plasticizers are:

- anionic surfactants (such as lignosulphonates, salts of sulphonates hydrocarbon)
- non-ionic surfactants (such as polyglycol esters, hydroxylated carboxylic acid products) and
- others such as carbohydrates, etc.
- among them calcium, sodium and ammonium lignosulphonates are commonly used.

Plasticizers are mixed from 0.1% to 0.4% by weight of cement used and it reduces 5% to 15% of water with the increment of workability from 25 to 75 mm slump. This effect of water-reducing admixtures on concrete mixtures can be utilized in three ways as shown in Figure 3-3.

**Figure 3-3.** Function of the water reducing admixtures.

In the mix, the cement grains absorbs the plasticizers molecules and results change in the surface charge of the same sign which causes repulsive forces and makes the dispersion which increases plasticity and workability as shown in Figure 3-4. Some Plasticizer also entrails the air but a good plasticizer is that which entrains air less than 2% only. The plasticizers are available in market in various brands with specifications for composition, dosages etc.

**Figure 3-4.** Dispersion of cement particles with release of entrapped water enhancing fluidity of mix after addition of plasticizers.
3.3.1.2 *Uses of plasticizers*

The plasticizers are used:

- To achieve a higher strength by decreasing the water cement ratio at the same workability as an admixture free mix.
- To achieve the same workability by decreasing the cement content to reduce the heat of hydration in mass concrete.
- To increase the workability to ease placing in accessible locations.
- Water reduction more than 5% but less than 12%
- The commonly used admixtures are Ligno-sulphonates and hydrocarbolic acid salts.
- Plasticizers are usually based on lignosulphonate, which is a natural polymer, derived from wood processing in the paper industry.

The plasticizers have a retarding effect:

- Plasticizers get adsorbed on the surface of the cement particles and form a thin sheath.
- This sheath inhibits the surface hydration reaction between water and cement as long as sufficient plasticizers molecules are available.

3.3.1.3 *Effects of plasticizers on the properties of concrete*

The effect of water-reducing admixtures is dependent on: dosage of the admixture, cement type, aggregate type and grading, mix proportions and temperature.

- **Workability**: Typically an initial slump in the range 25—75 mm can be increased by 50-60 mm.

- **Compressive Strength**: The compressive strength of concrete is increased by using water reducing admixtures to reduce water content while maintaining workability. The increase in strength is a direct result of the lower water/cement ratio. Example of the effect of water reducing admixtures on the workability and strength of concrete is shown in Table 3-1.

**Table 3-1. Example of the effect of using plasticizers on the properties of concrete.**

<table>
<thead>
<tr>
<th>Description of Mix</th>
<th>Plasticizer Dosage (% cement)</th>
<th>Cement (kg/m³)</th>
<th>W/C</th>
<th>Slump [mm]</th>
<th>Compressive strength [Mpa]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 d</td>
</tr>
<tr>
<td>Reference</td>
<td>--</td>
<td>300</td>
<td>0.6</td>
<td>70</td>
<td>7</td>
</tr>
<tr>
<td>Plasticizers</td>
<td>0.2%</td>
<td>300</td>
<td>0.6</td>
<td>100</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>0.3%</td>
<td>300</td>
<td>0.6</td>
<td>120</td>
<td>6</td>
</tr>
<tr>
<td>Strength increase</td>
<td>0.2%</td>
<td>300</td>
<td>0.56</td>
<td>70</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>0.3%</td>
<td>300</td>
<td>0.54</td>
<td>70</td>
<td>8</td>
</tr>
<tr>
<td>Cement saving</td>
<td>0.2%</td>
<td>280</td>
<td>0.6</td>
<td>70</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>0.3%</td>
<td>270</td>
<td>0.6</td>
<td>70</td>
<td>6</td>
</tr>
</tbody>
</table>
### 3.3.1.4 Precautions for use of plasticizers

**Overdosing:** The amount of water-reduction or gain in workability will be increased by overdosing. Overdosing can also, in certain instances, result in retardation and/or a degree of air entrainment. Where there is no air entrainment the gain in strength, and other properties will develop normally after the initial retardation period.

**Concrete Yield (Batch):** Where water—reduction is used to reduce cement content there will be a reduction in the volume of cement paste and hence in the yield. This must be taken into account in calculating potential economies.

---

### 3.3.2 High-Range Water-Reducing (Super-plasticizers) - HRWR

Super-plasticizers, also called high range water-reducing admixtures because of their ability to reduce three to four times the mixing water in a given concrete mixture compared to normal water-reducing admixtures, were developed in the 1970s and have found wide acceptance in the concrete construction industry.

#### 3.3.2.1 Super-plasticizer materials and mechanism in concrete

There are four types of super plasticizers that are generally used for concrete as given below:

- **Sulphonated melamine** formaldehyde condensates
  - It is suitable in low temperature areas
  - Dosage: 0.5 - 3% by weight of cement
- **Sulphonated naphthalene** formaldehyde condensates
  - It is more suitable in high temperature areas
  - Dosage: 0.5 - 3% by weight of cement
- **Modified Ligno sulphates**
  - It is suitable for Indian conditions where temperature variation is high
  - Dosage not more than 0.25% by weight of cement
- **Carboxylated admixture**
  - It is suitable where workability is required to be retained for large duration.

The superplasticizer is adsorbed onto the cement particles, thereby lowering inter-particle attraction and producing a more uniform dispersion of cement grains as with a normal water—reducer. Basically, the dispersion mechanism of concrete based Superplasticizers is mainly due to Steric hindrance effect. The graft chains of the polymer molecules on the surface of cement would hinder by themselves from flocculating into large and irregular agglomerates of cement particles. Steric hindrance effect...
stabilizes the cement particle capacity to separate and disperse thereby retaining the dispersed structure for the longer time. It gives concrete mix “Slump retention” for the longer time period.

Figure 3-5. Steric Hindrance Mechanism in concrete based SuperPlasticizers resulting in longer slump retention

### 3.3.2.2 Advantages and disadvantages of Super-plasticizers

The advantages of Super-plasticizers are:

- Significant water reduction
- Reduced cement contents
- Reduce water requirement by 12-30%
- Increased workability of concrete
- Reduced effort required for placement
- More effective use of cement
- More rapid rate of early strength development
- Increased long-term strength
- Reduced permeability of concrete

The disadvantages of Super-plasticizers are:

- Additional admixture cost (the concrete in-place cost may be reduced)
- Slump loss greater than conventional concrete
- Modification of air-entraining admixture dosage
- Less responsive with some cement
- Mild discoloration of light-coloured concrete
3.3.2.3  **Application of super-plasticizers in concrete mixtures**

**Self-Consolidating (Compacting) concrete (SCC):** Super-plasticizers used to produce high workability enable SCC to be placed more easily in congested and inaccessible sections.

**Floor slabs:** Flowing concrete enables floor and pavement slabs which are not laid to falls to be placed quickly, with little or no vibration and with very low labour content.

**Improved quality:** By a combination of water—reduction and improved workability superplasticizers can be used to improve the quality and durability of concrete.

**Early demoulding:** By using super-plasticizers to reduce water content and lower the water/cement ratio, it is possible to increase early strength and allow earlier demoulding. This is an alternative to using an accelerator or heat curing.

3.3.2.4  **Precautions for use of super-plasticizers**

**Mix design:** For high workability concrete, it is important to pay attention to the mix design so that the concrete will not bleed or segregate significantly and only the minimum quantity of super-plasticizer is required. In particular, it may be necessary to increase the proportion of fine aggregates by perhaps 5%. A trial mix is desirable.

**Dosing:** To obtain the full benefit of the effect of most types of super-plasticizer, they are usually added to the concrete just prior to discharge and mixed at full speed for about two minutes. In the case of ready—mixed concrete this means that arrangements must be made for adding the super-plasticizer after the truck has arrived on site.

**Duration of flowing properties:** The workability of flowing concrete decreases with time and, with most types of super-plasticizer, flowing properties are retained for no more than 30—45 minutes after the addition of the admixture.

**Vibration:** Excessive vibration can cause segregation and bleeding. Water—reduced high strength concrete should be vibrated in the normal way.

**Formwork:** The increased fluidity of flowing concrete means that additional pressures are brought to bear on formwork. Formwork should be designed to resist full hydrostatic pressure.
A comparison between the water reducing admixtures and high range water reducing admixtures is shown in Table 3-2.

Table 3-2. Plasticisers vs Superplasticisers

<table>
<thead>
<tr>
<th></th>
<th>Plasticiser</th>
<th>Superplasticiser</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main constituent</strong></td>
<td>Lignosulphonate Selected Carbohydrates</td>
<td>Melamine Polymers SMFC Naphthalene Polymers SNFC Polycarboxylate Ethers PCE</td>
</tr>
<tr>
<td><strong>Typical dose (40% Solution)</strong></td>
<td>0.3 to 0.5%</td>
<td>0.6 to 1.5%</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Plasticiser x 2 Not economic for cement cost savings</td>
<td></td>
</tr>
<tr>
<td><strong>Overdose</strong></td>
<td>Retardation Air Entrainment</td>
<td>Little effect till x 2 overdose Without water reduction, mix may segregate</td>
</tr>
<tr>
<td><strong>Water reduction</strong></td>
<td>8 to 12%</td>
<td>16 to 30% +</td>
</tr>
</tbody>
</table>

Blends of superplasticiser with lignosulphonate give cost effective mid range products with beneficial properties.

3.3.3 Air-entraining admixtures

Air-entraining admixtures are used to purposely introduce and stabilize microscopic air bubbles (of predominately between 0.25—1 mm diameter) in concrete. Air-entrainment will dramatically improve the durability of concrete exposed to cycles of freezing and thawing. Entrained air greatly improves concrete’s resistance to surface scaling caused by chemical deicers. Furthermore, the workability of fresh concrete is improved significantly, and segregation and bleeding are reduced or eliminated.

![Air-Entrained concrete](Image1)

![Non Air-Entrained concrete](Image2)

Figure 3-6. Effect of using air entraining agent in concrete
3.3.3.1 Air entraining agent materials and mechanism in concrete

The main chemicals used in air-entraining admixtures are:

- Natural wood resins
- Animal and vegetable fats and oils such as tallow, olive oil and their fatty acids such as stearic and oleic acids
- Various wetting agents such as alkali salts or sulphonated organic compounds
- Water soluble soaps of resins acid
- Miscellaneous materials such as sodium salts of petroleum sulphonic acids, hydrogen peroxide and aluminium powder, etc.

A typical dose of admixture is 0.0005 to 0.05% of active ingredient by weight of cement.

The factors affecting air entrainment are:

- Type and quantity of air entraining agents used
- Water cement ratio of mix
- Type and grading of aggregates
- Mixing time
- Temperature
- Type of cement
- Influence of compaction
- Admixtures other than air entraining agents used

Mechanism of air-entraining agent in concrete

The chemical formula of a typical air-entraining surfactant, which consists of a nonpolar hydrocarbon chain with an anionic polar group, is shown in Figure 3-7a; the mechanism of action is illustrated in Figure 3-7b.

The air voids are entrained and stabilized when a surfactant is added to the cement-water system:

- At the air-water interface the polar groups are oriented toward the water phase lowering the surface tension, promoting bubble formation, and counteracting the tendency for the dispersed bubbles to coalesce.
- At the solid-water interface where directive forces exist in the cement surface, the polar groups become bound to the solid with the nonpolar groups oriented toward the water, making the cement surface hydrophobic so that air can displace water and remain attached to the solid particles as bubbles.
3.3.3.2 Effect of air entrainment on the properties of concrete

Air entrainment will effect directly the following three properties of concrete:

- Increased resistance to freezing and thawing
- Improvement in workability
- Reduction in strength

Incidentally, air entrainment will affect the properties in following ways:

- Reduces the tendencies of segregation
- Reduces the bleeding and laitance
- Decreases the permeability
- Increases the resistance to chemical attack
- Permits reduction in sand content, water content, cost, & heat of hydration
- Reduces unit weight, alkali aggregate reaction, the modulus of elasticity

Figure 3-7. Mechanism of air entrainment when an anionic surfactant with a nonpolar hydrocarbon chain is added to the concrete.

Figure 3-8. Air—entraining admixtures — durability.
3.3.3.3 Application of air-entraining in concrete mixtures

**Freeze-thaw resistance:** The major use of air—entraining admixtures is in the production of concrete pavings for roads and airfields where improved resistance to frost and de—icing salts is required.

**Poor aggregates:** By reducing bleeding and improving workability and cohesron, air—entraining admixtures enable poorer quality aggregates to be used and are particularly valuable in overcoming harshness.

**Concrete pumping:** The properties of reduced bleeding, improved workability and improved cohesion also make air-entraining admixtures a useful aid to the pumping of concrete where pumping pressures are below about 6 N/mm² or 60 bar. At higher pumping pressures the entrained air is compressed to the point at which it ceases to be effective.

**Extruded concrete:** Air-entraining admixtures are used to reduce bleeding and improve cohesion, compaction and surface finish in extruded concrete.

3.3.3.4 Precautions of using air-entraining agents

**Mix proportions:** An increase in sand content from 35 to 45% will typically increase air content from % to 5%. An increase in cement content of 90 kg/m³ will typically reduce air content by 1%. Increase in cement fineness will also reduce air content.

**Dosing:** The dosage rate for air—entraining admixtures may typically be as low as 0.6 ml per 1 kg cement and accurate dosing is therefore essential.

**Air content:** The air content should be measured frequently using the Air-Content method specified in the standard.

**Temperature:** An increase in temperature will reduce air content. A rise in temperature from 10 to 32°C may halve the amount of air entrained but normal day-to-day temperature fluctuations are much smaller and do not cause significant problems.

**Mixing time:** The effect of mixing on the amount of entrained air varies with type, loading and condition of the mixer. In general, the air content will increase with mixing time up to about two minutes in stationary mixers, and up to about 15 minutes in transit mixers. Thereafter, the air content is likely to remain constant for a considerable period of time. Severely extended mixing times may decrease air content.

**Transportation:** When being transported air—entrained concrete can lose up to 0.5% air, although this tends to be in the form of the larger and least effective bubbles.
3.4 Set controlling admixtures

Set-controlling admixtures are used in concrete being placed and finished in other than optimum temperatures. Set-controlling admixtures alter the rate of the cement’s hydration and, therefore, the rate of setting (stiffening) of the paste. Coincidentally, they also may affect the hardening or strength gain after the paste has set. Set-controlling admixtures include accelerating and retarding admixtures.

3.4.1 Accelerating admixtures

Accelerating admixtures are water soluble inorganic chemicals which increase the rate of reaction between cement and water and thereby accelerate the setting and early strength development of concrete. Accelerating water-reducing admixtures also incorporate water—reducing properties. Accelerating admixtures can be divided into groups based on their performance and application:

a) Set accelerating admixtures, reduce the time for the mix to change from the plastic to the hardened state. They can be subdivided into two groups:
   - Sprayed concrete accelerators, which give very rapid set acceleration (less than 10 minutes)
   - Concrete set accelerators, which, according to EN 934-2, reduce the time for the mix to change from the plastic to the hardened state by at least 30 minutes at 20°C and at least 40% at 5°C.

b) Hardening accelerators, which increase the strength at 24 hours by at least 120% at 20°C and at 5°C by at least 130% at 48 hours. Hardening accelerators find use where early stripping of shuttering or very early access to pavements is required. They are often used in combination with a high range water reducer, especially in cold conditions.

Figure 3-9. The effects of setting and hardening accelerators upon the rate of heat evolution Q (W/kg) or temperature T (°C) during hydration of cement. [2]

---

### 3.4.1.1 Accelerators materials and mechanism

Most accelerators are based on one of the following chemicals:

- **Calcium chloride**: The use of calcium chloride is restricted in many other countries to unreinforced concrete due to its potentially corrosive influence on embedded metal.
- **Calcium formate**: Calcium formate is sometimes blended with sodium nitrite or other materials to obtain enhanced properties.

Dosage, typically 0.5–2.0% on cement.

#### Mechanism of accelerators

- Set accelerators appear to accelerate the formation of ettringite.
- Inorganic hardening accelerators increase the rate of dissolution of the tricalcium silicate, leading to an increase in calcium silicate hydrate (CSH) at early ages.
- Hardening accelerators based on high range water reducers reduce the distance between cement grains so that, for a given amount of CSH hydration product, there is more interaction between the cement grains and hence more strength.

### 3.4.1.2 Benefits provided by accelerators

The purposes of using accelerators and the advantages resulting from the use of accelerators are many.

- The benefits of a reduced setting time may include:
  - Earlier finishing of surfaces
  - Reduction of hydraulic pressure on forms
  - More effective plugging of leaks against hydraulic pressure
- Reduced bleeding and segregation and increase density of concrete,
- The benefits of an increase in the early strength may include:
  - Allow an earlier finishing of the concrete surfaces,
  - Earlier removal of forms
  - Reduction of the required period of curing and protection
  - Earlier placement in service of a structure or a repair
  - Partial or complete compensation for the effects of low temperatures on strength development
  - Improved protection against early exposure to freezing and thawing,
- Reduction of protection time to achieve a given quality,
- Enables earlier release from precast moulds thus speeding production.
- Cures concrete faster and therefore uniform curing in winter and summer can be achieved.
- Early use of concrete floors by accelerating the setting of concrete.
- Reduces water requirements, shrinkage and time required for initial set.
Figure 3-10. Accelerating admixture — strength gain.

Figure 3-11. Effect of calcium chloride addition on (a) setting time of portland cement (b) effect of calcium chloride addition on strength at various curing temperatures.[3]

---

3.4.1.3 Precautions of using accelerators

**Evolution of heat:** High dosage rates or, occasionally, normal dosage rates with high cement content mixes may cause rapid stiffening and considerable heat evolution with consequent risk of thermal and shrinkage cracking. Calcium chloride in particular should be used with care in hot weather.

**Corrosion of embedded metal:** Calcium chloride or admixtures containing calcium chloride are restricted in structural concrete which contains embedded metal.

**Dosing:** Calcium chloride can be obtained as a solution or in flake form. In the case of flake it is essential that the flake is completely dissolved in water before addition to the concrete mix. Calcium formate may also be supplied in powder form and in such cases should be added to the dry batch before mixing. Liquid admixtures are generally considered easier to dispense accurately and are more readily dispersable evenly through the mix.

**Settlement:** Some settlement of solids may occur from calcium chloride solutions after prolonged storage. Settlement from calcium formate solutions can occur after only a relatively short period of storage and facilities for agitation may be necessary.

3.4.2 Retarding admixtures

Retarding admixtures are used where setting time of concrete need to be delayed. Retarder delays the hydration process but doesn’t affect the eventual process. Initial setting time can be delayed by more than 3 hours. The main application of retarding admixtures is in eliminating the cold joints and controlling the setting time of concrete.

Dosage is typically 0.2–0.6% on cement if only supplied as a retarder. If it is a multifunction admixture with dispersing properties, the dosage will be in the same range as for plasticizing/superplasticizing admixtures.

![Figure 3-12. The effects of setting and hardening retarders upon the rate of heat evolution Q (W/kg) or temperature T (°C) during hydration of cement.](image)

---

3.4.2.1 Retarders - Materials and mechanism

Set retarding admixtures are mainly found among organic compounds, but inorganic chemicals may also act as retarders:

**Organic chemicals**
- Lignosulphonates
- Hydroxycarboxylic acid and their salts
- Phosphonates
- Sugars (saccharides)

**Inorganic chemicals**
- Phosphates
- Borates
- Salts of Pb, Zn, Cu, As, Sb

Lignosulphonates, which are commonly used as water reducers, have secondary retarding effects, while hydroxycarboxylic acids and their salts, common retarders, have secondary water reducing effects.

Among the inorganic retarders listed above, only phosphates are utilized commercially. The other inorganic compounds are seldom used as they are relatively expensive and some show toxicological effects. Probably, the retarding effect of heavy metal salts also depends on the alkalinity of the cement, i.e. the capability of these metal cations to precipitate as hydroxides.

**Mechanism**

As with normal water—reducing admixtures the chemical is adsorbed onto the surface of the cement particles, but the altered properties of the film slow the rate of water penetration to the cement and the chemical in solution slows down the growth of hydration products. Different mechanisms of action between retarders and cement are shown in Table 3-3.

**Table 3-3. Different mechanisms of action between retarders and cement.**

<table>
<thead>
<tr>
<th>Type of interaction</th>
<th>Mechanism of action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adsorption</td>
<td>Large admixture anions and/or molecules are adsorbed on the surface of the cement particles, which hinders further reactions between cement and water.</td>
</tr>
<tr>
<td>Precipitation</td>
<td>The admixture reacts with one or more components of the cement to form a precipitate on the cement particles, imparting a low-permeability coating on the cement particles.</td>
</tr>
<tr>
<td>Complexation</td>
<td>The admixture makes complexes with Ca2+ that is liberated by hydration and thereby enhancing the early hydration sheath that surrounds the cement grains.</td>
</tr>
<tr>
<td>Nucleation</td>
<td>Nucleation The admixture ‘poisons’ the Ca(OH)2 and/or the CSH nucleating sites and inhibits bond formation among the hydrated products.</td>
</tr>
</tbody>
</table>
Table 3-4. Air temperature and retardation of initial setting time [5]

<table>
<thead>
<tr>
<th>Description</th>
<th>Retardation of initial setting time (h:min) at temperature of</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30°C</td>
</tr>
<tr>
<td>Hydroxylic acid</td>
<td>4:57</td>
</tr>
<tr>
<td>Lignin</td>
<td>2:20</td>
</tr>
<tr>
<td>Lignosulfonates</td>
<td>3:37</td>
</tr>
<tr>
<td>Phosphate-based</td>
<td>---</td>
</tr>
</tbody>
</table>

3.4.2.2 Benefits provided by retarders

**Setting retarder:**

The main purposes of delaying setting time are:

- To offset the accelerating effect of high ambient temperature (hot weather)
- To keep the concrete workable throughout the entire transport, placing and finishing periods. Particularly important when transporting concrete over large distances, and for the elimination of cold joints and discontinuities in large structural units.
- To prevent setting of the concrete in the truck in case of delay

**Hardening retarder**

The main purpose of delaying the strength development might be:

- To give an overall decrease in the rate of heat evolution and thereby lowering the maximum temperature to a level where thermal cracks pose less problems.

3.4.2.3 Use of retarders

- **Large pours:** Retarders enable setting time to be extended thereby preventing the formation of cold joints in large pours. Additionally, water-reducing retarders allow a reduction in cement content with a consequent reduction in maximum temperature rise.

- **Sliding farm work:** Retarders enable the rate of advance of sliding formwork to be reduced to allow time for steel-fixing and sometimes for over-night stopping.

- **Hot weather concreting** The use of water-reducing retarders assist hot-weather concreting by: (a) delaying setting time and hence compensating for the accelerating effect of the high ambient

---

5 http://www.engr.psu.edu/ce/courses/ce584/concrete/library/materials/Admixture/AdmixturesMain.htm
temperature, and (b) permitting a higher initial workability which therefore extends the period during which the concrete remains workable.

**Ready-mixed concrete:** The delay in setting time and higher initial workability obtainable through use of a water-reducing retarder compensate for the time lost in transit of ready-mixed concrete.

### 3.4.2.4 Precautions of using retarders

**Overdosing:** Overdosing will result in excessive retardation but strength will develop normally after the period of retardation provided that curing is adequate and that the formwork is not disturbed.

**Timing of addition:** To obtain consistent results the retarder should be added with the gauging water. A delay in the addition of the retarder to the concrete mix increases the degree of retardation obtained but may lead to poor dispersion.

**Curing:** A retarded mix must be adequately cured in order to prevent plastic cracking, which can arise if the concrete is allowed to dry out before sufficient strength has developed.
### 3.5 Admixtures for special purposes

Table 3-5. Special types of chemical admixtures for concrete.

<table>
<thead>
<tr>
<th>Type of admixture</th>
<th>Desired effect</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air detainers</td>
<td>Decrease air content</td>
<td>Tributyl phosphate, dibutyl phthalate, octyl alcohol, water-insoluble esters of carbonic and boric acid, silicones</td>
</tr>
<tr>
<td>Alkali-aggregate reactivity inhibitors</td>
<td>Reduce alkali-aggregate reactivity expansion</td>
<td>Barium salts, lithium nitrate, lithium carbonate, lithium hydroxide</td>
</tr>
<tr>
<td>Antiwashout admixtures</td>
<td>Cohesive concrete for underwater placements</td>
<td>Cellulose, acrylic polymer</td>
</tr>
<tr>
<td>Bonding admixtures</td>
<td>Increase bond strength</td>
<td>Polyvinyl chloride, polyvinyl acetate, acrylics, butadiene-styrene copolymers</td>
</tr>
<tr>
<td>Coloring admixtures</td>
<td>Colored concrete</td>
<td>Modified carbon black, iron oxide, phthalocyanine, umber, chromium oxide, titanium oxide, cobalt blue</td>
</tr>
<tr>
<td>Corrosion inhibitors</td>
<td>Reduce steel corrosion activity in a chloride-laden environment</td>
<td>Calcium nitrate, sodium nitrite, sodium benzoate, certain phosphates or fluosilicates, fluoaluminates, ester amines</td>
</tr>
<tr>
<td>Dampproofing admixtures</td>
<td>Retard moisture penetration into dry concrete</td>
<td>Soaps of calcium or ammonium stearate or oleate, Butyl stearate, Petroleum products</td>
</tr>
<tr>
<td>Foaming agents</td>
<td>Produce lightweight, foamed concrete with low density</td>
<td>Cationic and anionic surfactants, Hydrolized protein</td>
</tr>
<tr>
<td>Fungicides, germicides, and insecticides</td>
<td>Inhibit or control bacterial and fungal growth</td>
<td>Polyhalogenated phenols, Dieldrin emulsions, Copper compounds</td>
</tr>
<tr>
<td>Gas formers</td>
<td>Cause expansion before setting</td>
<td>Aluminum powder</td>
</tr>
<tr>
<td>Grouting admixtures</td>
<td>Adjust grout properties for specific applications</td>
<td>See Air-entaining admixtures, Accelerators, Retarders, and Water reducers</td>
</tr>
<tr>
<td>Hydration control admixtures</td>
<td>Suspend and reactivate cement hydration with stabilizer and activator</td>
<td>Carboxylic acids, Phosphorus-containing organic acid salts</td>
</tr>
<tr>
<td>Permeability reducers</td>
<td>Decrease permeability</td>
<td>Latex, Calcium stearate</td>
</tr>
<tr>
<td>Pumping aids</td>
<td>Improve pumpability</td>
<td>Organic and synthetic polymers, Organic flocculents</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Organic emulsions of paraffin, coal tar, asphalt, acrylics, Bentonite and pyrogenic silicas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hydrated lime</td>
</tr>
<tr>
<td>Shrinkage reducers</td>
<td>Reduce drying shrinkage</td>
<td>Polyoxyalkylene alkyl ether, Propylene glycol</td>
</tr>
</tbody>
</table>

---

### 3.6 Storing and dispensing (dosing) chemical admixtures

- Liquid admixtures can be stored in barrels or bulk tankers.
- Powdered admixtures can be placed in special storage bins and some are available in premeasured plastic bags.
- Admixtures added to a truck mixer at the jobsite are often in plastic jugs or bags. Powdered admixtures, such as certain plasticizers, or a barrel of admixture may be stored at the project site.
- Dispenser tanks at concrete plants should be properly labeled for specific admixtures to avoid contamination and avoid dosing the wrong admixture. Most liquid chemical admixtures should not be allowed to freeze; therefore, they should be stored in heated environments.
- Consult the admixture manufacturer for proper storage temperatures.

![Storing of chemical admixtures at ready mix plants](image)

Figure 3-13. Storing of chemical admixtures at ready mix plants.

---

3.7 References

ACI Education Bulletin E4-12, (2013). Chemical Admixtures for Concrete. American Concrete Institute. Prepared under the direction and supervision of ACI Committee E-701 Materials for Concrete Construction.


