Admixture Technical Sheet – ATS 9

Corrosion inhibiting admixtures

1. Function

Corrosion inhibiting admixtures increase the passivation state of reinforcement and other embedded steel in concrete structures. This can inhibit the corrosion process over extended periods when passivation would otherwise have been lost as a result of chloride ingress or carbonation.

Corrosion inhibiting admixtures added to concrete during production are called “integral” corrosion inhibitors. Migratory corrosion inhibitors are also available which can be applied to the hardened concrete but these are not admixtures.

The most common cause of reinforcement corrosion is pitting corrosion due to the ingress of chloride ions through the covering concrete and subsequent diffusion down to the embedded steel. Although corrosion inhibitors can raise the corrosion threshold of the steel, they are not an alternative to producing impermeable, durable concrete which limits chloride diffusion.

Carbonation of the concrete leads to a lowering of the alkalinity around the steel and this causes a loss of passivation that can also result in general reinforcement corrosion. Corrosion inhibitors can help to guard against this form of attack.

Corrosion inhibitors can significantly reduce maintenance costs of reinforced concrete structures throughout a typical service life of 30 – 40 years. Structures especially at risk are those exposed to a maritime environment or other situations where chloride penetration of the concrete is likely. Such structures include bridges, tunnels, industrial plants, jetties, wharves, mooring dolphins and sea walls. Highway structures can be affected by the application of de-icing salts during winter months, as can multi-storey car parks where salt laden water drips off cars and evaporates on the floor slab.

2. Materials

The three most common generic types of corrosion inhibiting admixture are:

Calcium nitrite (normally contains a residual amount of calcium nitrate)
Amino alcohols
Amino alcohols blended with inorganic inhibitors

The calcium nitrite type has more than a 50 year history of use but has been used more for its accelerating than its corrosion inhibiting properties until recently. The amino alcohol types have been available for over 20 years but it is only recently that usage has become significant.

3. Mechanism

The mechanism by which corrosion inhibitors operate is dependent on their chemical nature.
Calcium nitrite based corrosion inhibitors convert or “oxidise” the ferrous oxide sites within the protective passive oxide layer into ferric oxide (+3 oxidation state) which is more stable and less reactive than the +2 oxidation state, ferrous oxide. When the chloride ions reach the ferric oxide layer,

no reaction occurs – the steel is in a passive state. It is the anodic corrosion sites on the steel that are protected against the chloride attack and for this reason nitrites are called anodic inhibitors. It is important that sufficient nitrite is present to counter the chloride ions. The dosage of the admixture is therefore based on the predicted level of chloride at the steel over the design life of the structure.

Amino alcohol based corrosion inhibitors coat the embedded steel with a monomolecular layer that keeps the chlorides ions away from the embedded steel. They also inhibit the reaction of oxygen and water at the cathodic sites on the steel which are an essential part of the corrosion process. As a result amino alcohols can be regarded as both anodic and cathodic inhibitors.

4. Use

4.1 Dosage

The dosage of corrosion inhibitors is dependent the client's expected serviceable life of the structure and on a range of factors that affect the durability of concrete. These include cement type, water to cement ratio, cover concrete to the steel, ambient temperature and level of exposure to chlorides.
The typical dosage range for a 30% solution of calcium nitrite is 10 to 30 litres/m^3 but is usually used between 10 and 20 litres/m^3.

The dosage of amino alcohol based corrosion inhibitors is usually between 3 and 4 % by weight of cement.

Both types can be used with other admixture types and their use with a high range water reducing admixture is usually recommended in order to ensure the quality and durability of the base concrete.

4.2 Cement type

Corrosion inhibitors are compatible with all cement types and blends with other binders such as fly ash or ground granulated blastfurnace slag (ggbs) as they are only being "carried" by the plastic concrete, not modifying the cement's properties or hydration as a water reducing or retarding admixture would.

4.3 Yield

Corrosion inhibitors do not affect the yield but care should be taken when calculating the free water to cement ratio of the concrete bearing in mind that in 15 litres/m^3 of a 30% aqueous solution of calcium nitrite, there will be approximately 13 litres/m^3 of water.

In the case of amino alcohol based corrosion inhibitors, the volume of admixture per cubic metre may also necessitate a reduction in the volume of mixing water to maintain a constant workability.

4.4 Overdosing

Amino alcohol based products do not have a significant effect on concrete properties even when overdosed.

Overdosing of calcium nitrite based corrosion inhibitors will result in an acceleration in setting of the concrete.

5. Effects on properties of concrete

5.1 Strength

Corrosion inhibiting admixtures have little effect on strength at later ages but may accelerate early strength development.

5.2 Workability

The workability of concrete containing corrosion inhibiting admixtures will not be significantly affected provided the water content of the admixture is included as part of the mixing water.

5.3 Slump loss

Amino alcohol based corrosion inhibiting admixtures do not produce a significant change in the rate of slump loss.

In the case of calcium nitrite based corrosion inhibitors, a faster rate of slump loss can be expected compared to an identical “control” concrete without containing the inhibitor. This is because of the accelerating effect of calcium nitrite. Some commercially available corrosion inhibitors based on calcium nitrite do contain a set retarder to offset the accelerating effect, thus reducing the effect on slump loss.

5.4 Setting time

Calcium nitrite based corrosion inhibitors do accelerate the setting times of concretes over a range of curing temperatures unless they are formulated with a set retarder to offset the accelerating effect.

Corrosion inhibitors based on amino alcohols have little or no effect on setting times of the concrete.

5.5 Air entrainment

Neither calcium nitrite nor amino alcohol based corrosion inhibitors cause air entrainment or affect the use of air entraining admixtures.

5.6 Bleeding

Neither calcium nitrite nor amino alcohol based corrosion inhibitors affect the rate at which concrete bleeds.

5.7 Heat of hydration

Neither calcium nitrite nor amino alcohol based corrosion inhibitors affect the maximum rise in temperature of concrete.

5.8 Volume deformation

Neither calcium nitrite nor amino alcohol based corrosion inhibitors significantly affect the creep or drying shrinkage of the concrete.

5.9 Durability

The function of this type of admixture is to enhance the long term durability of reinforced concrete by providing enhanced passivation to the cathodic and or anodic areas of embedded steel.

Structures built in the 1970’s with calcium nitrite have been reported to still contain the original level of nitrite and show no signs of deterioration.

The addition of calcium nitrite based or amino alcohol based corrosion inhibitors does not affect the long term durability of the base concrete but can offer extended life to the overall structure.

6 Health and Safety of Admixtures

Most admixtures are non hazardous and pose no abnormal health and safety risk but as with all forms of chemical it is essential that the material safety data sheets are read and understood before use. Risk assessments should be conducted to ensure all users are provided with a safe means of use and relevant PPE.

7 Other information

Other CAA information sheets are available including Environmental Product Declarations, use of admixtures in drinking water applications, sustainability, storage and dispensing. These are available at www.admixtures.org.uk under the ‘Publications’ tab.