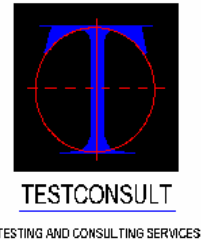


STRUCTURES DATA SHEET 2

Chloride Ion Content



Page 1 of 2

Chloride ions when present in reinforced concrete can cause very severe corrosion of the steel reinforcement. The chloride ions will eventually reach the steel and then accumulate to beyond a certain concentration level. The protective film around the steel is destroyed and corrosion will begin when oxygen and moisture are present in the steel-concrete interface. Chlorides can originate from two main sources as follows:

Chloride added to the concrete at the time of mixing, often referred to as **Internal Chloride**. This category includes calcium chloride accelerators for rapid hardening concrete, salt contaminated aggregates and the use of sea water or other saline contaminated water.

Chloride ingress into the concrete from the environment often referred to as **External Chloride**. This category includes both de-icing salt as applied to many highway structures and marine salt, either directly from sea water in structures such as piers, or in the form of air-borne salt spray in structures adjacent to the coast.

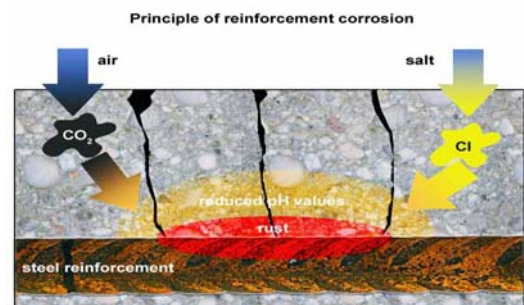


The effect of chloride salts depends to some extent on the method of addition. If the chloride is added at the time of mixing, the calcium aluminate (C^3A) within the cement paste will react with the chloride to some extent, chemically binding it to form calcium chloroaluminate. In this form, the chloride is insoluble in the pore fluid and is not available to take part in damaging corrosion reactions.

The ability of the cement to chemically react with the chloride is however limited and depends on the type of cement. Sulphate resisting cement, for example, has a low C^3A content and is therefore less able to react with the chlorides.

Experience suggests that if the chloride exceeds about 0.4% by mass of cement, the risk of corrosion increases. This does not automatically mean that concretes with chloride levels higher than this are likely to suffer severe reinforcement corrosion: this depends on the permeability of the concrete and on the depth of carbonation in relation to the cover provided to the steel reinforcement.

When the concrete carbonates, by reaction with atmospheric carbon dioxide, the bound chlorides are released. In effect this provides a higher concentration of soluble chloride immediately in front of the carbonation zone. Normal diffusion processes then cause the chloride to migrate into the concrete. This process, and normal transport of chlorides caused by water soaking into the concrete surface, is responsible for the effect sometimes observed where the chloride level is low at the surface, but increases to a peak a short distance into the concrete (usually just in front of the carbonation zone). The increase in unbound chloride means that more is available to take part in corrosion reactions, so the combined effects of carbonation and chloride are worse than either effect alone.

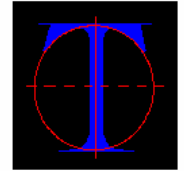


The depth/concentration profile for External chloride, which has penetrated hardened concrete, will show levels decreasing further from the surface. Chlorides present in the fresh concrete will tend to be evenly distributed throughout the concrete.

Passivation of the steel reinforcement in concrete normally occurs due to a two component system comprising a portlandite layer and a thin pH stabilised iron oxide/hydroxide film on the metal surface. When chloride ions are present, the passivity of the system is lost by dissolution of the portlandite layer, followed by debonding of the passive film. Physical processes operating inside the passive film may also contribute to its disruption.

STRUCTURES DATA SHEET 2

Chloride Ion Content



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Page 2 of 2

When chlorides have ingressed from an external source, particularly in conditions of saturation and low oxygen availability, insidious pitting corrosion of the reinforcement can occur, causing massive localised loss of cross section. This can occur in the early stages without disruption of the concrete underneath.



The critical chloride content required to initiate corrosion depends on whether the chloride was present at the time of mixing, or has ingressed after hardening, as discussed above. Clearly this also depends on the temperature and humidity of the concrete and also whether the concrete has carbonated. Good quality concrete can often show a remarkable tolerance for chloride without significant damage, however, at chloride contents up to about 1% by mass of cement (usually for chloride added at the time of mixing) reinforced concrete is much less tolerant of ingressed chloride.

There is little published data on the accuracy and precision of the methods for chloride analysis. For the presentation of results, TRL Contractor Report 32 warns of the potential errors associated with assuming a cement content as the small size of the samples taken for analysis may not be representative of the actual concrete composition.

BS 8110 limits the permitted chloride content from all sources to 0.35% by weight of cement for reinforced concrete structures. Concrete Society Technical Report No. 32 suggests that the risk of chloride-induced corrosion is significant for levels greater than 0.6%.

BA 35/90 states that where chloride ion content at the level of reinforcement exceeds 0.3% (total chloride ion content) by weight of cement, there is a risk of corrosion occurring.

To determine chloride ion content concrete dust samples are collected by drilling incrementally using a 25mm diameter percussion drill and collecting the dust (after discarding the first 5mm), at 5-25mm, 25-50mm, 50-75mm and 75-100mm. These samples are then tested in our UKAS accredited laboratory in accordance with BS 1881: Part 124: 1988.

References:

BS 1881: Part 124: 1988 – Testing Concrete, Methods for analysis of hardened Concrete

BS 8110: Part 1: 1997 - Structural use of concrete. Code of practice for design and construction

BA 35/90: 1990 – The Inspection and Repair of Concrete Highways Structures

TRL Contractors Report 32: 1986 - Methods to determine chloride concentrations in in-situ concrete