

Technology in Practice

What, Why & How?



TIP 13 - Chloride Limits in Concrete

This TIP addresses the limits on internal chlorides in concrete as addressed in the Building Code, ACI 318

WHAT is the Concern with Chlorides?

Chlorides in concrete result in the corrosion of reinforcing steel. Steel is naturally protected (passivated) from corrosion in the high pH (alkaline) environment when embedded in concrete. When chloride ions are present near reinforcing steel they override this passivation causing the initiation of the corrosion process. This is the more common cause of corrosion. Sources of chlorides can be external, such as from deicing chemicals and seawater, or internal from ingredient materials in concrete. Chloride limits apply to internal sources of chlorides.

Carbonation is a reaction of components of cement paste with carbon dioxide in the atmosphere. Carbonation reduces the pH of the concrete pore solution and will initiate corrosion when the carbonation front reaches the reinforcing steel. The pH of concrete pore solution is in the range of 13 to 13.8. Carbonation can reduce the pH to below 9 at which point initiation of corrosion can occur.

Chloride limits apply to structural prestressed or reinforced concrete. Chloride limits do not apply to plain concrete with minimum reinforcement or embedded welded wire mesh that is typically provided to control crack widths that occur due to temperature and/or shrinkage. However even for plain concrete, it is prudent to limit the chloride content to 1% by weight of cement, which is equivalent to using 2% calcium chloride accelerating admixture.

WHY are there Limits on Chlorides?

Corrosion of reinforcing steel results from an electrochemical process that involves oxidation at the anode (similar to the positive electrode in a battery) resulting in the formation of rust. Rust occupies more volume than the original steel and causes spalling of cover concrete. Water and oxygen are required for corrosion to occur.

The initiation of corrosion occurs when the chloride concentration at the reinforcing steel exceeds a *threshold* concentration. At this point the passive layer protecting the steel breaks down. This can happen at a localized area on the reinforcing steel. Threshold chloride concentration values vary but are typically in the range of 0.05 to 0.1% by weight of concrete – about 2 to 4 lbs/yd³. Chloride limits are expressed on the basis of the weight of portland cement. These threshold chloride values can be approximated to about 0.4 to 0.8% by weight of cement (assuming approximately 500 lb/yd³ of portland cement in concrete). Use of corrosion inhibiting admixtures and corrosion resistant steel, including epoxy coated and galvanized steel, allow for a higher chloride threshold concentration to be tolerated before the initiation of corrosion.

Chloride limits are expressed on the basis of chloride ion (Cl⁻). Not all chlorides in concrete contribute to corrosion. Some chlorides are chemically bound in the cement hydration products – typically cements with higher C₃A (tricalcium aluminate) content and hydration products of supplementary cementitious materials. It is estimated that between 50 and 75% of the total chloride content in the concrete will be water soluble and will impact the corrosion process. The limits on chlorides are stated on the basis of the water-soluble chlorides and not the total or acid-soluble quantity.