Concrete and chlorides:
extending the durability of reinforced concrete

Chloride attack is one of the most important factors when considering the durability of reinforced concrete, especially for structures in marine, highways and other chloride-laden environments. Chloride attack leads to the aggressive corrosion of steel reinforcement, even in alkaline concrete, causing cracking and spalling, and – in the very worst cases – structural failure. ***Chris Lloyd*** *of* ***Flexcrete Technologies*** *reports.*

Above: Evidence of chloride attack.

Steel reinforcement is protected against corrosion by the inherent highly alkaline environment of the concrete created by the release of calcium hydroxide from the cement hydration. This results in the formation of a passivating layer of ferric oxide on the embedded steel. As long as this surface film is maintained, the steel remains protected from corrosion.

However, when concrete structures are repeatedly exposed to salt spray or submerged in saltwater, chloride ions penetrate the pores of the concrete, eventually reaching the steel, breaking down this layer and causing corrosion.

In the case of marine structures, corrosion most rapidly occurs in the splash zone, where the intermittently wet and dry conditions exacerbate the penetration of chlorides and there is enough oxygen to facilitate the corrosion process. There is also sufficient moisture present to increase the electrical conductivity of the concrete, leading to an aggressive form of localised corrosion called pitting corrosion. This can potentially cause rapid loss of steel section and major cracking and spalling of concrete, thereby compromising structural integrity.

In tidal and submerged zones, the concrete is saturated and oxygen levels are limited as the pores in the structures are constantly filled with water. Nevertheless, in areas where there is low concrete cover, corrosion can still occur – causing a challenge for its reinstatement. The depth and quality of the cover concrete is vital, as the relatively thin layer of concrete protects the reinforcing steel from corrosion by maintaining an alkaline environment and preventing the ingress of chloride ions

New-build structures protected with Cementitious Coating 851.

Latest generation

The latest generation of cementitious coatings will overcome many of the limitations of resin systems and can be applied to damp substrates without risk of osmotic blistering. Offering high resistance to wash-out, they withstand immersion as little as 60 minutes after placing. Their high-build application and rapid cure makes them less susceptible to damage, especially during their early life. Furthermore, as water-based systems, the environmental credentials are attractive, posing minimal risk in application, with all equipment being washed in water after use.

Testing on structures suffering from carbonation that have been treated with such cementitious coatings shows that the concrete will realkalise and the depth of carbonation is reduced to afford further protection to the reinforcement, particularly in the presence of chlorides.

and the other fuels for corrosion. This is recognised in the latest Standards, with BS 8500[1] defining the concrete mix design and giving the requirements for cover.

Marine structures

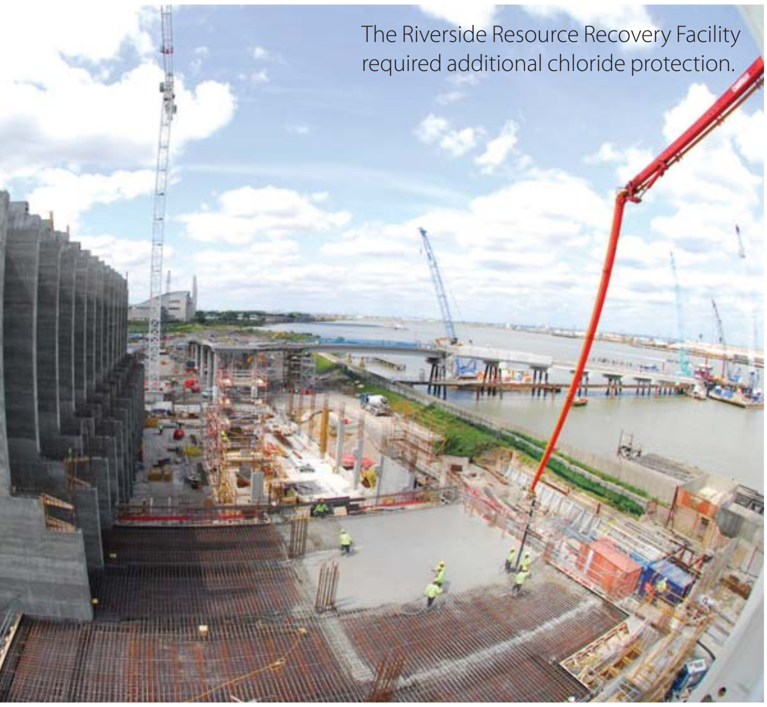
While marine structures are subject to constant exposure to chlorides, highway structures are similarly affected during the winter periods when de-icing salts are used. These readily dissolve in snow or rainwater and the resultant highly concentrated salt solution or spray from vehicles can pose a threat to concrete structures within the vicinity of a highway, with the potential for chloride ion ingress, exacerbated by repeated wetting and drying cycles.

As soon as low concrete cover has been identified, it is important to take swift action, otherwise the lack of protection to the reinforcement bars will lead to premature depassivation of the steel and subsequent corrosion. Inadequate concrete cover will not only speed up the damaging effects of carbonation but also allow even more rapid ingress of chlorides, moisture and oxygen. At worst, sections of concrete may need to be demolished or partial recasting may need to be carried out. However, both these options are very costly and often difficult to carry out.

Over the past 30 years, major technical advances in cementitious coating technology have allowed extended service-life solutions to be implemented. Such coatings can be directly applied to reinforced concrete structures that are either approaching the end of their design life or which have suffered from premature degradation.

These high-performance coatings can also be used on new-build structures as part of the original design or to provide a solution to non-conformance with specification. Where critical structures such as bridges are being built in onerous marine environments, consultants recognise the benefits of such coatings to help ensure the 120-year design life is achieved without the risk of costly future maintenance.

One product that is frequently specified on both existing and new structures to waterproof, reinstate cover and provide an effective barrier to chloride ingress



The Riverside Resource Recovery Facility required additional chloride protection.

Chloride-induced corrosion and spalling at the top of columns.

Cementitious Coating 851 has been applied to the underside of Holt Fleet Bridge to reinstate concrete cover and provide chloride protection. The bridge is a 200-year-old, Grade II listed structure in Worcestershire.

is Cementitious Coating 851, a highly advanced, two component, waterborne cementitious modified polymer coating.

A 2mm coating of 851 is equivalent to 100mm of good-quality concrete cover. Independent tests carried out in the laboratory at the Vinci Technology Centre in Bedfordshire have confirmed that 851 provides an effective barrier to chlorides for at least 28 years.

Unparalleled

The performance of the coating in this test is unparalleled. Not only has it shown minimal permeability and constant yet very low diffusion coefficients, but also it has not shown any signs of deterioration despite being fully immersed in a chloride solution for over 28 years. From Vinci's experience, many coating systems tend to degrade over time when on test in the cell. Even products that initially perform well can subsequently blister, resulting in more chloride ions passing through the product. Following the latest investigations and studies in concrete technology, Vinci's internal testing can now determine a chloride ion diffusion coefficient from non-steady-state conditions.

Based on the total chloride quantity that has been determined to diffuse through the 851 coating during 28 years on test, it has been calculated that this equates to a chloride ion diffusion coefficient of $8.53 \times 10^{-13} cm^2/s$. By comparison for the uncoated reference concrete specimen, a chloride ion diffusion coefficient of $1.03 \times 10^{-8} cm^2/s$ was calculated based on the total chloride quantity that had diffused in the first 98 days on test when steady state was achieved. To put this in context, it would have taken 270 years for the product cell with the 851 to reach the same chloride concentration that the uncoated specimen reached in just 98 days. ■

Reference:

1. BRITISH STANDARDS INSTITUTION, BS 8500. *Concrete. Complementary British Standard to BS EN 206. Part 1 – Method of specifying and guidance for the specifier. Part 2 – Specification for constituent materials and concrete*. BSI, London, 2015+A1:2016.