The need to protect port and marine structures

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Due to the hostile environment, it is vital to protect port and marine structures against deterioration. The damaging effects of chlorides in seawater, as well as the aggressive action of waves and currents plus carbonation attack, can all drastically reduce the design life of coastal defences, wharfs and jetties, leading to expensive maintenance bills and at worst, force premature demolition.

In the case of reinforced concrete structures, the 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 - due to their minute size - penetrate the pores of the concrete, eventually reaching the steel, breaking down this layer and causing corrosion. 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.

Identifying corrosion risks

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 absolutely 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 and the other fuels for corrosion. All too often, even in new construction, elements are rejected during quality control cover checks on-site and it becomes necessary for remedial measures to ensure the design life of the structure is achieved.

As soon as low concrete cover has been identified, it is important to take swift action, otherwise the lack of protection to the re-bars will lead to premature de-passivation 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.

Various options may be open here. These could range from the drastic and costly measures of demolishing sections that fail to meet the required specifications, or partial recasting with new concrete. This involves removal of the concrete back to behind the level of reinforcement typically using ultra high pressure water blasting techniques, repositioning the formwork to achieve the desired cover and recasting the concrete. However, in port and marine environments it can often be difficult to access the area to carry out remedial work.

Protective coatings

A more practical and cost-effective means of reinstating cover on port and marine structures is to apply a protective coating. There are many different products available on the market and it is important to assess factors such as substrate compatibility, life span and the film thickness required to provide the necessary cover, not to mention successful track record of use on similar structures and independent approvals such as CE marking in accordance with BS EN 1504.

One product which is frequently specified for reinstating effective cover on precast and in-situ reinforced concrete is Cementitious Coating 851 - a waterborne, cementitious modified polymer coating. Independent tests show that a two millimetre coating of Cementitious Coating 851 is equivalent to 100 millimetres of good quality concrete cover, as well as providing a complete barrier to water under 10 bar pressure. Being cement-based, it chemically reacts with the substrate to form an integral part and will have a design life equivalent to that of the concrete to which it is applied. 851 can be applied to green concrete by brush or spray techniques, it exhibits minimal hazard during application and is non-toxic when cured.

Preventing chloride ingress

The ability to combat chloride ingress is a critical factor on marine structures and the VINCI Construction Technology Centre has assessed the chloride ion diffusion of Cementitious Coating 851 for the past 24 years, and to date, no steady state of flux of chloride ions has been detected, whereas the control concrete achieved this in just 28 days.

Remedial options for steel

Steel structures in port and marine environments are also more prone to corrosion, not least of all due to the damaging effects of the aggressive environment but also a lack of planned preventative maintenance in many cases. There are several different products on the market for remedial works, with varying degrees of effectiveness. Traditional resin coatings are one option and whilst some products will offer protection against long-term environmental degradation, high levels of surface preparation are needed, including removal of all contaminants and corrosion by-products back to bright metal free from chlorides - a scenario which is often impossible in marine environments with restrictive tidal windows.

Cementitious coatings, such as those manufactured by Flexcrete, are an alternative option and are designed to overcome the shortcomings of traditional resin coatings. Able to be applied to damp substrates, they require much less surface preparation as they achieve bond when just surface rusting has been removed. Offering high resistance to wash-out they withstand immersion as little as 60 minutes after placing and their high build and rapid curing properties make them far less susceptible to damage, especially during early life. Furthermore, they have a water-based,

Cementitious coatings can also be used to enhance cover on new construction, such as the link bridge at Belvedere Riverside Energy from Waste (EFW) facility in South East London

Cementitious Coating 851 was specified for application to supporting pillars of a jetty in the North West of England

solvent free, environmentally friendly composition and pose minimal risk during application.

Accelerated low water corrosion

Accelerated Low Water Corrosion (ALWC) is a form of corrosion which can occur on sheet piling and other marine structures at or around the low water level. Unheard of in the UK until the 1990s, this is a phenomenon which has been described as a 'steel-eating bug epidemic' and is characterised by localised areas of soft orange corrosion products, overlaying a black organic sludge containing colonies of several types of bacteria. It is a concern to many port authorities and engineers worldwide as it can pose unexpected engineering and financial challenges. Cases of ALWC have been found on structures within just 20 years of operation, thereby requiring extensive and costly repair work on structures which would have otherwise been expected to have an effective life of 60-120 years. The problem is not just associated with salt water, it has also been found on structures exposed to fresh water. The most economical solution is to provide protection from accelerated corrosion at an early stage, thus maximising the design life and avoiding the risk of catastrophic, sudden failure with all the associated expense of repairs, lost business and risks to health and safety. Flexcrete's waterborne cementitious coatings offer an effective defence strategy to ALWC as they cure to form a dense coating with high levels of protection from water, oxygen and chloride ion penetration.

Cases in action

The benefits of cementitious coating technology have been clearly demonstrated in many port and coastal projects both in the UK and further afield. One prestigious project is a concrete and steel jetty in the north west of England which is capable of handling vessels up to 65,000 tonnes. In operation since 1960, Cementitious Coating 851 was specified in 1987 in order to extend the service life of the jetty, as inspection of the 70 supporting pillars had uncovered localised concrete spalling and corrosion of the reinforcement due to chloride attack. An inspection in 2010 confirmed that 851 had fulfilled its function as a waterproof, chloride resistant finish in the tidal environment. Following the inspection, Bernard Jones, technical director at Mouchel stated:

"The application of Cementitious Coating 851 would appear to have been effective in enhancing the durability of the reinforced concrete which had suffered considerable deterioration during the initial 27 years of exposure when the concrete was left without any secondary protection."

Cementitious coatings are also suitable for the corrosion protection of steel, as demonstrated by a project at Wadebridge Estuary in Cornwall, where Cemprotec E942 – a two component polymer and epoxy modified coating – was applied to the steel sheet piling as an anti-corrosion product. The piling forms a tidal defence on the River Camel for a 200 metre section and as the river experiences large tidal rises, the steel was suffering from significant corrosion. E942 was specified as it could be applied without extensive and costly coffer dams.

Designers have also specified cementitious coatings to increase durability on new construction. For example, when a link bridge was constructed at Belvedere Riverside Energy from Waste (EFW) facility in South East London, the consultants specified Cementitious Coating 851 to protect the structure from chloride ingress, thereby ensuring the design life of the structure was achieved. Enhancement of 35 millimetre cover to 91 precast beams was required and a 2 millimetre coating of 851 ensured the structure was a barrier to both chloride and water ingress, providing the equivalent of 100 millimetre concrete cover. In order to blend in, the colour of 851 was matched to that of the parent concrete.

High performance cementitious coatings present an ideal solution to non-conformance with specification. Not only do they reinstate cover, they also provide structures with additional protection against freeze/thaw cycles, de-icing salts, water and chloride ion penetration, thus ensuring that the life span of the structure is both achieved and extended.

ABOUT THE AUTHOR

Chris Lloyd is director of Flexcrete Technologies Limited and he resides in Southport, UK. Mr Lloyd is a Graduate of Civil Engineering from the University of Liverpool, and after four years working at Castle Cement, he joined Flexcrete in 1984. There he started to develop his knowledge and understanding of cement and polymer technology to formulate unique and innovative products for specialist civil engineering applications, which are known worldwide for their class-leading performance. In May 2005, in conjunction with a colleague, Mr Lloyd acquired the Flexcrete business from the Iotech Group.

ABOUT THE COMPANY

Flexcrete Technologies Limited is the UK's leading independent manufacturer of engineering quality technical mortars and high performance coatings. With origins dating back to 1983, the company manufactures a wide range of concrete repair mortars, fairing coats, waterproof cementitious coatings and decorative protective coatings. With its head office and manufacturing complex based in Leyland, North West England, Flexcrete products are available from stockholding distributors all around the UK. The company also has a global presence through international agents and distributors in 65 countries worldwide with export sales accounting for over 50 per cent of its business. Flexcrete was the first British manufacturer to achieve CE Mark registration in compliance with EN1504, the pan European standard for concrete repair.

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