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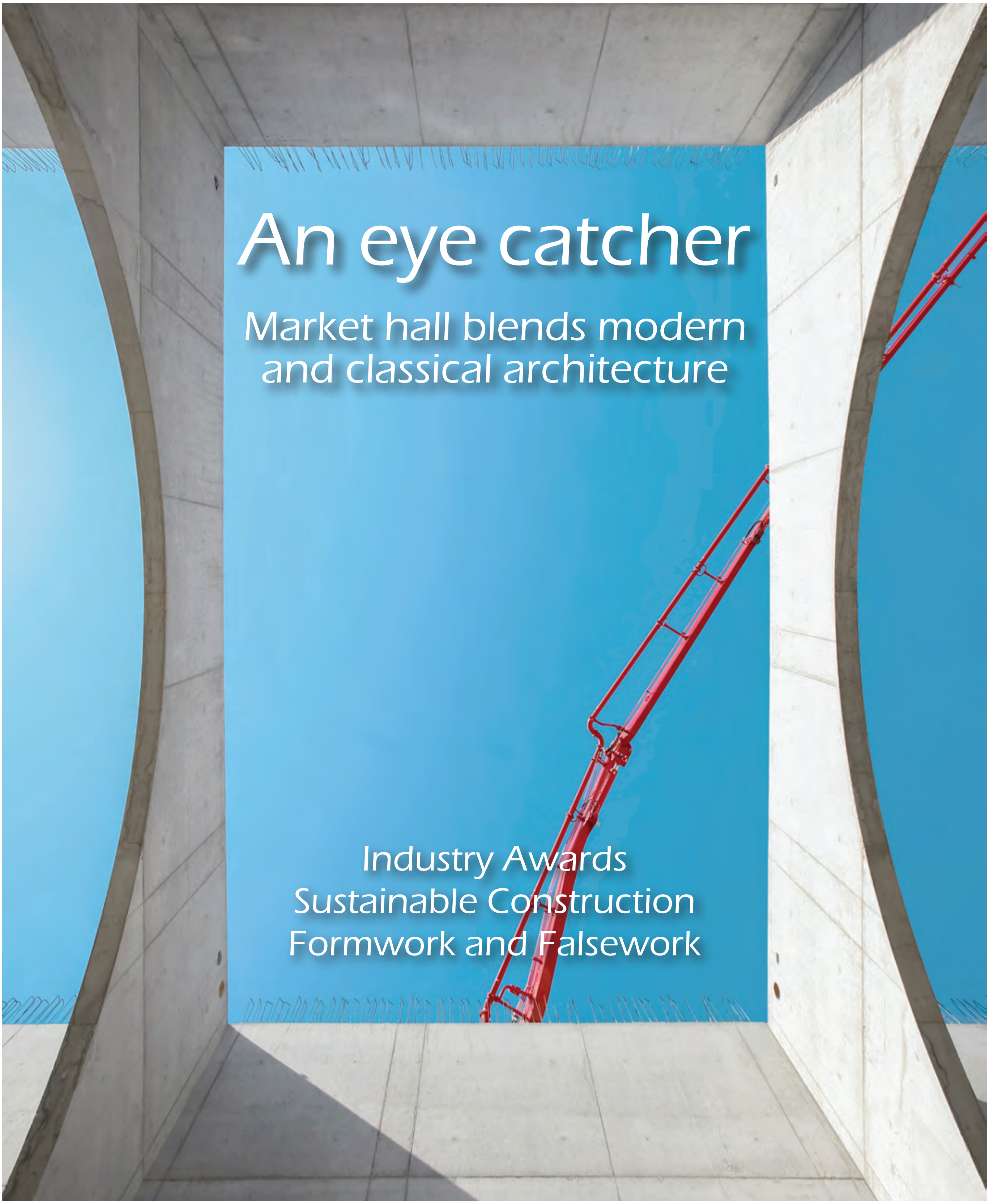

Application of MCI on Peljasec Bridge.

Application of MCI technology on Peljesac Bridge, Croatia

Bridges are of vital importance to the European infrastructure network. The European market is dominated by concrete bridges. A condition assessment survey of European bridges showed that one third have symptoms of deterioration, with carbonation and/or chloride induced steel corrosion as the main degradation mechanisms. Accordingly, significant resources are put in the maintenance of such bridges, often at higher costs than planned.

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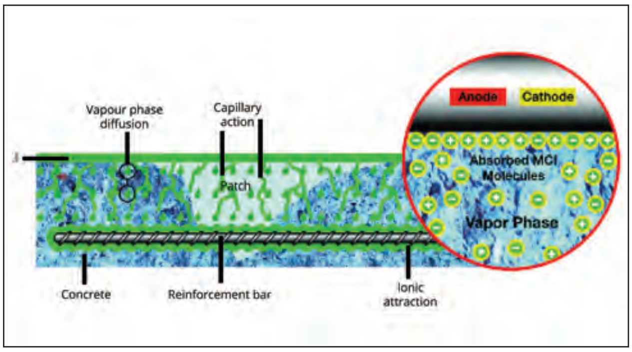


Peljesac bridge, Dubrovnik, is one of the most important and largest infrastructure projects in Europe. Connecting Croatia's Peljesac peninsula with the mainland to bypass a short stretch of the Bosnia and Herzegovina border, the bridge was finished and opened to traffic in July 2021. It ranks among the most demanding bridges in the world – not only in terms of complexity of construction but also in a complex design – and is 2404m long. The project cost €550 million, although most of the funding came from the European Union.

Left: Migrating corrosion inhibitor process.

In order to meet the main criteria of quality design, such as stability, durability, economy and integration into the environment, the inventive design proposed the construction of an extradosed bridge with an integrated hybrid structure comprising five central spans, each 285m long, and six low pylons. A careful approach was taken to ensure durability for the extended lifespan. Bridges and viaducts are specific structures that are of public interest. Special rules apply to these structures so they can safely serve for at least 100 years.

Corrosion of embedded steel is a leading cause of deterioration in reinforced concrete structures. While concrete mix designs have become more durable, the possibility of cracking due to shrinkage, movement or other forces is a consideration when designing for a long service life. The need for a corrosion inhibitor that can provide protection where there are minor cracks is very real.

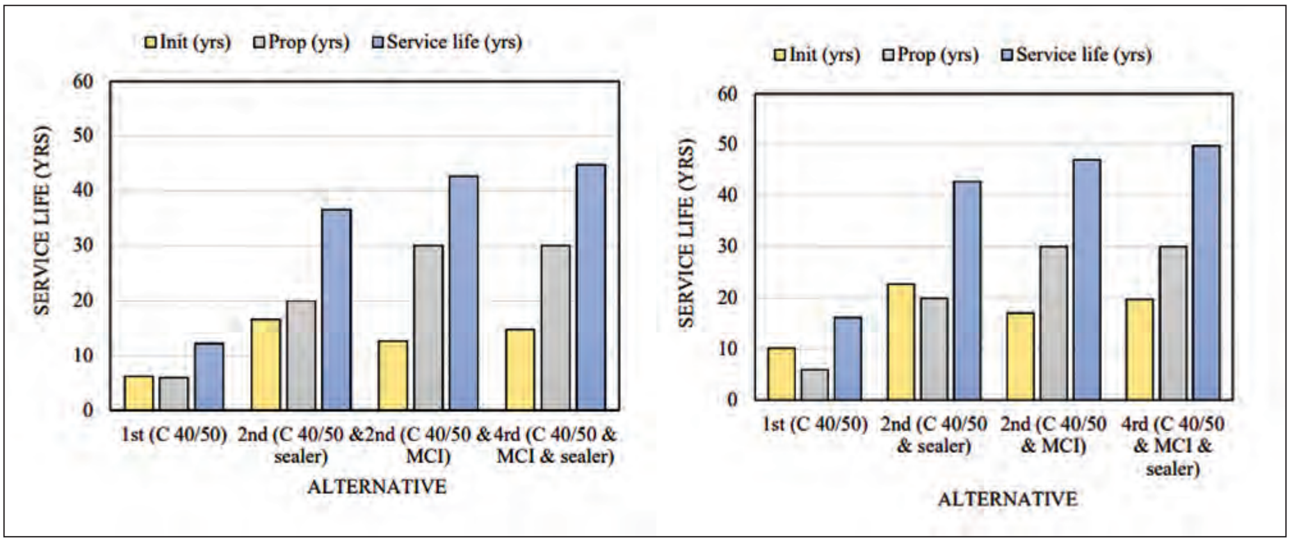
In addition, preserving integrity and extending the useful service life of existing structures is of paramount importance. Organic migrating corrosion inhibitors (MCIs), have been used for more than 30 years in construction applications, as an economical method.

Surface corrosion inhibitor treatments must be capable of penetrating to the depth of embedded reinforcing steel. Organic MCIs meet these challenges in a cost-effective manner. They are available in many different forms for all types of construction: admixtures for new concrete; repair mortars and grouts; topical treatments; injectable products; and many speciality formats.

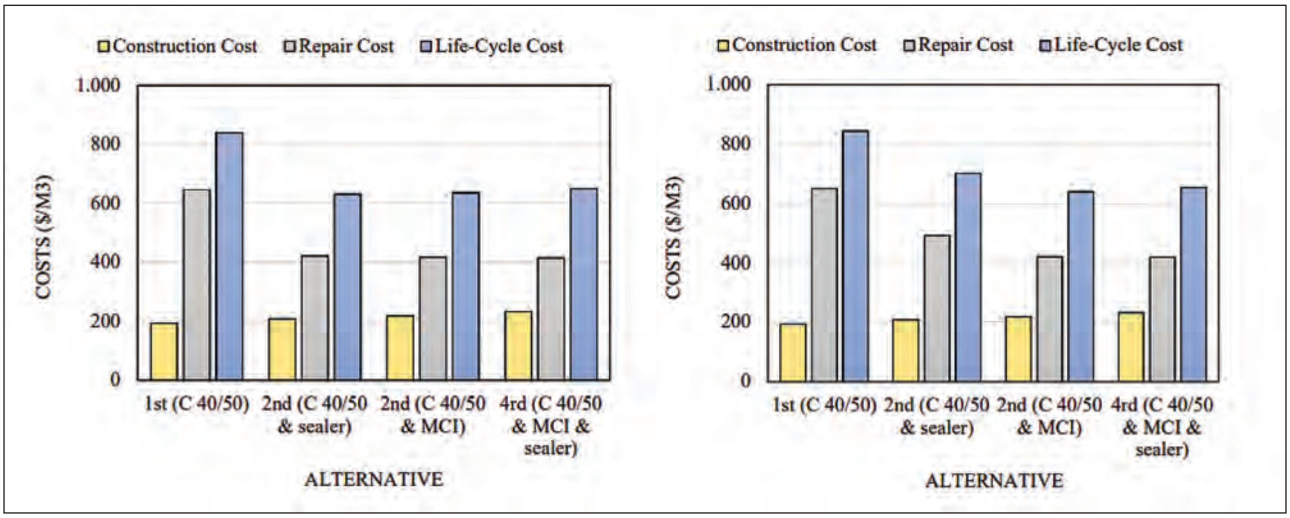
Cortec's MCI-2018 silane containing time-proven MCIs were specified on this project during the design phase as a surface impregnation to protect against the harmful effects of aggressive contaminants, thus extending the service life of the bridge. MCI-2018 is a 100% silane-based concrete sealer containing MCIs that allows deep penetration into concrete and provides water repellence by chemically reacting with the cementitious substrate. It seals surface pores, preventing the intrusion of chlorides, reduces carbonation and protects from the ingress of wind-driven rain.

MCIs affect both anodic and cathodic portions of a corrosion cell. They move through the concrete matrix via capillary action and migrate in a vapour phase throughout the concrete pore structure. When MCI comes into contact with embedded metals, it has an ionic attraction to it and forms a protective molecular layer. This slows corrosion, greatly extending concrete's service life.

Below: Prediction of service life for concrete columns exposed to: (left) marine spray zone; (right) marine tidal zone.



Below: Life-cycle costs for concrete columns exposed to: (left) marine spray zone; (right) marine tidal zone.



Treated concrete surfaces are fully breathable and their natural moisture–vapour transmission is not affected. After the repair of surface damage and defects and cleaning of discolourations that appeared during the construction phase, the concrete surface of the pylons needed to be protected with a colourless silane coating to improve durability and increase the resistance of the concrete surface to long-term external influences.

Application

A combination of anti-corrosion coatings, cathodic protection of steel reinforcement in piles and pile heads, a concrete cover of 65–85mm, and stainless-steel reinforcement were used. In addition, impregnation of all concrete surfaces with MCI-2018 was chosen as the strategy to help the bridge achieve the designed service life. The product was applied on the entire substructure of the bridge. All concrete parts were coated with a spraying technique. The work was performed in accordance with the project requirements and after surface preparation to full functionality. This included:

- access to pylons
- rehabilitation of the concrete surface of the pylons

- cleaning the concrete surface of the pylons (washing with water)
- impregnation of the concrete surface of the pylons with MCI-2018.

For the Peljesac bridge, continuous monitoring of the condition of the structure at one central place was undertaken during the construction phase and will be continued during the exploitation phase to examine parameters of structural behaviour, time, seismic activity and structural durability. The designer of the bridge specified corrosion protection for all concrete segments in order to achieve a 130-year service life.

Influence on service life

An analysis and life assessment of the reinforced concrete elements was done by modelling in Life 365 in various scenarios, which also included the use of MCI technology with a focus on the most common deterioration mechanism – chloride-induced steel corrosion (very common in marine environments, or cold regions where de-icing salts are applied). Modelling was performed using an annual temperature profile relevant to the location of Peljesac bridge, in terms of monthly average temperatures in degrees Celsius. Two exposure conditions were evaluated: marine spray zone and marine tidal zone.

Life 365 analysis

Life 365 analysis can be divided into four sequential steps: a) predicting the time to the onset of corrosion of reinforcing steel, commonly called the initiation period, ti; b) predicting the time for corrosion to reach an unacceptable level, commonly called the propagation period, c) tp; time to first repair, tr, is the sum of these two periods: tr = ti + tp; and d) estimating the life-cycle cost based on the cost of the initial concrete, protection and future repairs.

A Life 365 service-life prediction model for concrete structures was used to calculate the life-cycle cost for four scenarios of concrete-column construction including:

- ordinary concrete (C40/50 strength class)
- ordinary concrete (C40/50) with sealer with MCI-2018
- ordinary concrete (C40/50) with MCI admixture
- ordinary concrete (C40/50) with MCI admixture and sealer with MCI-2018.

LCC analyses were carried out for estimating the lifetime of structure exposed to marine corrosion and are shown in the graphs on the previous page. The concrete service life and life-cycle costing methodologies implemented in the Life 365 software were used to analyse benefits from MCI-2018 sealer and MCI admixture application as reinforcement protection. The performed analysis clearly shows long-term benefits for both MCI incorporation into the concrete and application of MCI-2018 sealer on the concrete surface.

Although initial costs are 7, 11 and 17% higher for the second, third and fourth alternative, the life-cycle costs for examined concrete columns are 25, 24 and 23% in marine spray zone conditions, and 17, 24 and 23% in marine tidal

Above: Peljasec bridge, Dubrovnik.
Left and below: Application of MCI on Peljasec bridge.

zone conditions, lower, respectively, compared with the first alternative. This is achieved through the increased service life of the concrete elements of 62, 66 and 67%, respectively in marine spray zones, and 67, 71 and 73%, respectively in marine tidal zones, compared with the concrete columns produced with ordinary concrete (first alternative) and exposed to the same environment.

In addition to the prolonged service life, the costs are reduced due to fewer repairs being needed throughout the design life of structures treated with corrosion inhibiting sealer and/or admixture.

The application is easy by using a spray, roller or squeegee. Application rates vary depending on surface porosity and the number of applications. The approximate coverage rate is 3–4.3m^2/litre. Before applying, it is recommended that preliminary tests are carried out to determine dosing. The product should only be applied when temperatures are between 5 and 37°C and not on extremely windy days when evaporation of the solvent would be too rapid. Fresh concrete should be allowed to cure for 28 days before application; also, allow repair material to fully cure before applying MCI-2018.

Peljesac bridge is ranked among the five largest and most attractive European bridges, constructed at the beginning of the 21st Century. A strategic investment such as this bridge, demonstrates the European Commission's commitment to bringing people together and uniting territories, while reinforcing the territorial cohesion of the region and helping other neighbouring countries. ■