CONCRETE ENGINEERING International

January 2025
Volume 29 Number 1

Narbo Via

Narbonne's new museum of Roman antiquities

Decorative Concrete

Low-Carbon Construction

Industry Awards

Addressing the challenges of Europe's ageing bridge infrastructure

The vast majority of infrastructure, including bridges, buildings, tunnels and dams, is constructed primarily from concrete. More than 90% of bridges on Croatian state roads are made of reinforced or prestressed concrete. A similar distribution of materials is observed in bridges on other roads in Croatia and worldwide. According to the Croatian national annex to HRN EN 1990:2011/NA:2011[1], the designed service life is 50 years for bridges of average importance and standard dimensions and 100 years for bridges of exceptional importance and large dimensions. The impact of migrating corrosion inhibitors (MCIs) on the construction and maintenance of bridges, is discussed, tailored to address the challenges of Europe's ageing infrastructure.

Ana Juraga and Ivana Liposcak, Cortec, Zagreb, Croatia

The structural reliability of infrastructure should remain above the minimum allowable level throughout the designed service life, provided that regular maintenance is carried out. However, numerous concrete bridges, due to structural and material deterioration, are in this poor condition after only 20–30 years of use and cannot reach their designed service life without complex and costly repairs. The causes of bridge deterioration and the shortening of their service life include: design errors and omissions; poor construction quality; lack of maintenance; deterioration mechanisms caused by an aggressive environment; increased service loads and extraordinary actions; and very often a combination of several of the aforementioned causes.

Corrosion of reinforcement in concrete is the most common form of deterioration of reinforced concrete structures, especially bridges exposed to the sea and/or de-icing salts. Early detection of corrosion is crucial for effective maintenance.

Chloride-induced reinforcement corrosion

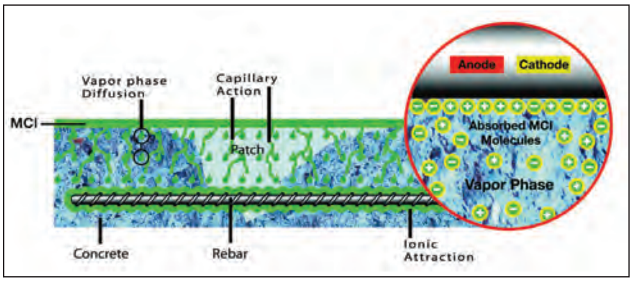
Undamaged, good-quality concrete, with a sufficient thickness of the protective concrete cover, acts as a physical barrier that protects the passive film on the steel reinforcement from depassivation caused by reaching the critical chloride concentration at the level of the reinforcement. Furthermore, cracked concrete may allow for faster penetration of chlorides to the level of the reinforcement, which shortens the depassivation time, and in the propagation phase it provides sufficient amounts of oxygen at the anodic and cathodic parts of the reinforcement, resulting in a higher corrosion rate. However, there is still very little research aimed at quantifying the impact of cracks in concrete, as well as other defects, on the corrosion of reinforcement in existing structures in a real environment, with accompanying numerical analysis.

Reinforcement corrosion accounts for 39% of causes of deterioration to concrete bridges, according to studies in Germany, the UK, and France[2]. A key activity in bridge management is visual inspection. However, this can only detect reinforcement corrosion at an advanced stage when structural repairs are needed and the opportunity for optimal bridge maintenance has already been lost.

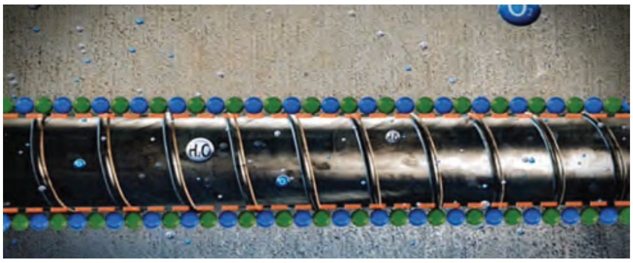
Germany – a land of deteriorating bridges

Many bridges in Germany, as the recent disaster in Dresden has shown, are in a catastrophic state. On 13 September 2024, after the collapse of approximately

Below: 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 prevents corrosion rates, greatly extending concrete's service life.



Below: MCI's form a protective layer on the surface of embedded steel reinforcement.



100m of the Carola Bridge in Dresden, the condition of infrastructure throughout Germany has come into focus. Experts are calling for urgent investments and many bridges need to be renovated as soon as possible, but there is no money for it.

In principle, all bridges built before 1980 are "problematic patients," said a professor at the University of Bochum. Unfortunately, due to a real construction boom after the Second World War, most of them are in poor condition.

Corrosion as a possible cause?

Tram tracks, and pedestrian and bicycle paths ran over Carola Bridge. The rest of the bridge is also considered to be in danger of collapse.

The investigation has shown that the collapse was caused by corrosion of the concrete structure, which was built from 1967 to 1971. Renovation work has been ongoing on the same multi-lane bridge since 2019 and the collapsed section was supposed to be repaired the following year.

In addition to corrosion, there is another problem, according to the German Chamber of Civil Engineers. When older bridges were built, today's traffic could not be taken into account. "If you look at bridges today, one truck after another crosses them and each truck causes the bridge to sway slightly. And that damages the bridges, this constant dynamic load from trucks every day, several thousand times."

This disaster, which only by chance did not cause human casualties, has caused alarm throughout the country. In

Above: Carola Bridge, Dresden.

Germany, thousands of bridges are in such poor condition that they need to be urgently renovated.

It is estimated that there are a total of approximately 130,000 bridges in Germany. Almost 40,000 are on highways and main roads important for national traffic. According to the Federal Ministry of Transport, approximately 5000 of these bridges urgently need to be repaired or even demolished and rebuilt.

Repairs to Peljesac Bridge in Croatia.

Deteriorating infrastructure is a global challenge

In 2018, the Morandi Bridge collapsed in Genoa, Italy – another tragic accident indicating how neglecting corrosion can have fatal consequences. Engineers raised numerous concerns about its unusual concrete-encased common steel cables. The designer of the bridge warned four decades ago that it would require constant maintenance to remove rust, given the effects of corrosion from sea air and pollution on the concrete. Also, the problem of fatigue corrosion on metal elements, particularly insidious in steels of high mechanical strength such as strands, is still a little-known subject.

As this reinforced and prestressed concrete bridge has been there for more than 35 years, corrosion of tendons or reinforcement was a contributory factor. The long-term behaviour of viaducts subjected to heavy traffic and situated in an aggressive environment shows that at the time of planning, many concepts about the sustainability of the bridge were not known and considered.

Building durable structures

Over the past two decades, there have been huge advances in technology to extend the lifespan of structures and avoid possible tragedies. Patented MCI technology was designed to protect reinforcing metal in concrete from corrosion and is widely used around the globe. Application of migrating corrosion inhibitors (MCI) products has experienced rapid growth in recent years due to a number of factors such as proven efficiency and environmental advantages. By using this technology, corrosion initiation is delayed and the life cycle of structures is significantly extended. One of the most efficient uses of MCIs is when they are applied directly during the construction phase, as well as being used as part of the maintenance repair system in existing structures.

There are many current cases of using migrating inhibitor technology in projects around the world, such

Bridge reconstruction is crucial for public safety, efficient transportation, economic growth and environmental protection.

Krk Bridge in Croatia. Prepared repair mortar that is applied by spraying onto the surface treated with the MCI 2020 inhibitor in a single layer shows excellent adhesion and no binding layer is required.

as erecting the new Frederikssund Bridge in Denmark. The aim was to replace the old bridge built in 1935 by providing an alternative to the only currently active bridge over the fjord. The project included the design and construction of an 8km-long dual-carriageway highway, along with a bridge over the Roskilde Fjord. Cortec MCI 309 was used for corrosion protection of PT concrete segments.

MCIs are based on amine technology. They are classified as mixed inhibitors, meaning they affect both anodic and cathodic portions of a corrosion cell. MCI is applied in many forms, including a concrete admixture or a topical treatment. It moves as a liquid through the concrete matrix via capillary action and migrates into a vapour phase throughout the concrete pore structure. When MCI encounters embedded metals, it has an ionic attraction to it and forms a protective molecular layer. This film prevents corrosive elements from further reacting with the reinforcement and reduces existing corrosion rates, greatly extending concrete's service life.

Peljesac Bridge in Croatia

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

Cortec MCI-2018 is CE certified, which indicates conformity with health, safety and environmental protection standards for products sold within the European Economic Area (EEA). The product is intended to penetrate deep into concrete, providing corrosion protection to reinforcing steel from existing water and chloride ions, or other contaminants.

Every project presents unique challenges: geology, weather, traffic load, and available materials all influence bridge design and construction. Fortunately, today’s advancements in corrosion protection offer significant benefits for the construction industry. To maximise these advantages, we must apply these technologies effectively for the benefit of everyone. ■

References:

1. HRVATSKI ZAVOD ZA NORME, HRN EN 1990. *Eurocode: Basis of structural design – National Annex*. HZN, Zagreb, Croatia, 2011.
2. DUVNJAK, I., KLEPO, I., SERDAR, M. and DAMJANOVIĆ, D. Damage Assessment of Reinforced Concrete Elements Due to Corrosion Effect Using Dynamic Parameters: A Review. *Buildings*, Vol.11, No.10, 425; *https://doi.org/10.3390/buildings11100425*, 2021.

(Photo: Stig Alenäs.)

Construction site of Crown Princess Mary Bridge in a panoramic view.