A Safe Corrosion Solution for Potable Water Reservoirs

Based on past successes, a Spanish water authority selects migrating corrosion inhibitors for its newest project

by Jessi Meyer, Jesús Orte Crespo, Josep Xavier Pujol, and Julie Holmquist

Consorci d'Aigües de Tarragona (CAT) is the nonprofit water consortium authority responsible for high-pressure drinking water distribution in Tarragona, Spain. CAT had experienced carbonation and corrosion problems in many of their existing concrete facilities and wanted to prevent this in future structures. As they began planning a 5000 m^3 (1.32 million gal.) water buffer tank, they turned to Quimilock S.A., a Spanish distributor of anti-corrosion products, for help.

Past Successes

Quimilock S.A. had helped CAT address corrosion issues on its 30-year-old network of prefabricated reinforced concrete pipes in 2014. Migrating corrosion inhibitors (MCIs) from Cortec Corporation in Saint Paul, MN, were used to treat more than 7000 m^2 (75,350 ft^2) of 1600 mm (63 in.) diameter pipeline extending 1506 m (4941 ft) in length. The rust and damaged concrete were removed from the pipes and corrosion-inhibiting admixtures were added to grout and repair mortars. This was followed by surface application of MCIs over the entire length of the pipeline. CAT was pleased with the results, as tests showed that corrosion rates dropped.[1]

Based on this successful history, CAT was convinced the same technology would be beneficial in the construction of their new reservoir.

They specified an amine-carboxylate-based MCI to be added directly to the concrete mixing water. Amine-carboxylate MCI admixtures are known to typically double or triple the time it takes for initiation of corrosion. Once corrosion starts, these admixtures can reduce rates by approximately five to 15 times compared to a control.[2] The result is a dramatic increase in expected structure service life. CAT felt confident that MCI was an economical way to help them meet their 50-year design life requirements.

Reservoir Scope

The reservoir is a rectangular tank measuring 43.5 x 23 m (142 x 75 ft) in plan and providing a maximum water capacity of

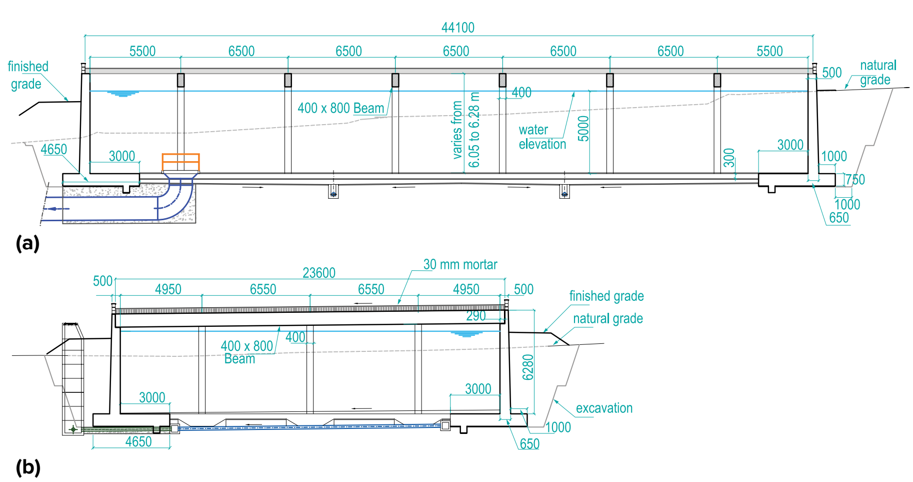

Fig. 1: Schematics of the Tarragona Reservoir: (a) longitudinal section; and (b) transverse section (Note: Dimensions in mm; 1 mm = 0.04 in.)

5000 m^3. The tank walls were designed as retaining walls supported on footings. The wall thickness varies from 650 mm (26 in.) at the base to 500 mm (20 in.) at the top, and the footings are 750 mm (30 in.) thick (Fig. 1). The bottom of the reservoir comprises a 300 mm (12 in.) thick reinforced concrete slab. Columns (400 x 400 mm [16 x 16 in.] in section) are arranged in a 3 x 6 grid frame into 800 mm (31.5 in.) deep beams that span the short dimension of the tank and terminate in notches in the exterior walls. The roof deck comprises prestressed hollowcore slabs (precast with a 40 mm [1.6 in.] thicker cover for corrosion resistance) that span between the frames. The tank was backfilled so that only 0.8 to 2.5 m (2.6 to 8.2 ft) of the structure could be seen above the ground, and the exposed edges of the hollowcore deck were concealed behind a masonry parapet. The admixture was dosed into all reinforced concrete tank portions that were placed on site, totaling 1500 m^3 (1962 yd^3) of concrete. The dosage rate was 0.6 L/m^3 (16 fl oz/yd^3). There were no negative effects on the setting time or other physical characteristics of the concrete.

Figure 2 shows construction progress.

MCI Technology

MCIs are organic blends of amines and salts of carboxylic acids. Products containing these molecules can be applied to concrete surfaces or directly added into mixing water at the concrete batching plant. Regardless of how they are applied, MCI molecules migrate through concrete pores until they reach embedded reinforcement. This penetration occurs in two ways—first as a liquid, then as a vapor through the pore structure of the concrete. Governed by Fick's law, the molecules travel from high to low areas of concentration until equilibrium is reached. Finally, they have an ionic attraction to metals when they encounter them, creating a monomolecular barrier against aggressive chlorides, carbonation, and other corrosive contaminants. Independent testing has confirmed that this layer is between 20 and 100 Å thick. Tests have also shown that the MCI molecules are adsorbed 75 to 85 nm deep into the metal surface, below the 60 nm penetration of chloride ions measured in the same test series.[3]

As an ambiodic inhibitor, MCI molecules protect reinforcing bars from corrosion at both the anode and cathode, reducing the corrosion current and rates.

Drinking Water Considerations

Although the high alkalinity of fresh concrete creates a natural protective layer on reinforcing bars, the pH diminishes over time as atmospheric carbon dioxide (CO_2) reacts with the alkaline components of the cement paste. The lower pH destroys the protective oxide layer, and the reinforcing bars in the concrete are left to the attack of moisture, chlorides, and various contaminants that can ingress and start a corrosion cell.

The reaction between CO_2 gas and the cement paste takes place in solution and is higher at high humidities, so carbonation and subsequent corrosion was exactly the problem that CAT had been experiencing with many of their previous water structures. While they did not want it to happen in their new project, they also had to be cautious about what product was used to prevent carbonation corrosion because the reservoir would contain drinking water for human ingestion. They needed a product that would be both strong against carbonation and corrosive elements (the water is treated with 0.2 to 1.2 mg/L of chlorine) in a moisture-ridden environment but that would also be safe for potable water contact.

They were aware that they could not use admixtures that rely on nitrites to inhibit corrosion because nitrites are dangerous for human consumption and are very soluble in water. Fortunately, MCIs are certified to meet ANSI/NSF Standard 61[4] and are much less likely to leach out and dissolve in water in the first place. They are also more environmentally friendly because of their biobased content (in the United States, the admixture qualifies as a USDA Certified Biobased Product).

Admixture Effect

The project required concrete meeting the Instrucción de hormigón structural (EHE 08) (Spanish Code on Structural Concrete) HA30-B/25/IV/Qa classification.[5] This calls for

Fig 2: Progress photos taken during construction of the reservoir *(photos courtesy of CAT)*

reinforced concrete with a specified characteristic strength of 30 MPa, 60 to 90 mm slump, and 25 mm maximum size aggregate (roughly, 4000 psi, 2.5 to 3.5 in. slump, and 1 in. aggregate) to be designed for noninsulated installations in contact with chlorides. That generally requires ordinary portland cement, a maximum water-cement ratio of 0.50, and a minimum cement content of 350 kg/m^3 (590 lb/yd^3).

When MCI was added directly to the concrete, it did not interfere with the concrete's physical properties. This is an important factor for construction. Even if nitrite-based inhibitors had been an option, they tend to shorten setting time and increase shrinkage cracking in newly placed concrete. MCI series admixtures do neither. They meet ASTM C1582/C1582M[6] requirements for all physical properties—compressive strength, flexural strength, setting time, shrinkage, and resistance to freezing and thawing.

In the future, if the reservoir begins to crack, MCIs will provide continued protection to the steel reinforcement, whereas other treatments that rely primarily on pore blockers would have no way to stop the ingress of chlorides and other contaminants once a breach is made. Under past modified ASTM G109[7] testing (cracked beam) that analyzes corrosion protection capabilities in damaged concrete, corrosion measurements hovered around 100 coulombs for MCI-treated concrete after 20 cycles of testing (a 1-week cycle equals 96 hours of 6% chloride solution ponding and 72 hours of air drying). In contrast, measurements for the control concrete steadily climbed to 700 coulombs by 20 weeks. Measurements for concrete mixtures treated with calcium nitrite (CNI) and amine esters climbed to about 500 coulombs over the same period,[8] as shown in Fig. 3.

CAT needed a very unique product for its water reservoir. The fact that the concrete would be in contact with drinking water heightened the need for corrosion protection and also narrowed their options for corrosion control. By using the MCI admixture recommended by Quimilock, CAT found an excellent, safe solution that would help ensure a long life span for

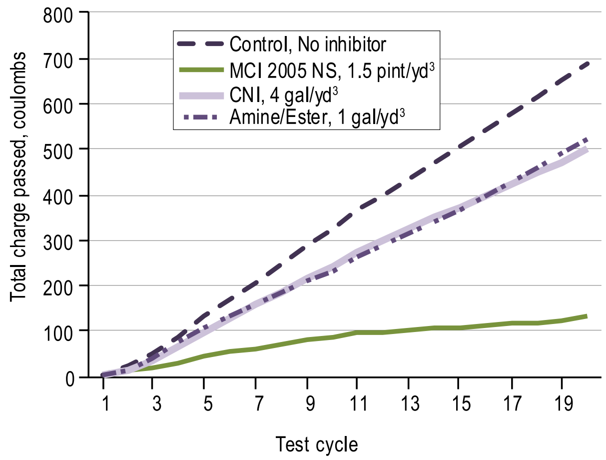

Fig. 3: Results from past modified ASTM G109 testing of concrete specimens with no inhibitor (control), MCI admixture, and other corrosion inhibitor chemistries (Note: 1 pint/yd^3 = 0.62 L/m^3; 1 gal./yd^3 = 4.95 L/m^3) *(illustration courtesy of Jessi Meyer)*

an important structure directly affecting the health and well-being of the local population.

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Selected for reader interest by the editors.

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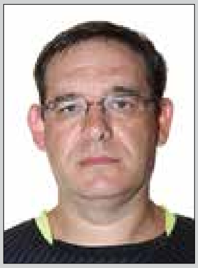

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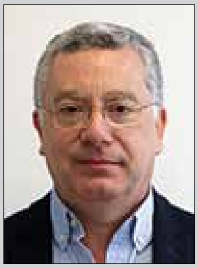

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