Restoration of Historic Concrete at Ronald Reagan Washington National Airport

Washington, DC

Submitted by Vector Corrosion Technologies

The new airport for the nation's capital, which opened for business on June 16, 1941, was designed to be one of the most modern facilities. At that time, National Airport was considered the "last word" in airports—a concentration of ultramodern developments in building design, handling of planes, air traffic and field traffic control, field lighting, facilities for public comfort and convenience, and surface vehicle traffic control.

The terminal façade was constructed of conventionally reinforced cast-in-place concrete. Long-term exposure to atmospheric carbon dioxide caused the concrete cover to carbonate, resulting in a loss of alkalinity to a level that was insufficient to keep the embedded reinforcing steel in a passive, noncorroding state.

Observed Problems

During the exterior façade survey, the most significant concrete conditions observed were pervasive cracking, delamination, and spalling. Almost the entire cornice was spalled. Corrosion of the reinforcing steel was pervasive and apparent from the surface. There had also been a history of inappropriate repairs including repairs made with sealant and other adhesive products.

1941 aerial view of National Airport

Repair Objectives

The repair design was to honor this structure as a historic and significant building. Original material was to be retained, including pour lines and decorative elements. The design was to be at minimum a 50-year repair that was to have a low maintenance cycle. In addition to repair of the damaged areas, corrosion mitigation would be required to meet the desired 50-year design life.

Testing Program

A nondestructive in-place test program was developed to supplement the façade mapping and visual survey; it included evaluation of the depth of reinforcing steel and extent of corrosion. A limited number of cores were also taken. The core samples were subjected to a range of laboratory tests to analyze the process of concrete deterioration.

- Depth of carbonation;
- Petrographic analysis (thin-section microscopy);
- Evaluation of chloride content;
- Pachometer testing; and
- Half-cell potential.

A pachometer survey revealed that the nominal depth of cover was highly variable—sometimes significantly less than 2 in. (50 mm) and many times less than 0.25 in. (0.64 cm) from the surface. The nominal concrete cover over the reinforcing steel was under 0.75 in. (19 mm) in many areas of the structure.

Eight cores were pulled and tested for carbonation. Phenolphthalein (a chemical indicator of pH) testing showed the depth of carbonation ranged from 0.25 to 1.88 in. (6.4 to 47.77 mm). Carbonation depths averaged 1 in. (25 mm).

Test results indicated widespread carbonation combined with low concrete cover led to corrosion-induced spalling of the concrete façade. Isolated sections were also determined to be contaminated with chloride ions added during the original construction. The use of chloride-based set accelerating admixtures was common during World War II as a way to speed construction.

Damage included cracking, spalling, and reinforcing steel corrosion

Nondestructive testing was performed including pachometer readings

Typical corrosion condition before and after concrete removal

Repair and Corrosion Protection Options

Corrosion mitigation alternatives considered included:

- Impressed current cathodic protection;
- Galvanic protection;
- Electrochemical treatments (particularly realkalization and electrochemical chloride extraction);
- Corrosion inhibitors; and
- Concrete removal/replacement.

Selected Corrosion Mitigation Approach

The selection of materials and procedures was based on providing a long service life with minimum impact on the historic façade.

Electrochemical realkalization and electrochemical chloride extraction (ECE) were used to provide long-term corrosion mitigation while respecting the historic nature of the facility. Realkalization was used in areas with carbonated concrete. ECE was used in the limited areas were chloride contamination was determined during the condition evaluation.

Electrochemical treatments:

- Address the underlying cause of corrosion without widespread removal of contaminated concrete;
- Are short duration treatments that provide long-term corrosion mitigation;
- Were determined to be cost-effective for providing corrosion protection over large areas; and
- Cause minimal disruption to the concrete surface making this an appropriate solution for historic structures.

The primary objective of the electrochemical treatments was to passivate active corrosion by modifying the concrete environment in the vicinity of the reinforcing steel.

Both the realkalization and ECE systems were applied to the structure on a short-term basis. An electric field is applied between the reinforcement in the concrete and an externally mounted mesh. The mesh is embedded in a conductive media, generally a sprayed-on mixture of potable water and cellulose fiber. With the realkalization process, the conductive media is saturated with an alkaline solution such as potassium carbonate whereby the potassium (K^+) ions are transported into the concrete by the application of the electric field. The realkalization treatment generally takes 4 to 7 days to complete and will not recarbonate over time.

With ECE, the conductive media is saturated with lime water and negatively charged chloride ions (Cl^-) are repelled away from the negatively charged reinforcing bar and drawn out of the concrete toward the positively charged external mesh. This action significantly lowers the amount of chloride in the concrete cover and adjacent to the steel. The ECE treatment takes 4 to 6 weeks to complete.

Installation of the Electrochemical Treatment Systems

After the spalled and cracked concrete was repaired, the electrochemical treatment system was installed as follows:

- Low cover areas were identified. All areas with less than 0.5 in. (13 mm) of concrete cover were addressed to prevent electrical short circuits between the reinforcing steel and the anode mesh;

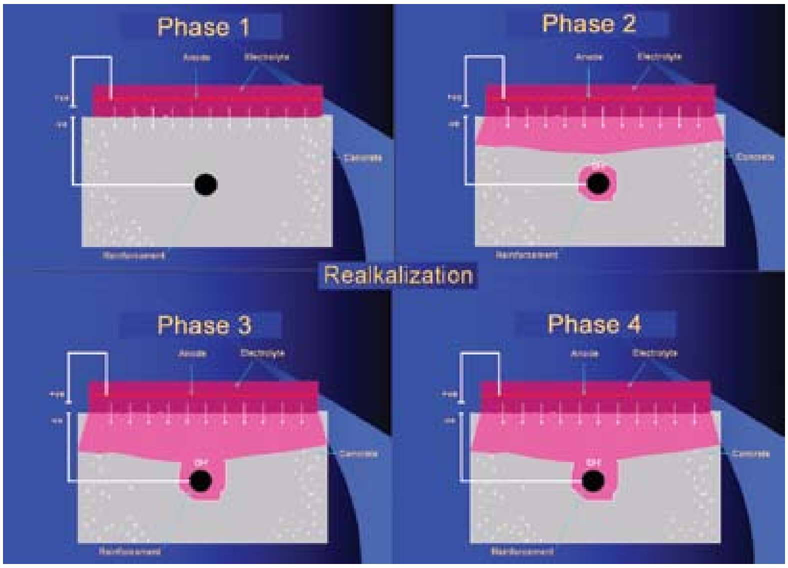

Illustration of realkalization driving an alkaline solution into the concrete


Completion of airside façade

- For quality assurance, one test area was selected for every 1000 ft^2 (93 m^2). Pre- and post-treatment core testing was used to verify successful realkalization;
- Verification of electrical continuity of the reinforcing steel and establishing continuity of isolated bars as required;
- Windows were protected from the alkaline solution by covering with plastic board and sealing the edges with polyurethane caulking;
- Two reinforcing steel connections were established per 1000 ft^2 (93 m^2) treatment zone;
- Wooden battens were fastened to the concrete surface with plastic anchors to create a space between the anode mesh and the concrete surface;
- Welded wire reinforcing mesh was installed onto the wooden battens. In the areas to receive chloride extraction treatment, an inert mixed metal oxide-coated titanium mesh anode was used. Because the chloride extraction process requires a longer treatment time than realkalization, the titanium mesh anode was used to minimize concrete staining that would have occurred from using steel mesh;
- A wet cellulose fiber mixture was sprayed onto the installed mesh to create ionic continuity between the mesh and the concrete surface. The cellulose fiber also served as an electrolytic reservoir for the treatment process;
- Reinforcing bar connections were wired to the negative side of the electrical rectifier and the mesh anode was connected to the positive side;
- All areas were kept saturated with potassium carbonate solution which was electrically driven into the concrete cover and attracted to the reinforcing steel;
- After 5 days of treatment, post-treatment core samples were taken and tested to verify that realkalization of the concrete cover had been achieved. Each core was split lengthwise and sprayed with phenolphthalein pH indicator solution to verify the pH of the carbonated concrete had been restored;
- The system was removed from the surface. All core holes and reinforcing bar connections were patched; and
- After the system was removed and repairs completed, an architecturally acceptable decorative coating was applied.

In total, over 34,000 ft^2 (3160 m^2) of carbonated concrete façade was successfully realkalized as verified by the independent quality inspector. Electrochemical chloride extraction was performed on 1895 ft^2 (176 m^2).

Ronald Reagan Washington National Airport

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