Charleston Condominium Association Proactively Addresses Corrosion

*By: **Jorge Costa, PE**, Vice President, Corrosion Solutions, STRUCTURAL TECHNOLOGIES*
***Steve Strete**, General Manager, Dockside Association, Inc.*

Located in the historic skyline of Charleston, South Carolina, Dockside Condominiums offers unobstructed scenic views of the Charleston Harbor. The Dockside complex includes a high-rise residential building, a series of low-rise townhouses, community spaces, and a reinforced concrete parking garage under an ample plaza deck. The 19-story waterside high-rise is one of the tallest buildings in the district and was constructed in 1976, before height restrictions were implemented. Today, new buildings in Charleston are bound by zoning ordinances that limit the height of buildings to 3 stories, so the views offered by Dockside are unique and highly desirable.

Over the years, salt (chlorides) carried through the air progressively deposited on the reinforced concrete surfaces at Dockside – a common occurrence in marine environments. Eventually, this resulted in corrosion of the reinforcing steel. Corrosion of the steel in concrete produces expansive oxides (rust) surrounding the bars and exerts tensile pressure on the surrounding concrete. This can cause cracks, delamination, and spalls and the effects of this process can range from simple aesthetic concerns (i.e. rust stains) to safety hazards (i.e. concrete falling from the building).

As the signs of corrosion damage and aging became noticeable, the ownership and management at Dockside needed a clear understanding of the root cause and extent of the problem to develop and implement a viable long-term solution. With this objective in mind, a condition assessment plan was developed. This plan included structural assessments, quantification of damage, and a comprehensive corrosion assessment of the balconies, parking garage, and other related structural elements.

Corrosion is an electrochemical process that involves the release of energy bound in the steel during its manufacturing process. This energy is impregnated in the steel in the form of heat and some of this energy, under the proper conditions, is released in the form of minute electrical currents. In concrete, steel is relatively immune to corrosion until sufficient chlorides arrive at the surface of the steel. Once this occurs, the steel loses its immunity and begins to discharge the bound energy. For every unit of electrical energy discharged into the environment, an equivalent amount of iron is oxidized, growing in volume around the bars and damaging concrete.

The condition assessment at Dockside focused on understanding what lead to the corrosion damage, a prognosis for the progression, and the collection of field data, including chloride content, corrosion potentials, corrosion rates, and concrete resistivity measurements. Each of these measurements plays an important role in determining and developing the most appropriate solution:

- Chloride testing determines the chloride content throughout the depth of the structure.
- Corrosion potentials are used to locate areas of corrosion activity in a concrete structure.
- Corrosion rates determine the amount of steel section loss that can be projected over time.
- Concrete resistivity values provide an indication of the corrosivity of the concrete.

Several options for corrosion protection were considered after the condition assessment was completed, including conventional repairs, topical treatments, and cathodic protection. Cathodic protection was the optimal solution after extensive review of current conditions, the amount of disturbance to residents each solution would require, and a desired repair life expectancy of greater than 20 years.

Cathodic protection is the application of an electrical current to the steel to oppose the losses from the steel. If sufficient energy is counterposed, the losses from the steel are eliminated and corrosion is stopped. Cathodic protection systems are either categorized as galvanic (GCP) or impressed current (ICCP). The difference between the two types is primarily the source of power to drive the current. GCP systems use the natural voltaic difference between two metals to create a natural battery and drive the protective current. ICCP systems use external sources of power to this end, including transformer-rectifiers, batteries, and solar panels.

After careful review of each option, an ICCP system was selected for Dockside's balconies and a GCP system was selected for the garage. These selections were based on specific conditions encountered in each of the structures, life expectancy, and performance histories. ICCP systems provide design and operation flexibility needed for the protection of the balconies with components that have life expectancies in excess of 30 years. This ensures minimal disturbances to occupants during installation and throughout the lifetime operation of the system. The GCP system for the garage was selected for its flexibility to mitigate the corrosion in the garage while allowing for future expansion of the ICCP system if warranted. This strategy was also a more cost-effective solution.

Repair specifications were prepared by Sutton Kennerley and Associates, Greensboro, NC. Along with the concrete repair specification, the project specification included a detailed performance specification for the cathodic protection system design and installation. Close coordination of the repair and cathodic protection design specification ensured design compatibility between the structural repairs, railing replacements, storm shutter repairs, and all installation sequencing between the repair and protection strategies.

STRUCTURAL, a Structural Group company was selected to install the Cathodic Protection System. The Electro Tech CP™ ICCP system chosen for this project was designed and manufactured by STRUCTURAL TECHNOLOGIES, another Structural Group company, providing the client with a single source for both the cathodic protection system and its installation.

Extensive coordination was required between all parties to foremost ensure safety, and for the several hold points required for the ICCP system that overlapped with the concrete repair contractors scope of work. The sequencing and scheduling of the contractors and subcontractors was crucial to keeping the schedule moving forward and progressing while attending to the required safety, quality and occupants concerns. Project management was challenging for a project of growing complexity with a variety of stakeholders.

STRUCTURAL crews installed the ICCP system on the top side and front edge of the balcony slabs. The ICCP system consisted of a mixed metal oxide coated titanium expanded ribbon mesh anode installed in saw slots and is divided into 20 individually controlled zones. Two reference electrodes per zone allow for performance monitoring of the system. There are a total of four cabinets located in the garage that house the Power Supply Units (PSU) which provide the DC output to each of the individual zones. All zones are managed by a microprocessor controlled Main Control Unit (MCU) that is connected to a phone line allowing for offsite remote access, monitoring, and adjustments.

The installation of ICCP involves several quality assurance checks to ensure that the system will properly function when complete. The testing at Dockside performed by STRUCTURAL TECHNOLOGIES consisted of:

- Electrical continuity of steel rebar and other metallic embedment
- Depth of cover over rebar
- Reference cell calibration pre and post installation
- Cathode and steel connection continuity
- Anode to cathode isolation
- Anode encapsulation testing
- Insulation testing
- Temporary energization

Dockside also opted to replace the PSU for an existing ICCP system installed on the roof slab of the building. The upgraded PSU allows integral monitoring of both ICCP systems.

The GCP system installed in the parking garage utilized Corrspray®, an Aluminum, Zinc and Indium alloy anode applied by thermal spray. This alloy was developed under a research program sponsored by the FHWA to provide a high output option for galvanic systems for concrete structures in cooler and dryer environments, condition present at Dockside. Three instrumented areas were installed to monitor the performance of the anode.

Installation of the GCP system also involves a series of quality assurance steps that include:

- Electrical continuity testing
- Surface preparation tests
- Recorded environmental conditions
- Anode thickness measurements
- Anode adhesion testing

The initial engineering and permitting processes required 18 months to complete. An additional 22 months were required to complete the 803 cubic feet of concrete repairs on the balconies, 304 cubic feet of concrete repairs in the garage, and to install the ICCP and GCP systems.

Crews successfully completed the work despite having to manage the challenges of working at heights during hurricane season and during the winter months with temperature sensitive materials. Successful scheduling and coordination between two contractors with sometimes seemingly conflicting priorities was the result of an ultimate understanding by all parties that the highest priorities were safety, quality of the finished product, and timeliness.

With repairs completed and the cathodic protection systems installed and continuing to be monitored, Dockside will have the desired service life extension to their building and parking structure with minimal maintenance and interruptions to their residents. Management at the complex had the foresight to recognize these investments as adding value to an already prized asset. Dockside continues to prioritize the safety of its residents and the preservation of the biggest amenity it provides – some of the best views of Charleston.

The durability of concrete structures is impacted by the corrosion of the reinforcing steel, especially in aggressive marine environments like Charleston. To optimize durability of any reinforced concrete structure, it is important to understand the mechanisms that initiate and contribute to the aging and deterioration. Identifying the root cause leads to best decisions and solution building for repairs, protection, and service life extension.