Historic Category

Bok Tower Restoration

Lake Wales, Florida

Submitted by Sika Corporation

Close-up of beautiful coquina brick on Bok Tower

Coquina brick and underlying masonry had separated from tower

The Historic Bok Sanctuary in Lake Wales, FL, is 40 miles south of Orlando. The 250-acre sanctuary consists of botanical gardens with hiking trails, an estate, and Bok Tower. Construction of the gardens started in 1921 as a vision of a wealthy editor from Philadelphia named Edward Bok and was completed in 1926. Bok Tower was constructed between 1927 and 1929 as the focal point of the sanctuary. The tower houses a 60-bell carillon (set of tuned bells in a tower played by a baton keyboard) and produces a glorious sound, similar to that experienced by Bok as a child in his native country of Holland.

The tower is 205 ft (62 m) tall, has seven floors, and is constructed of a masonry-encased steel frame. The Gothic revival architecture has three forms of masonry that adorn the elaborate exterior: coquina brick makes up the majority of the exterior, intricate marble detailing and sculptures clad the steel columns, and decorative tile panels accentuate the Anton Brees Carillon Library located on the 5th floor. A brick backup on the interior further encases the structural steel members and provides support for the exterior masonry.

On August 21, 1972, the tower was listed as a National Historic Landmark with the National Register of Historic Places.

Problems that Prompted Repair

Cracks developed in the coquina brick, largely in the areas of the spandrel beams. Furthermore, highly distressed areas showed signs of bowing or displacement from the beam and masonry backup. In some cases, the coquina brick had failed completely, creating a health and safety risk due to the danger of falling masonry.

Inspection/Evaluation Methods

Two site visits were performed by the engineer to explore the feasibility of application of an impressed current cathodic protection (ICCP) system for corrosion prevention of the mortar-encased steel structure. In January of 2006, several areas of the exterior and interior masonry and brick were removed to expose the steel for further inspection. Tests confirmed that the horizontal steel members of Bok Tower were indeed substantially in contact with the mortar. A small quantity of anodes were connected to a DC power supply and used to impress an electrical current through the mortar to the surface of the steel. Electrochemical potential measurements indicated that the electrical current was able to mitigate corrosion in the test areas. Finally, electrochemical potential measurements were taken in various areas to characterize the present state of corrosion.

Test Results

Once it was determined that the structure was fit for application of ICCP, a mockup tower section was constructed to help identify design specifics. The wall was broken up into a grid pattern, five columns across and five rows down. A number of potential measurements were taken at each section (A1, A2, etc.) of the wall while it was dry and again after being saturated

with water. Testing and theoretical considerations revealed that the anodes needed to be applied above and below each horizontal beam to apply an adequate current on all exposed surfaces.

Causes of Deterioration

Coquina brick is porous brick made of crushed seashells and similar material. Corrosion of horizontal structural steel members caused the coquina brick and underlying masonry to separate from the tower. The root cause of the corrosion was found to be ingress of moisture through the porous coquina brick and from openings in the top of the tower. In addition, there were cavities present, some of which were created by plastic sheeting that was installed behind the coquina brick during repairs completed in the 1970s. The cavities served as the primary sites for accelerated corrosion.

Repair System Selection

The primary areas of corrosion were the top plate on the horizontal beams and the intersection between the columns and beams. A secondary area was the full perimeter of the spandrel beams including the variable corrosion condition of the web and exposed flanges.

The engineer specified the following:

1. Remove the coquina brick and underlying masonry from in front of the horizontal beams and top plate;
2. Clean the structural steel surfaces, coat with a cementious coating, and encase with brick mortar;
3. Reinstall new coquina brick; and
4. Encase the areas behind the conquina brick at the corners of the towers with Type K mortar.

Because of the geometry of the tower and need to preserve the appearance of the exterior, a discrete anode system was chosen for the ICCP system. The discrete anode system allows for installation of the anodes from inside the tower, resulting in an easier installation and preservation of the decorative brick and marble exterior.

The ICCP system design consists of the following:

Anode System

- Provide sufficient current to ensure the even distribution of current discharge to the steel for the working life of at least 25 years.

Monitoring System

- Reference electrodes having a predicted accuracy of +10 mV for the electrode life expectancy of 25 years.

Control and Management System (Power, Control, and Monitoring)

- Capable of full remote control and operation; and
- Network all units to avoid excessive additional cabling to the building.

Main Control Unit (MCU)

- Read and set the operating parameters of each of the power, control, and monitoring units; process any alarms; and treat collected data for reporting purposes for a period of 25 years or more.

Control Software

- Capable of remotely controlling the ICCP system; accessing the main control unit; and collecting, analyzing, and reporting the data and changing password protection via the Internet in a secure environment.

Tower Repairs and Installation of ICCP System

The tower exterior consists of eight faces. The coquina brick removal and replacement was completed on seven of the eight faces in a previous phase between May 2004 and November 2004. This project involves removing and replacing the coquina brick at the last face (SE corner of the tower) and the installation of the entire ICCP system.

Site Preparation

Given the historic nature of the tower, site preparations were extensive and included the following:

- Bok Tower is surrounded by a moat and accessed via an ornate marble bridge. A temporary wooden bridge was built for the previous phase, disassembled, and rebuilt for this phase for construction access;
- The coquina masonry had no regular or symmetrical pattern. Each brick was field measured and photographed to manufacture replacement stone to exactly match the original in size and configuration;

Coguina brick replacement

Inserted anodes

- Wood framing and plywood was constructed to encapsulate and protect the ornate features of the tower (balconies, sculptures, elaborate detailing, and entrance);
- The tower, although not accessed by the public, remained open and completely in use throughout construction; and
- Project hours when construction activities were permitted were from 7:00 am to 6:00 pm Monday through Saturday. However, work activities were forbidden during the Carollian Harmonic schedule between 10:00 to 10:15 am, 1:00 to 1:30 pm, and 3:00 to 3:30 pm every day.

Surface Preparation

The stone was removed using air impact chisels and small grinders. Once the steel member was exposed, it was cleaned to bright metal. The steel member was then coated with a protective cementitious coating that was brushed on.

Application Method and Repair Process Execution

Areas behind the coquina brick at the corners of the tower and behind the columns were completely encased with a Type K mortar. The stone above and below the steel members was set in a full bed of mortar on the sides and back. The replacement stone was also reinstalled in this manner. For the 12 in. (305 mm) band within the flanges of the structural steel beams, the stone was completely filled with mortar and masonry. After the bed mortar set, the outer 3/4 in. (19 mm) of the stone work was pointed with a low-compressive-strength mortar matching the color of the existing pointing mortar.

ICCP System

Installation of the ICCP system proceeded up the building on a zone-by-zone basis. Zone 1 served as the mockup to confirm that the system, as designed and installed, was operating as expected. All zones were started up and achieved the required polarization well within the specified requirements on January 8, 2007.

The ICCP system is currently under a 1-year monitoring and maintenance contract through the cathodic protection contractor. At the end of that period, the owner will contract directly with the corrosion specialist for an extended monitoring and maintenance agreement.

Preserving History

Because of the significant protection requirements given the ornate characteristics of the tower and its National Landmark status, a team of specialists experienced in historic preservation and cathodic protection was used to ensure project success. Bok Tower has been repaired to the highest standards to ensure long-lasting, high-performing durability consistent with its prominent listing as a National Historic Landmark.

Mockup tower section

Fully repaired Bok Tower

Bok Tower

Owner
Bok Tower Gardens Foundation, Inc.
Lake Wales, Florida

Project Engineer/Designer
Matco Associates, Inc.
Pittsburgh, Pennsylvania

Repair Contractor
Vector Corrosion Technologies
Winnipeg, Manitoba, Canada

Material Supplier/Manufacturer
Sika Corporation
Lyndhurst, New Jersey

Project Partners
Corrosion Specialist
C-Probe Systems, Ltd.
Cheshire, England

General Contractor
Concept Enterprises, Inc.
Odessa, Florida

Architect
Renker Eich Parks Architects, Inc.
St. Petersburg, Florida