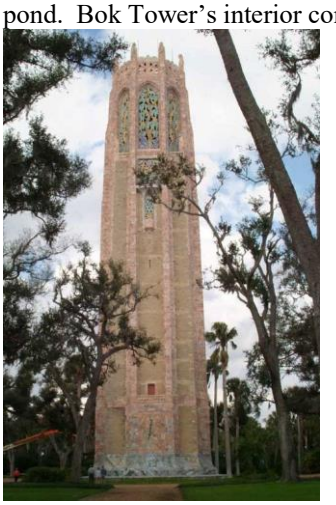
Case History: Bok Tower

Bok Tower is one of America's most unique and beautiful landmarks. The construction of the Bok Tower Historic Sanctuary in Lake Wales, Florida began in 1927 and was completed on February 1st, 1929. This historic building is the focal point of the sanctuary which houses one of the world's finest carillons. The tower is 15.5 meters square at the base, changing form at 45.7 meters high to an octagon some 11.3 meters on a side, with sculpture design by Lee Lawrie. It is surrounded by a 4.6 meter moat which serves as a lily pond. Bok Tower's interior contains the Anton Brees Carillon Library, said to be the largest carillon library in the world.



The case study provides a description of design requirements and installation procedures for an ICCP system for the Bok Tower. The Bok Tower, is a masonry-encased steel framed building with marble and coquina siding. The coquina brick used to cover most of the tower exterior is a porous brick made of crushed seashells and similar material. Corrosion of horizontal structural steel members caused the coquina brick façade and underlying masonry to separate from the tower. The root cause of 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 a previous repair. The cavities served as the primary sites for accelerated corrosion. During recent repairs, the coquina brick and underlying masonry was removed from the front of the horizontal beams and top plate (which is connected to the horizontal beam and supports the coquina brick). The structural steel surfaces were cleaned, coated with a cementious coating, and encased with brick and mortar. New coquina brick was then fitted to the outside. Furthermore, the areas behind the coquina brick at the corners of the tower were completely encased with ASTM C 270 Type K mortar.

Two onsite visits in the winter of 2006 were performed to in order to explore the feasibility of application of an ICCP system for corrosion prevention of the mortar-encased steel structure. The on-site investigation identified several areas of tower composite wall that may contain voids and empty spaces due to shrinkage of the mortar. Comparative potential measurements between the surface of the coquina façade and encasing mortar (exposed by removal of the façade) confirmed these observations. Application of temporary titanium anodes and impressed current provided adequate cathodic protection for the masonry-encased steel, indicating cathodic protection is indeed applicable for this situation; provided that the coquina façade is bypassed as it did not serve as a continuous electrolytic path for cathodic protection.

Bok Tower is situated in a moderately corrosive environment. It was found through testing that the steel beams are not actively corroding, likely because of the recent repairs. The masonry was found to be of adequate quality for application of cathodic protection, and the environment is moderately aggressive in that the beams are constantly exposed to moisture and a fresh supply of oxygen. All encased steel members are assumed to be electrically continuous according to schematics and observations. And finally the steel surface area and total electrical current required to cathodically protect those surfaces was calculated based on onsite and in-house testing. These requirements are discussed below.

Problematic areas on Bok Tower were identified and an ICCP system was designed in order to protect those areas. The primary areas of concern were identified as the top plate on the horizontal beams and the intersection between the vertical and horizontal beams. Other areas of concern were the web and flange area of the horizontal beams that faced outward as well as the bottom surface of the horizontal beams.

Because of the geometry of the tower and need to preserve the appearance of the exterior, a discrete anode system was designed for the ICCP system, using 11 discrete zones. Use of multiple zones allows for application of different amounts of cathodic protection as needed by each zone. Other systems employ the use of ribbon, wire mesh, or coating anodes. These methods are more invasive and found to not be appropriate for use on Bok Tower. The discrete anode system will allow for installation of anodes from inside the tower. This will allow for easier installation and preservation of the decorative brick and marble exterior.

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. This array allows for the target areas of steel to exhibit the 100 mV potential shift required for cathodic protection. The design criteria for the Bok Tower cathodic protection system are provided as follows.

- The approximate steel surface area to be fully protected to the 100 mV potential shift criteria is 143 m^2.
- Approximate steel surface to receive cathodic protection for partial corrosion mitigation is 424 m^2.
- The maximum required current density under worst case operating conditions is 10.8 mA/m^2.
- The required current density for normal operating conditions is 2.7 mA/m^2.
- The total number of discrete anodes required is 880.
- The total number of reference electrodes required is 43.

As the bell room at the top of the Bok Tower includes openly exposed structural steel, a SACP system employing thermal spray metallizing was selected for this location.