Case History: Utah State Capitol Building

The 90 year old Utah State Capitol Building in Salt Lake City, Utah, underwent renovation and seismic upgrade in order to extend its life by another century. It is located at the top of State Street and overlooks the Salt Lake Valley. Construction on this great and beautiful building began on December 26th, 1912, and the building was dedicated on October 9th, 1916. The building is 123 meters long, 73 meters wide, and 87 meters from the base of the building to the top of the dome.

Built before seismic-resistant engineering and building codes existed, the Utah State Capitol Building has successfully withstood the loadings over the past 90 years without signs of major structural failure. However, corrosion of steel reinforcement has been taking place and required attention.

Concrete serves as a base for terra cotta panels. Spalling, corrosion, efflorescence, and other problems are occurring in the steel reinforced concrete in interior portions of the dome, which is shrouded with an exterior copper roof. As a first step in the selection and specification of a cathodic protection method to be employed in the dome renovation, an on-site corrosion survey and audit of the interior of the dome was conducted. Electrical potential measurements showed the active corrosion of the rebar in many locations. However, continuity testing for the rebar was positive, meaning that a cathodic protection system is viable for this structure. The on-site investigation and preliminary laboratory evaluation revealed that visible internal cracking and steel reinforcement core (rebar) corrosion starts at a level just below where the external copper roof ends.

After the optimum cathodic protection technique and current for the dome renovation was identified, work was then undertaken to develop and establish the specifications for its installation and operation. Provisions were made for a reference electrode system to monitor corrosion.

Before determination of the cause can be made for the deterioration and corrosion of the concrete/steel reinforcement, laboratory petrographic analysis of a sample retrieved on-site was required. Petrographic analysis of concrete cores showed the concrete to be of poor quality as a result of low alkalinity (carbonation), and a high water/cement ratio which resulted in a low compressive strength. The high water/cement ratio also produces a very porous concrete. The high alkalinity normally associated with concrete protects embedded steel from corrosion. However the potential for corrosion of embedded rebar will increase in the presence of low alkalinity, chloride ions and moisture. Chloride ions were found by energy dispersive x-ray (EDS) analysis in the corrosion products collected on site.

It should be noted that some of the submitted core samples exhibited more than 50% loss of thickness of rebar. It was found that cathodic protection would stop further corrosion. However, it would not compensate for load bearing of corroded rebar. Stress calculations needed to be performed to ensure the structural integrity of the reinforced concrete after repairs.

In the second phase of this project, electrochemical studies were performed on the dome concrete and steel reinforcement cores to identify the most suitable cathodic protection technique for corrosion control of the renovated dome. These studies also aided in the determination of current requirements.

Electrochemical laboratory tests were specifically designed to simulate the effect of the practical application of titanium mesh and zinc spray metallized coating as anodes to the renovated (concrete added) inner surface of the Utah state capitol dome. On this basis of lower required current densities, as well as the anticipated greater service lifetime of titanium mesh (40 years) versus zinc metallized coating (10 – 15 years), titanium mesh was selected as the anode for cathodic protection of the renovated Utah state capitol building dome.

Based on discussions with the lead engineering firm on the project, the following characteristics of the Utah state capitol building dome concrete were determined for the purpose of specification of the titanium anode mesh cathodic protection system to be installed.

- Estimates of the minimum and maximum distances of the rebar from the inner surface of the concrete dome.
- Additional concrete thickness added to the dome inner surface for the rehabilitation, and the distance of the rebar from this rehabilitated dome inner surface.
- Overall surface area of interior concrete, and surface area of interior concrete with severe deterioration.
- Surface area of rebar in the existing and rehabilitated concrete dome.

The request was to provide cathodic protection on an area totaling 286 m^2, and with use of titanium mesh anodes, a corrected minimum anode current, taking into account contact of steel structural members with concrete, as well as rebar, the total minimum required current was approximately 10 A.

Some guidelines were presented for construction and installation of the cathodic protection system, including the following topics.

- Repair of the damaged concrete in the dome.
- Additional petrographic analysis of the dome concrete.
- On-site testing to verify current requirements.
- On-site testing for verification of the existence of electrical continuity in the steel-bar network in the existing dome structure and in the concrete addition.

- On-site testing to verify discontinuity of rebar with other foreign metallic structures in the dome, including copper roofing itself.On-site testing to conduct potential mapping to identify corrosion “hot spots.”
- Installation of reference cells in each section.
- Installation of a predestinated activated titanium mesh in each section.
- Bonding of all sections of the mesh.
- Placement of the concrete overlay.
- Completion of the system electrical wiring.
- Rectifier quantity and placement.
- Start-up of the CP system.
- Post start-up and operation monitoring.

The specification covered distributed titanium mesh anodes which are placed on a blasted, cleaned surface and then covered with a concrete overlay. It was determined that NACE Standard RP0290-2000, “Standard Recommended Practice: Impressed Current Cathodic Protection of Reinforcing Steel in Atmospherically Exposed Concrete Structures,” should be followed at all times.

The approved anode system was a titanium mesh anode system. Titanium mesh anodes systems consist of expanded titanium mesh coated with a precious metal oxide catalyst which is fastened to a prepared surface and overlaid with concrete to provide a new riding surface. These systems are designed and installed such that the average current density at the surface of the anode does not exceed 110 mA/m^2.

The titanium mesh anode recommended may be either one of two types: an anode with a current rating of 24 mA/m^2, or an anode with a current rating of 40 mA/m^2.

Several material, construction and installation related specifications were covered. Some important points that should be noted are as follows.

- All wiring must be done in conformance with the latest version of the proper electrical codes.
- Titanium mesh anode must not contact any existing steel structure, rebar, or anchors.
- Titanium mesh is divided into four independent anode units, or electrical zones, employing one rectifier with four terminals. The rectifier should be autopotential and IR compensated. A minimum of eight reference electrodes should be employed, with a minimum of two reference electrodes per zone.
- Titanium ribbons should be welded to mesh in vertical and horizontal directions; then lead to titanium wire should be connected to the positive terminal of the rectifier.
- Prior to installation, on-site testing must be performed to verify theoretical calculations and to confirm discontinuity between the rebar and the copper roof and other steel structural members.
- Consideration should also be given to perform petrographic analysis on other parts of the dome to test the integrity of the concrete and make sure these sections do not exhibit carbonation or accelerated corrosion of the rebar.