Special Projects Category

Earth-Covered Magazine Protection Using Electro-Osmotic Pulse Technology

Fort A.P. Hill, Virginia

Submitted by Electro Tech CP

Typical steel arch earth-covered magazine (ECM)

The magazines in which electro-osmotic pulse (EOP) systems were installed are steel-arch, earth-covered structures constructed in the 1950s. The magazines consist of a reinforced concrete floor with reinforced concrete head walls at each end. The side walls and ceiling consist of a reinforced knee wall approximately 15 in. (380 mm) high with a galvanized corrugated steel-panel arch bolted on top and at various points into the head walls. EOP systems were installed in 11 magazines of two different sizes: two were 11 x 30 ft (3.3 x 9.1 m) and the remaining nine were 24 x 50 ft (7.3 x 15.2 m).

PROBLEMS THAT PROMPTED REPAIR

Because of failures of the waterproofing membranes and french drains at Fort A.P. Hill, VA, large amounts of water were seeping through the concrete walls, floors, wall/ceiling joints, and ceiling panel joints of the earth-covered ammunition storage magazines. During periods of high rainfall, standing water inside some of these ammunition bunkers reached a depth of 1.5 in. (38 mm). The earth-covered magazines (ECMs) are used for storage of a wide variety of explosive ordnance, from small arms to artillery rounds, as well as fuses, shaped charges, hand grenades, and pyrotechnics. Water intrusion through the structure not only corrodes ammunition and equipment stored inside the magazines but also can corrode the reinforcement steel embedded in the concrete floors and walls. Additionally, the propagation of mold and bacteria in these confined spaces causes respiratory distress (for example, allergies and asthma) for Army personnel and contractors working inside the bunkers.

If standing water in the ECMs freezes, the concrete structures can crack and become severely degraded due to freezing-and-thawing cycles, further exposing the reinforcement steel to corrosive conditions and creating additional avenues for water entry. The frozen water on the ECM floor is also a safety hazard for forklift operators, and it seriously delays or prevents the delivery of munitions for troop training.

The conventional method for preventing water intrusion is to remove the earth cover, replace the waterproofing membrane on the magazine, repair or replace the drainage tile system around the affected area, and then replace the earth cover. This process is expensive, labor intensive, and time consuming. It disrupts facility operations to an unacceptable degree and has a high probability of failure once completed. It also fails to address the difficult problem of water intrusion through the bunker floor.

INSPECTION/EVALUATION METHODS

A scale model of an ECM was constructed. The model had an EOP system installed in it similar to the planned design for the full-scale magazines. The model, which included the ECM lightning protection and grounding systems, was buried in a laboratory test bed using a sandy clay backfill. The backfill was kept damp during the testing period.

TEST RESULTS

Laboratory tests were done first, and then the results were confirmed with field testing, with the following results:

- Sparking potential: The electrical field produced by an EOP system in an ECM will not induce potential conditions for a spark to occur between materials stored inside the structure or between the materials and the ECM;
- Generation of hydrogen gas: The electrical field produced by an EOP in an ECM will not generate hydrogen gas at the steel reinforcing in the concrete;
- Stray current corrosion potential: The EOP process will not cause stray current corrosion when a large percentage of cathodic current is directed to the reinforcing steel;
- Concrete drying: The electrical field produced by an EOP in an ECM prevented water from entering the ECM through the concrete. EOP maintains a fairly uniform moisture level throughout the concrete thickness between 20 and 40% relative humidity. If moisture enters the structure, EOP prevents it from reaching the interior surface;
- Relative humidity: EOP only minimally affects the relative humidity of the air inside the ECM. If there is standing water inside the ECM, however, the EOP system will speed dry and reduce much of the moisture from entering the air and increasing the humidity;
- Cathodic protection: A properly installed EOP system will protect the reinforcing steel from stray current corrosion by providing an electric charge on the reinforcement and cathodically protecting it;
- Radio frequencies: The EOP system in an ECM does not produce radio frequencies that could affect stored ordnance; and

Laboratory model of ECM

Laboratory model of ECM covered and saturated

Reference electrodes set up for stray current testing

- Electromagnetic radiation: The EOP system operating with typical current pulses ≤1A does not produce magnetic field transients that would pose a threat to ordnance. Furthermore, with linear extrapolation to the maximum 3A operating level of the system, a factor of three increase in the EOP-generated magnetic field strength would still be safe.

SYSTEM INSTALLATION

The first step was to locate the reinforcing steel in the concrete to identify locations to tie into the reinforcing steel to protect it from stray current corrosion and prevent damaging it while cutting or chipping the slots to embed the anodes during the installation process. Crews then saw cut or chipped slots and grooves in the concrete for anode placement, and then holes were drilled for the cathodes. Next, holes were drilled for the reinforcing

EOP control unit

After system installation, ECM is saturated with water for testing

steel connections and the reinforcing steel. Wiring slots were cut in the concrete parallel to the anode slots to embed lead wires.

Mesh-style anodes were prepared beforehand by cutting them to a predetermined length and exothermically welding a titanium wire connector. These prepared anodes were placed in the prepared slots according to the EOP design. The lead wires were connected to the anode and the connection was sealed using heat-shrink tubing. The anodes were tested for shorts onto the reinforcing steel. Where shorts occurred, the anode was wrapped with electrical tape on each side of the short location. The lead wires were attached to each anode segment and the anodes were grouted into place with cementitious grout.

The cathodes are standard 8 ft (2.4 m) long copper clad steel grounding rods. The top 3 ft (0.9 m) of the cathodes were wrapped using electrical tape and driven through the prepared holes into the soil outside the structure so the top 0.5 in. (12.7 mm) of the rod was above the bottom of the core cut. The bottom of the drilled hole was then packed with oakum. The lead wire was attached to the cathode using an exothermic weld. The top of the cathode and the lead wire connection was embedded in epoxy. Once the epoxy was cured, the hole was filled with the same cementitious grout used to grout in the anodes. Then, a hole was drilled through the exposed reinforcing and the hole was threaded using a threading tap. A standard round wire connector was attached to the lead wire and attached to the reinforcing steel using a screw. The reinforcing steel was embedded in epoxy; and once it had cured, the hole was filled using cementitious grout. A hole was drilled at the floor level through the head wall to pass the lead wires out of the magazine. The lead wires were placed in the prepared slots and fed through the hole to the exterior of the magazine. The lead wires were then embedded in the concrete using the nonshrink cementitious grout.

A connector/distribution box with bus connectors was mounted on the exterior of the front end wall. The lead wires were fed through polyvinyl chloride (PVC) conduit from the head wall hole in the magazine to the connector box. The central EOP controller was installed centered between the 11 magazines. The control unit was mounted to a frame and power was provided through underground conduit. The control unit is designed to convert the incoming AC power to the pulsed direct current and distribute it to each magazine. To test the EOP installation and ensure that all of the water leaks were addressed, water was sprayed on top of the magazines at a rate of 750 gal./min (2840 L/min) for 30 minutes. This thoroughly saturated the soil cover. Leaks were located and then injected using a hydrophilic urethane material.

SPECIAL FEATURES

For this sensitive location, extraordinary safety and corrosion testing was used to qualify the new technology as the most cost-effective method for stopping water intrusion in these unique concrete structures. It provided a repair for which no other technology could effectively compete and would provide the desired result for the owner. It is a repair that will last the life of the structure.

Earth-Covered Magazine

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