PROTECTING PARKING GARAGES WITH ELEVATED CHLORIDE LEVELS USING SURFACE APPLIED CORROSION INHIBITORS

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Parking garages (Fig. 1) are exposed to many harsh environments. Whether in the form of deicing salts used during wintertime, or airborne salt from seawater in coastal environments, these two sources of chlorides can make for one of the harshest environments a parking garage has to endure. According to a United States Geological Survey (USGS), of the 43 million tons (39 billion kilograms) of salt produced in the U.S., roughly 19 million tons (17.2 billion kilograms) are used for deicing purposes[1]. In addition to direct use of chlorides for deicing purposes, vehicles also track additional chlorides from the roads on which they were driving into garages.

Fig. 1: Typical parking garage

In parking garages, chlorides will build up at the concrete surface and migrate into the concrete over time. As chloride ion concentration increases in concrete, elevated chloride levels increase the potential for embedded steel reinforcement to experience corrosion. The threshold level at which reinforcing steel is susceptible to corrosion is commonly defined as 1.2 to 1.5 lbs/cy (0.7 to 0.9 kg/m^3)[2]. The migration of chloride ions into concrete, and time to corrosion initiation, depends on several factors including, but not limited to, quality of concrete, concrete cover over reinforcing steel and amount of chloride exposure (chloride level).

Following corrosion initiation and propagation, concrete cracks, delaminations, and concrete spalls can occur (Fig. 2) and need to be repaired. Improperly addressing these issues in a timely manner could have potential long-term consequences. Garage collapse can occur in severe cases of concrete deterioration (Fig. 3).

Garage repairs cost an owner on two fronts. First, the actual repair cost, and second through lost revenue due to closure. There is no absolute cost associated with the inconvenience and disruption to tenants; however, potential customers could utilize other facilities, thus creating an indirect cost to the owner in lost profits.

When a repair is necessary, it is always recommended that codes, specifications, and guidelines published by the American Concrete Institute (ACI) and International Concrete Repair Institute (ICRI) be followed; although this step does not guarantee a successful repair. Quality repair materials and workmanship are among several factors affecting longevity of repairs. Traditional techniques used to repair concrete spalls and delaminations may only address symptoms of the real problem. Many patch repairs have been found to last only a few months to a year before the appearance of new corrosion damage. If no further action is taken once the repair is completed, corrosion can continue to propagate, especially along the perimeter of the repair area due to a phenomenon called Incipient Anode or Ring Anode effect.[3]

Several methods and products are commercially available to mitigate the accelerated corrosion caused by incipient anodes. They include, but are not limited to, admixed corrosion inhibitors, corrosion resistant reinforcing steel, sacrificial or impressed cathodic protection, and coatings. A cost-effective alternative to these products is also available which has been shown to significantly extend the time between repair cycles on reinforced concrete structures containing elevated chloride levels.

Laboratory and field testing has shown that surface applied corrosion inhibitors (SACIs) can be effective at reducing corrosion rates. Berke, et al., showed that in environments containing up to 10 lbs/cy (5.9 kg/m^3) of chlorides at steel depth, the SACI was able to reduce corrosion rates, thus providing a cost benefit to using the product compared to untreated reinforced concrete.[4] In same study, a Net Present Value (NPV) analysis based on results from a 5-year lab study showed that a significant savings could be achieved over a 10-year period (Fig. 4). The cost benefit to using SACI was realized in less than 5 years. NPV calculation based on a parking garage with 100,000 sf (9290 m^2) total area and repair costs assumed to be \$35/sf (0.1 m^2) or \$50/sf (0.1 m^2).

Fig. 2: Spalled concrete due to corrosion of reinforcing steel

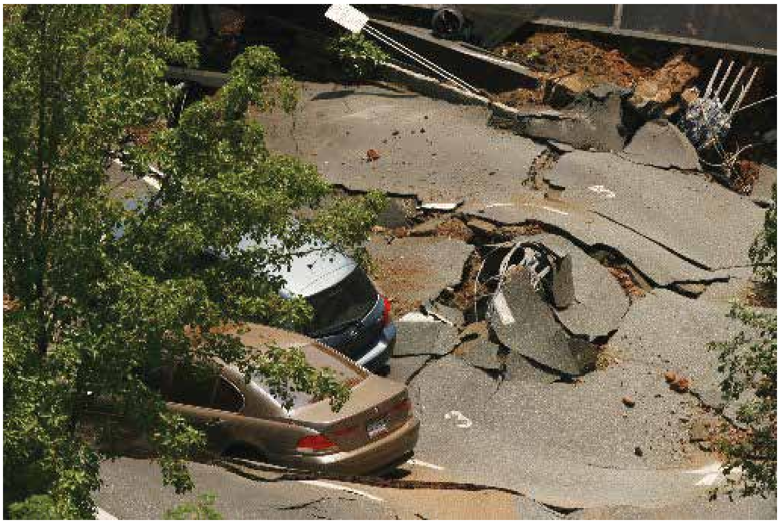

Fig. 3: Garage collapse due to reduced structural capacity

EXISTING STRUCTURE CASE STUDY

The municipal parking garage for East Stroudsburg, Pennsylvania was found to have greater than 10% floor slab surface area containing delaminations and/or concrete spalling in 1996. Following a repair program, SACI was applied to all horizontal floor surfaces of the garage. Non-destructive corrosion monitoring was conducted annually using Linear Polarization Resistance. Field monitoring showed that corrosion rates declined after treatment with the SACI, and no significant increase in corrosion activity was observed for 11 years (Fig. 5)[5]. Repair cycles for the garage averaged every 5 to 7 years prior to incorporating a SACI into their repair protocol. A condition survey conducted 10 years after treatment with SACI revealed less than 1% floor slab surface delaminations and no concrete spalls. SACI treatment resulted in a significant reduction in overall maintenance costs to the owner over 10 years.

NEW CONSTRUCTION

In addition to increasing time between repair cycles for existing parking garages, SACIs have also been shown to increase time to the first repair required in new structures. When applied to new parking garages, service life modeling shows that one can achieve greater than 50 years until corrosion initiation with 2 in (50 mm) of concrete cover over reinforcing steel when compared to less than 15 years if a treatment is not applied[6]. In this study by Berke, et al., conducted on new reinforced concrete slabs, the SACI treatment did not show any signs of active corrosion after 2 years of cyclic salt (chloride) ponding. Conversely, untreated slabs showed extensive corrosion activity resulting in cracking of the slabs in multiple locations. Unlike the previously mentioned study by Berke, there were no admixed chlorides in the concrete mix. The chlorides were introduced only via ponding with 15% sodium chloride solution in water.

CONCLUSION

To achieve maximum service life designs for garages, it is recommended that a preventative maintenance plan utilizing annual or semi-annual inspections be conducted in accordance with ACI 362.2R[7]. Simple tasks, such as yearly wash downs to remove salt, or visual inspections to identify and address unforeseen problems such as crack development, can help achieve full design service life and increase time to major repairs.

By the time visual inspections reveal damage in a parking garage, corrosion activity has most likely been occurring for several years. When designing a preventative maintenance or repair strategy for parking garages exposed to harsh environments as a result of elevated chlorides, SACIs can be considered for corrosion mitigation. It is recommended that a licensed design professional (LDP) be consulted to determine what repair materials and methods best fit the long-term goals of the owner or occupant of a building. Sustainable long-term repair performance can be achieved using surface applied corrosion inhibitors.

Treatment	Initial Costs	NPV Repair 5 Years	NPV Repair 10 Years	Total NPV
Not Treated \$35/sf ($0.1m^2$) Repair costs (\$350,000 for 10% of Surface Area)	0	\$288,000	\$237,000	\$525,000
Not Treated \$50/sf ($0.1m^2$) Repair costs (\$500,000 for 10% of Surface Area)	0	\$411,000	\$338,000	\$749,000
SACI	\$150,000	0	0	\$150,000

Fig. 4: Net Present Value (NPV) Analysis

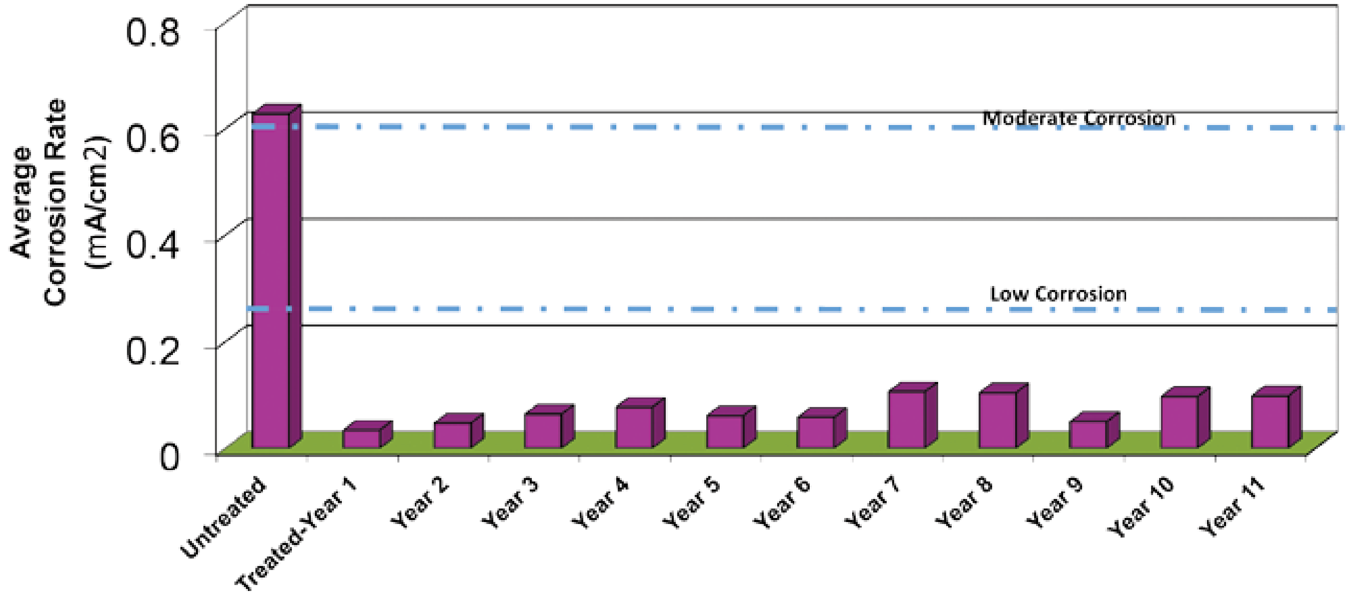

Fig. 5: Corrosion monitoring on municipal parking garage in East Stroudsburg, PA

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