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Practice Points NUMBER 13

Data Interpretation and Early Corrosion Test Program for Historic Concrete Buildings

GINA CREVELLO

Introduction

Reinforced concrete is ubiquitous and has become an esteemed part of nineteenth- and twentieth-century built heritage. Historically, concrete provided revolutionary solutions to many construction challenges, while today it has become a restoration and repair enigma to many practitioners in the field of preservation and restoration. The diagnostics and evaluation of existing concrete is a much-studied field, as the concrete-repair industry reaches $18 to 21 billion per annum in the United States alone.[1] It is estimated that $8.3 billion of this amount is spent on the repair of reinforced-concrete corrosion failures.[2] Additionally, understanding the deterioration and condition of existing concrete is vital, as 50 percent or more of all concrete repairs are estimated to fail within 10 years.[3]

There are multiple mechanisms of failure that contribute to the deterioration of concrete structures. Corrosion of the reinforcing steel is arguably the most detrimental deterioration mechanism affecting concrete. The symbiotic relationship between the concrete and the steel ensures that if defects exist within the original design or material selection and if load factors that enhance corrosion are present, deterioration will ensue. The corrosion process for embedded steel is well established and can be defined as three distinct phases: initiation, propagation and deterioration. The initiation phase is the time taken for conditions within the concrete to become conducive to corrosion, such as a drop in pH or chloride ingress. The propagation phase is the period in which the accumulation of corrosion will lead to the onset of damage. Deterioration is the accelerated corrosion of the steel reinforcement ultimately leads to rust staining, cracking, and spalling of the cover concrete.[4] The deterioration stage of corrosion behavior is exponential in nature and increases with time.

With advances in nondestructive equipment and an understanding of the material durability of concrete, one can determine corrosion risk, corrosion-rate activity, and projected time frames until corrosion-related failures. Established coefficients and scientific laws for diffusion, metal loss, and critical section loss can be used in durability and service-life models to predict when the structure may see failures ranging from microcracking to obsolescence. This methodology approaches deterioration in a holistic manner, addressing all factors that affect concrete corrosion and durability. This approach can be very insightful when assessing historic concrete buildings where the original material and the structure itself are a cohesive unit (Figs. 1 through 3).

Fig. 1.
College center building, Santa Barbara, California, c. 1960, west elevation, 2010. Typical conditions encountered when assessing historic concrete building, including corrosion at the bases of the columns. All images by the author, unless otherwise noted.

Evaluation Approach

When a building is being evaluated for corrosion, there are many methods that can be used to test various conditions that can determine corrosion behavior, as well as conditions that accelerate corro-

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Fig. 2.
College center building, west elevation. Detail of corrosion-related deterioration at column bases.

Fig. 3.
College center building, west elevation, detail of edge of balcony slab. The structure has relatively low concrete cover, and the subsequent corrosion of the steel has caused spalling and has exposed reinforcing steel.

sion activity. Test procedures are also dependent on construction materials, microclimates, external temperatures, and environmental factors. The team specifying the testing must understand all relevant factors that are at play on a structure prior to determining what and where to test.

To address corrosion at the most elementary level, a half-cell potential survey can yield insight into the probable condition of a reinforced-concrete structure. As outlined in ASTM C876-09, *Standard Test Method for Corrosion Potentials of Uncoated Reinforcing Steel in Concrete*, a half-cell potential survey provides the practitioner with a general assessment procedure for the probability of corrosion risk.[5] This method has been developed and employed for the evaluation of bridge decks and structures within an aggressive chloride environment. Thus, the established thresholds outlined within the standard can be misleading when tasked with assessing aged concrete buildings.

Test data from historic concrete buildings, whether early structures from the turn of the twentieth century or mid-twentieth-century icons, will most always fall outside of industry-established thresholds. Acceptable values for risk and deterioration for assessing concrete infrastructure and industrial structures are not suitable for the assessment of historic concrete buildings. The interpretation and integration of this data needs to be formulated by an experienced professional who can discern the irregularities between historic concrete buildings and aging infrastructure.

The key to avoiding the loss of materials and, more importantly, the loss of human life is to approach corrosion in a preventative manner and ensure that testing for corrosion is carried out early and interpreted correctly. To enhance a corrosion-testing program, a number of nondestructive techniques and methods are required. The data from an in-situ testing program must be correlated with a number of laboratory tests. The number and types of tests performed for an evaluation can vary based on structural components, age, aggregate, environments, etc.; therefore, a well-planned and well-developed testing program is required prior to site testing. As all construction materials have a limited service life, which is dictated by a multitude of conditions, the aim of the concrete-corrosion evaluation is to determine where the structure is within its service life and to provide the client with an estimation of the building's long-term behavior.

Nondestructive and Semi-Destructive Testing Procedures

When evaluating concrete buildings, the test procedures should be carried out and analyzed by a team of professionals fluent in material science, concrete chemistry, corrosion science, and structural or civil engineering. A common misstep in the analysis of such structures is the use of field technicians who are not fully capable of understanding the intricacies of the materials and what these may do to influence results. Additionally, if one does not have a full understanding of all test procedures and expected outcomes, then the interpretation of the results may prove to be erroneous or inconclusive.

The aim of test programs on existing structures is to provide a condition analysis, a risk analysis, whole-of-life-cycle management, short- and long-term maintenance plans, and risk mitigation from catastrophic failures. With reinforced-concrete structures, evidence of corrosion in the form of staining, cracking, and spalling will most often occur prior to structural failures. For historic and landmark concrete buildings, minimizing even the smallest of levels of deterioration is paramount to preserving and maintaining the integrity of the building. While it is anticipated and accepted that concrete will crack, if the architecture and engineering team can anticipate more drastic behaviors, then a proactive approach to maintenance and conservation can be developed.

A holistic building survey with durability modelling should be planned to understand the performance and service-life requirements of the concrete. Prior to the in-situ testing, a condition survey should be carried out in accordance with an accepted standard,

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such as NACE SP0308.[6] This standard outlines scope, influencing factors, methodology, and procedures for a visual inspection, testing techniques, required equipment, and presentation of data. Although this standard mentions some limitations in testing, it does not provide an interpretation of results, nor does it mention anomalies encountered on historic concrete.

There is an extensive number of test procedures that require a very well-trained individual or team who understands the various test methods available and the various types of equipment needed for these testing programs. Those conducting the tests must also be able to understand the data of the test methods independently and be able to provide the holistic interpretation of the results when multiple test methods are used.

Generally, concrete structures of significance, such as privately owned or government-owned landmark buildings, have the means to have condition and risk assessments carried out. The second- or third-tier concrete building may not have the same amount of funding available. Whatever the financial case may be, by carrying out a test program early in the building's life cycle prior to significant deterioration, the corrosion professional can provide the client with a list of the structure's high-risk areas, near- and long-term treatment plans, and assessments for the best treatment options based on information gained through the early testing.

Most often a team of professionals is headed up by the lead firm on a rehabilitation project, with different companies carrying out various elements of the testing. Coordination of all tests results (if not carried out by the corrosion professional) must be provided to the corrosion professional, who can then interpret the corrosion condition, life expectancy, and impacts of the conditions on concrete durability for the design team. It is vital that there is not a misinterpretation of results when assessing historic concrete, as this could affect the understanding of the corrosion condition of the structure and, hence, long-term behavior.

Misperceptions in Data When Performing a Corrosion-Test Program

The most commonly misidentified results of testing historic concretes come from performing half-cell potential testing without linear-polarization resistance and then misunderstanding the effect of carbonation on the test data. Two key elements in potential mapping that are often misinterpreted are highly saturated concretes with high (more negative) potentials (i.e., -550mV) and those with low potentials caused by a carbonation front (i.e., +150mV). A highly resistive carbonation front also affects resistivity values, which is key to understanding how current will flow within the concrete matrix. Similarly, the depth of the carbonation front can be misidentified, depending upon which reagent is being used for the test. Carbonation can influence rebar up to 5mm beyond the identified carbonation front.[7]

Half-cell potential. ASTM C876 provides a general guide for half-cell potential mapping with a copper/copper sulfate electrode. The standard established the risk of corrosion activity based on the readings obtained from the half-cell testing. Tables 1 and 2 provide the risk matrix based on ASTM thresholds for a half-cell potential survey. The potential ranges presented within this standard are probable indicators of corrosion activity, with -350mV being 90 percent probable of occurring corrosion activity. A practitioner utilizing this standard would also assume that all readings less negative than -150mV have a 10% probable risk of corrosion. It is noted in the specification that variances of 150mV are indicative of high corrosion activity and that locations of corroding steel are more reliably obtained through comparisons of potential gradients on the half-cell-potential map versus the actual stated requirements by the ASTM standards.[8] The interpretation of the standard was devised from salt-induced corrosion of cast-in-place bridge decks.[9] For this reason, the variation in potentials, the types of concrete and existing conditions must be addressed.

In the presence of carbonated concrete and complex concrete matrixes, etc., the potentials obtained through half-cell testing may not be indicative of the true corrosion condition and, if compared to ASTM C876, may be very misleading. Carbonation, which primarily affects historic and aged concrete buildings, has the ability to make the potentials read more positive; thus, the entire surface area mapped could be in the +100mV to -150mV range. To attempt more accurate results, the surface could require wetting.[10] The results could be interpreted as a structure having little to no corrosion activity, thus presuming that the concrete is in good condition. It has been long established that a delta of ±25mV is indicative of corrosion activity.[11] Therefore, if all readings from a historic building are in the range of +100mV to -150mV, indicative of low risk in accordance with ASTM C876, with potential gradients greater than ±25mV, it should be assumed corrosion is actively occurring on the structure.

In highly saturated concretes, the readings can range between -350mV to -550mV or greater, as seen in marine structures or on structures where water ponding is constant. These results would indicate that the entire structure is at a high risk for corrosion activity. If no probe openings are made to expose the steel in question, the worst could be assumed, with unnecessary repair schemes being designed and implemented. Higher potentials could be an effect of limited oxygen at the steel surface, since oxygen diffusion is

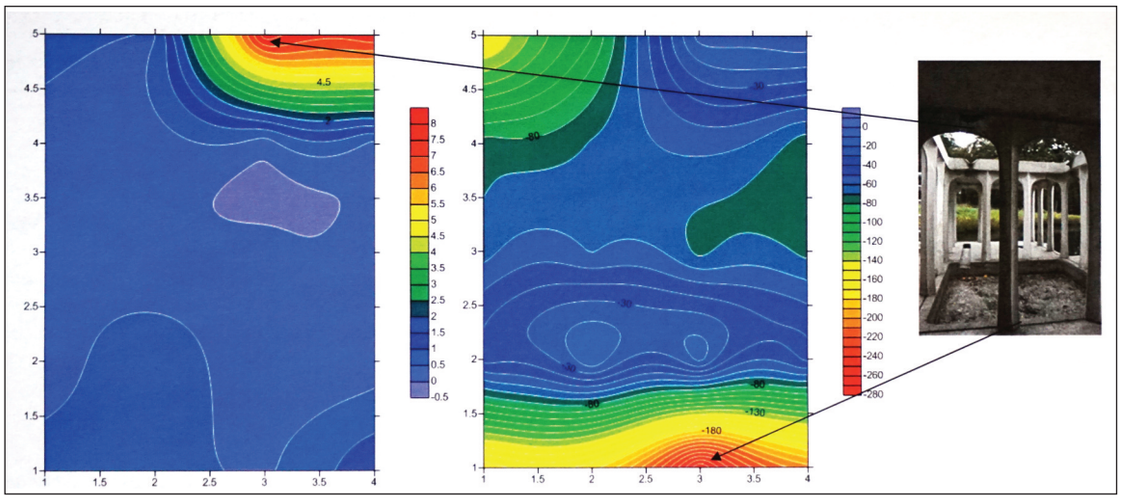

Fig. 4.
Pre-cast concrete structure, c. 1960. The electrochemical test program is represented with contour maps illustrating corrosion rate (left) and corrosion potential (right). The most negative potentials indicating highest risk do not correlate with the highest corrosion-rate activity.

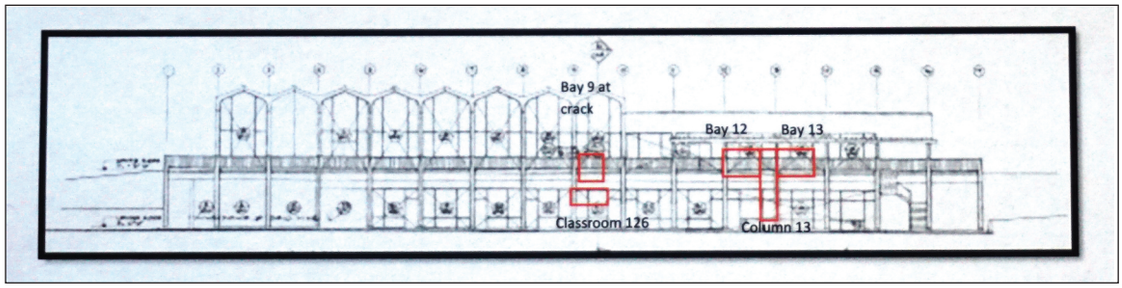

Fig. 5.
College center building, west elevation, areas of electrochemical testing outlined in red.

limited due to the submerged status of the reinforced concrete.[12] As long as there is not a high variance in potential-to-potential readings, actual corrosion activity could be very low.

Tables 3 and 4 illustrate data from the author's testing programs. It can be seen that aged concrete buildings that have not been left derelict have half-cell potentials that all fall within the <-150mV category of 10 percent risk in accordance with ASTM C876. In all instances, the areas tested had corrosion activity. This status was confirmed by potential gradients, linear-polarization resistance, and visual observation.

Corrosion-rate testing. Linear-polarization resistance, or corrosion-rate testing, allows for actual corrosion activity to be plotted in the same test locations as the data of the potential measurements. It has been determined by corrosion scientists and engineers in the field that the linear-polarization testing or "the corrosion rate is the nearest the engineer will get with currently available technology to measuring the rate of corrosion, including electrical impedance and electrochemical noise."[13] Though this is a tried method of determining deterioration activity, there are key elements that can influence readings. The data provided through linear-polarization resistance is the penetration rate of the corrosion activity based on corrosion current.

Corrosion rates are particularly influenced by environmental conditions on a daily basis. Temperature, moisture, and the internal RH of the building will influence corrosion behavior. "The rate of the oxidation reaction is affected by the amount of heat energy available to drive the reaction."[14] Readings taken on a hot, humid day will differ from readings taken at the same spot during milder times of the year. It is essential that the field engineer understands this phenomenon, so that if readings are taken at climatic extremes in regions where temperatures fluctuate throughout the year, the actual reading can be identified as being extremely high or comparatively low to projected activity.

As an example, the author conducted testing on one structure in the fall, with temperatures ranging in the mid-40s°F. Moderate corrosion rates were identified. Additional testing was carried out on the same structure when temperatures were in the high 30s°F, and little to no corrosion activity was identified. Upon opening the structure, it was evident that corrosion was present, just not active at the time of testing.

Relative humidity (RH) in the concrete matrix and heavily saturated structures can produce potentials more negative than -500mV. As the structure becomes saturated with H_2O at levels greater than 95% RH, the corrosion reaction slows, due to oxygen starvation even in the presence of chlorides. Though corrosion may be low during saturation, once the structure begins to dry, there can be a temporary increase in corrosion activity as oxygen is reintroduced into the matrix. Until the concrete is fully dry, corrosion rates can increase from the saturated state.[15] These conditions

Table 1. Probability of Corrosion Based on Potential with Regard to Copper/Copper Sulfate Electrode

Corrosion Potential (mV vs. $Cu/CuSO_4$)	Probability of Corrosion
>-200	<10 %
-200 to -350	Uncertain
<-0.350	>90 %

Table 2. Probability of Corrosion Based on Potential with Regard to Silver/Silver Chloride Electrode

Corrosion Potential (mV vs. Ag/AgCl)	Probability of Corrosion
>-150	<10 %
-150 to -250	Uncertain
<-250	>90 %

Table 3. Data from Testing Programs of Potential (mV) with Regard to Ag/AgCl

Structure Type, Age, Exposure	Concrete Dock with Chloride Contamination 1964	Concrete Walkway with Chloride Contamination 1964	Pre-Cast Concrete Structure 1964, Exterior	Concrete Building 1973 Exterior	Potention mV with regard to Ag/AgCl	Probability of Corrosion
Potential (mV) with regard to Ag/AgCl						
Minimum	+75	+95	+1	+299	>-150	<10 %
Maximum	-710	-544	-282	-141	-150 to -250	Uncertain
Average	-182	-280	-85	+206	<-250	>90 %

Table 4. Data from Testing Programs of Potential (mV) with Regard to Ag/AgCl

Structure Type, Age, Exposure	Concrete Building, 1911 Ground floor, Interior, Derelict	Concrete Building, 1911, Fifth-floor Slabs, Interior, Derelict	Concrete Building, 1911, Roof Slabs, Interior, Derelict	Concrete Building, 1960s, Columns Slabs, Exterior	Concrete Building, 1940s, Twelfth Floor, Interior	Concrete Building, 1940s, Fourth Floor Precast Wall Panel, Exterior
Potential (mV) with regard to Ag/AgCl						
Minimum	+17	+27	+290	+138	+122	-18.5
Maximum	-532.0	-654	-643	-281	-194	-279.0
Average	-192.1	-390	-189	+8	+48	-136.6

should warn the inspector that corrosion is probable, although it may not actually be active at the time of testing.

By comparing the potentials and corrosion rates, a good picture is often generated as to where corrosion is occurring. Most often, one finds that, although the readings may be low according to standard, the most negative potentials may not always coincide with the highest corrosion rates of the particular subject (Figs. 4 through 9). By combining the two methods of electrochemical evaluation, a clear picture is defined by the introduction of the corrosion-rate measurements with the potentials. One item to keep in mind, however, is that the corrosion rate does not distinguish between general corrosion or pitting corrosion. It is often found that the highest corrosion rates do not always occur near the highest potentials. Table 5 illustrates that all the data collected from Bay 13 in the testing program had potentials more positive than (>)-150mV, or within the low risk category for corrosion probability, yet corrosion rates were as high as 5.59 microns per year. Corrosion rates of 4 microns per year should be of concern when assessing an historic concrete building. Also note, that the average cover of the balcony slab was just over 1 inch, which is not a suitable cover for a durable concrete structure.

Results of resistivity readings can also vary based on conditions at the time of testing. On very hot days, when the concrete matrix is dry, readings may be extremely high. Extremely wet conditions can also give erroneous readings. Aged concretes with carbonation fronts will provide data that is unusually high, indicative of no possible corrosion activity, when in fact the structure is visibly corroded. Typical resistivity values for concrete structures range between 10K to 50KΩ. In historic buildings, values have been recorded as high as 300K, particularly when taking measurements from interior surfaces.

Carbonation is often the general cause of corrosion activity in historic structures where chlorides are not present. A drop in pH is directly related to the ingress of CO_2 into the concrete matrix, and in the presence of oxygen and moisture, the reinforcing steel corrodes. If the pH has not dropped, then the steel would still be passive and would not be showing signs of corrosion.

A sampling of carbonation testing should also be carried out. Rainbow indicator and phenolphthalein are good, fast, and fairly accurate test procedures. However, the limitations are that the carbonation front can affect steel up to 5mm from the color indicator and that complex matrixes can change the colors of the reagent provided by the manufacturer's scales. If testing is not immediately carried out and cores are sent to a laboratory for testing, carbonation may occur in the interim period, providing a false depth or erroneous carbonation condition. Use of colored aggregates in construction can also affect the reliability of the color indicator.

Chlorides are very aggressive, negatively charged ions that accelerate corrosion-rate activity. The presence of chlorides may be missed in a corrosion-testing program in a historic or aged building, since chlorides are usually associated with very aggressive environments. Chloride ions attack the passive layer and cause pitting of the steel. The chloride ions are absorbed by the protective oxide layer provided by concrete. As the chloride ions are released on the metal surface and are not consumed in the corrosion reaction, the reaction becomes self-generating, and no further chloride ions are required for corrosion.

Chlorides can come from a variety of sources, internal or external. External chlorides penetrate hardened concrete after construction and include salts from ex-

Fig. 6. College center building, west elevation, areas of testing locations for Figures 7-9.

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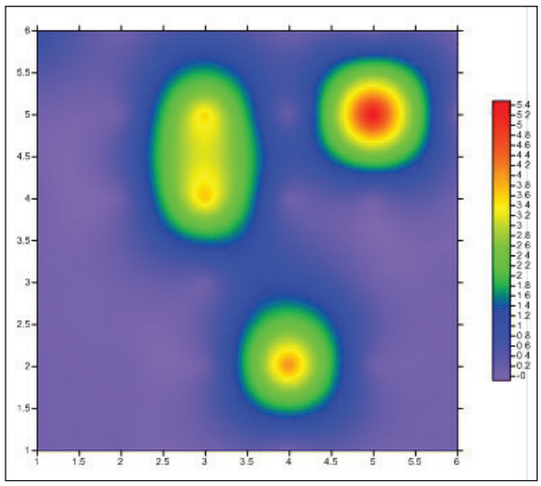

Fig. 7.
College center building, corrosion-rate contour map for Bay 13 as identified in Figure 5.

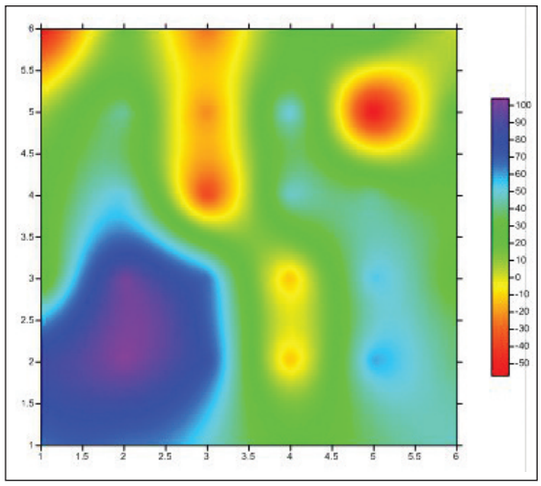

Fig. 8.
College center building, half-cell-potential contour map for Bay 13.

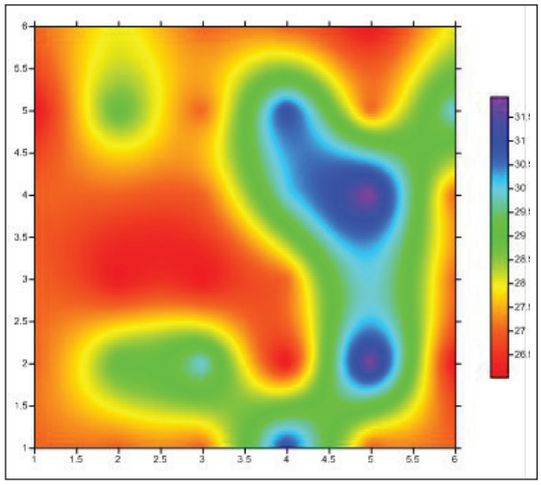

Fig. 9.
College center building, contour map of concrete cover for Bay 13.

posure, i.e. marine mist, seawater, deicing salts, and chemicals. These are also called “free chlorides,” indicating that no chemical bond occurred during construction.

Internal, or bound, chlorides are added at the time of mixing. These chlorides are chemically bound within the concrete matrix. This category includes calcium chloride accelerating admixtures, contaminated aggregates, and the use of seawater or other saline-contaminated water. These chlorides can be released by the carbonation process, thus freeing the bound chlorides.

In early concretes, chlorides were used as an admixture for accelerating curing time, while sugars were used to delay curing. Though the Portland Cement Association warned that salts caused corrosion, literature from the 1920s tacitly accepted the use of calcium chlorides as "a better anti-freezing agent than salt." Presumably the Portland Cement Association was discouraging the use of sodium chloride or potassium chloride in construction at the time. However, this text supports a theory that chloride-contaminated admixtures are present in early concrete construction and should therefore be tested when assessing historic concrete buildings.

When concrete carbonates by reaction with atmospheric carbon dioxide, the bound (internal) chlorides are released. This reaction provides a higher concentration of soluble chloride immediately in front of the carbonated zone. Normal diffusion processes then cause the chlorides to migrate further into the concrete. This process, in addition to the normal transport of chlorides caused by water soaking into the concrete surface, is responsible for the effect sometimes observed where the chloride level is low at the surface but increases to a peak a short distance into the concrete (usually just in front of the carbonation zone).

An increase in unbound chlorides means there are more available chloride ions to take part in the corrosion reaction; the combined effects of carbonation and chloride are worse than either effect alone.

Increases in chlorides can cause an increase in potential (more negative). However, if the aged concrete is carbonated, potential readings can still be in the positive range.

Materials Affecting Results

Aside from the complexities of test equipment and data interpretation, there is the need to understand that certain materials used in repairs, additions, or new construction may change readings. As part of the early investigation, the team needs to understand all construction materials, past repairs, and current conditions. If one does not know that a system is cathodically protected, potentials can be over -900mV. Testing a structure with an extant system without one being aware that such a system is in place could possibly result in damage to the cathodic-protection system, thus disrupting protection to the steel.

The use of epoxy-coated rebar (ECR) greatly affects corrosion test programs and the resulting data. Readings can presumably be collected only where failures in the coating have occurred. If black (mild) steel is used in concert with epoxy coating and the epoxy is damaged, macrocell corrosion can exist, leading to corrosion of the ECR. The isolation or dielectric shielding between the ECR and black steel can cause extreme corrosion, and assessing the anodic polarization through macrocell testing is recommended to determine the corrosion of the ECR.[16]

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Table 5. Results of Testing

Reading	Potential wrt Ag/AgCl(-mV)	Corrosion Rate (µm/yr)	Cover (mm)
Minimum	137.6	0.027	26
Maximum	-85.5	5.59	32
Average	49.6	0.58	27.8

Galvanized steel can provide particularly misleading results. As the zinc is active, the potentials found are in fact a mixed potential. Readings in the range of -650mV$_{CSE}$ to -850mV$_{CSE}$ have been recorded, which is considerably more positive than zinc, at -1000 mV$_{CSE}$, but less positive than steel in concrete, at -250 mV$_{CSE}$. Further testing with wet and dry conditions in the laboratory have been found to be in the range of -1100mV$_{SCE}$.[17] This can all be very misleading in the field.

Elements such as prestressed or post-tension rods cannot be tested easily. If these elements are used in conjunction with traditionally reinforced concrete, the isolation of the post tensioning means that no readings will be possible if the direct connection is to the rebar.

Variations in concrete-mix designs will invariably impact potential readings. Aged and historic concrete can have a number of uncommon additives or material types. Cinder concretes can be highly acidic, with pH values at 5 or less, while potentials may be low and even positive. This environment can be very corrosive to the embedded steel. Marbles and high-quality aggregates can generate readings that also provide false resistivity readings, indicating that the structure may be in better condition than it actually is. Parge coats can also impact potential and resistivity values; at the same time, they may limit carbonation.

Variations within the electrolyte's resistivity can also impact corrosion. The use of cinder concretes, which have very low resistivity, next to portland cement or cast stone can cause imbalances impacting corrosion. Additionally, the use of lesser quality, low-resistance patching compounds in an area of repair can accelerate corrosion in historic or existing structures.

Some materials used in repairs will also alter readings. Corrosion inhibitors have the ability to increase corrosion rates at patch repairs, due to the electrochemical imbalances that occur as the patch material dries. Until the extant concrete and the new patch achieve equilibrium, corrosion rates may increase temporarily during the curing phases. The author recorded corrosion rates of reinforcing steel of over 90μ/yr cm^2 adjacent to new patch repairs. The measurements were made one week after the inhibitor-patch material was installed. The linear-polarization resistance testing indicated that the general condition of the overall structure, built c. 1954, was fair and exhibited rates no higher than 4μ/yr cm^2. The use of migrating corrosion inhibitors (MCIs) can also serve as pore blockers and will impact electrochemical tests from the surface upon which they were applied. It has been found that they impede surface-mounted electrochemical readings. As such, data collection should be taken from embedded probes deep within the concrete.

Understanding Corrosion Condition

There are very few academic courses that provide in-depth training for the engineer or scientist to fully understand the complexities of corrosion testing. Most of the knowledge is gained on site or through laboratory training, with the more experienced professional handing down their knowledge to recent graduates or engineers in training. After the catastrophic collapse of a bridge in Minneapolis, Minnesota, in 2007, state departments of transportation and the National Association of Corrosion Engineers (NACE) International, began working together to provide corrosion training and evaluations for bridge structures.

While such seminars are important and very useful to the seasoned professional, a one-day training course is far from sufficient for an early-career professional to become fully versed in corrosion conditions. However, with a trained and seasoned professional at the helm of the test equipment, a very accurate picture of a structure can be formulated.

The combined knowledge of a detailed corrosion survey and deterioration models, analyzed in concert with a laboratory testing program, can allow the client to know when to anticipate failures on the structure. This information can provide the client with whole-of-life maintenance and repair strategies to extend service life of the structure.

Preventative Maintenance

The term "preventative maintenance" is generally defined as the schedule of planned maintenance activities that will prevent a failure. By understanding a corrosion condition, a design team can assess the long-term needs of a structure. This can be largely beneficial to prevent corrosion, the loss of concrete or masonry, and lower repair costs in the future.

Ideally, a planned inspection-and-testing routine should be established at the end of construction, so that the owner or facilities manager can begin to determine the overall cost of the structure, the physical requirements to maintain the structure, and the associated costs. Often, inspection cycles are carried out not in a planned manner but after a failure. Two-, five-, and ten-year inspections should be carried out, with various test programs for each of the cycles.

Some governments insist on routine inspections for infrastructure or buildings over a certain height, where the loss of material could or has resulted in the loss of human life. In these instances, a structural or civil engineer often serves as the inspector, rather than a corrosion or material scientist. While the structural engineer is an invaluable team member, the corrosion or materials team member should be involved from the start. Minor issues resulting from corrosion could then

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be identified easily prior to damage, resulting in relief from a major cost burden.

The overall added value of precise, well-understood corrosion inspections can lead to added benefits to the client. The importance of the role of the corrosion specialist is beginning to take hold within the general engineering community and government organizations. For instance, the U.S. Congress considered the Bridge Life Extension Act, 2008, which would approve the use of corrosion engineers for all new-build, repair, and rehabilitation plans for bridges. Although this legislation died in congress, the need for corrosion conditions is beginning to be addressed at a more comprehensive level. More recently in 2014, representatives from NACE, Congresswoman Elizabeth Esty (D, CT-5), and Congressman Pete Olson (R, TX-22) formed the Corrosion Prevention Caucus to raise awareness of the devastating effects of unmitigated corrosion and to promote proper corrosion-control technologies. This approach is also beginning to take hold in the architectural-preservation community, where the quest to conserve materials in a more holistic manner is a readily acceptable practice.

Author's Note: It must be noted to the owner prior to the investigation that most of the test methods are semi-destructive. However significant the concrete building may be, understanding conditions which may impact long-term performance warrants some level of material removal for analysis. Understanding the limitations of sampling prior to site mobilization will allow the team to critically analyze the best locations for material removal. Communicating this need to the owner is vital, as is providing an adequate repair when patching sample locations.

GINA CREVELLO is principal of Echem Consultants. Her firm specializes in corrosion diagnostics and electrochemical repair for historic and existing structures. She was trained at Columbia University's Graduate School of Architecture, Planning, and Preservation and received training in electrochemistry in the UK. She has 18 years of experience in building diagnostics and architectural conservation.

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The Association for Preservation Technology International

3085 Stevenson Drive, Suite 200
Springfield, IL 62703
217.529.9039

fax (toll free) 888.723.4242
info@apti.org
www.apti.org