Chapter 7
Technical Issues and Solutions

Aquatic Park Bathhouse, constructed 1939, San Francisco, California (HABS photograph by Jet Lowe, 1981)

Making New York City Parks Accessible
A Work in Progress

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New York City parks have become much more accessible in the past two decades but considerable work remains to meet the needs of a contemporary city. The challenges faced by New York, and many other cities across the country and around the world, result from rapid infrastructure expansion in the early- to mid-twentieth century followed by fiscal crises that resulted in insufficient maintenance staff and dollars. Comfort stations, playgrounds, pools, and other public resources were closed and abandoned. The renaissance of the New York City park system as an accessible resource is a story of renovation and redefinition that can both inform and encourage other cities facing similar challenges.

New York City has one of the largest, most diverse planned urban park systems in the world. Although the system contains such notable landscapes as Frederick Law Olmsted's Central and Prospect Parks, the system is perhaps better characterized by its small, less famous but nonetheless vital neighborhood parks. Comprising more than 4,000 individual parcels, ranging from planted triangles to 4,000-acre tracts, from historic house museums to recreation centers, the system grows annually with significant new parks (Figure 1).

These resources, which have evolved over the 300-year history of the New York City parks, embody the design and civic ideal of their day, but few meet contemporary expectations for an accessible urban park system.

Perhaps the most ubiquitous New York City park type is the playground. There are more than 950 playgrounds citywide, each requiring renovation approximately every twenty years to meet changing safety requirements and to remedy intensive wear and tear. During the tenure of Robert Moses as Parks Commissioner from 1934 to 1960, the renowned city planner, parks commissioner, and builder, the number of playgrounds swelled from 119 to 861 and could be found in every corner of the city. Moses achieved this massive development of play spaces partially through the federally subsidized Works Progress Administration, which, at its height, employed more than 80,000 landscape architects, architects, and construction staff in New York City parks.[1] These designers developed playground and park standards that established a formulaic imposition on the landscape; there were comfort station types a, b, and c, and drinking fountain types a, b, and c. Play equipment came in the parks' own form of Sears catalogue: standard slide, standard swing, and standard seesaw (Figure 2).

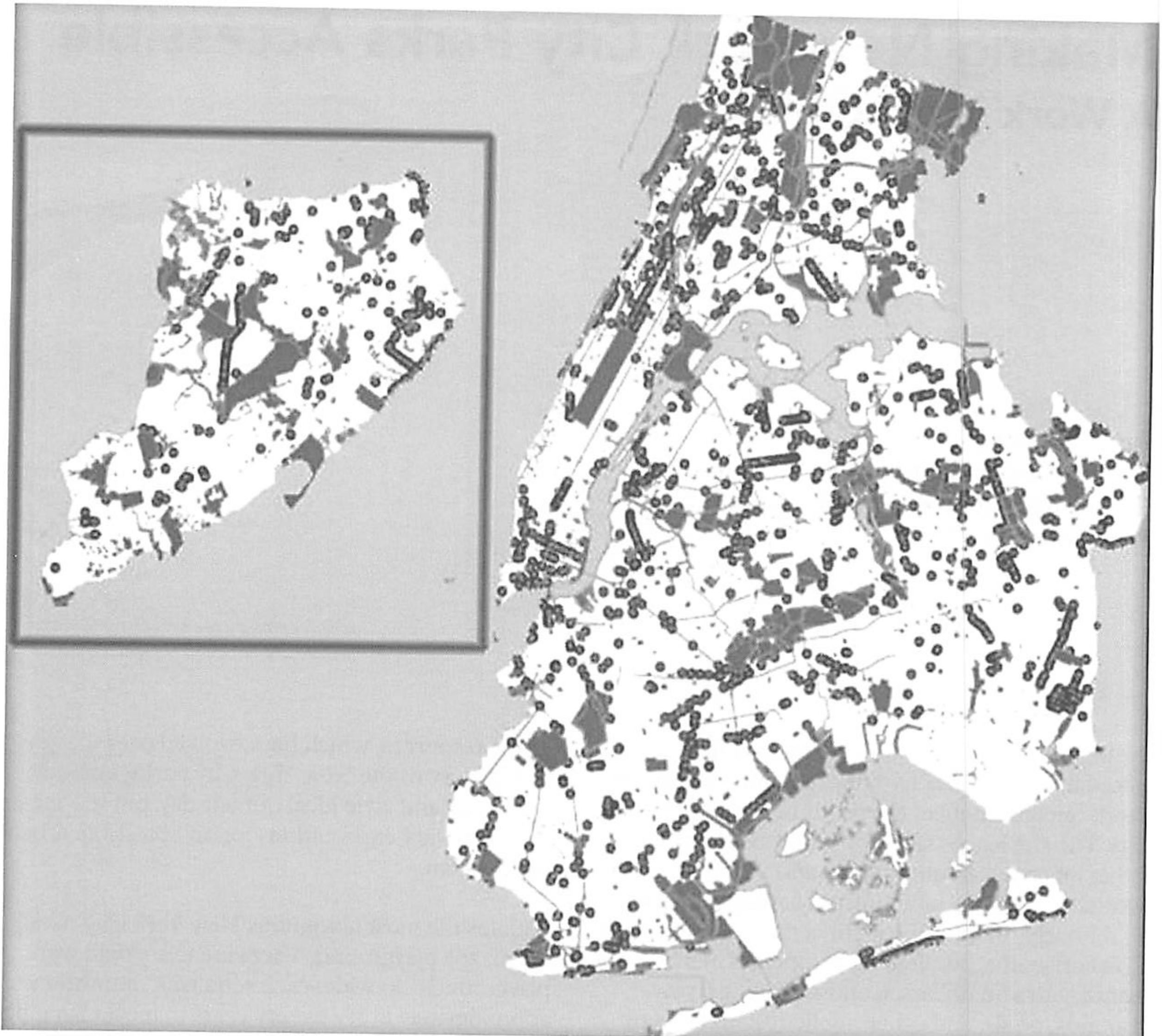

Figure 1. New York City Parks (New York City Department of Parks and Recreation, 2005)

While this congruity allowed for rapid design, installation, and economy, it also established a somewhat generic, albeit classic, New York City playground "look." These design standards, recently compiled and reviewed by Patricia Watkins Alesi of the Department of Landscape Architecture and Regional Planning at the University of Massachusetts, became, as noted by Ethan Carr, the essential "play book" for urban parks across America and beyond.[2]

And then in the 1970s New York City's economy crashed. Moses himself realized that the extraordinary explosion of parks during his tenure would inevitably place a considerable burden on a struggling city, and his concern materialized when playgrounds and comfort stations across the city closed due to insufficient maintenance and crumbling infrastructure. Central Park became the butt of late night television jokes—even Miss Piggy was mugged in Central Park in the 1984 film *The Muppets Take Manhattan*. The grand era of New York City park design now appeared to be a relic of an assembly line approach, resulting in urban recreation sites with as little variety as the housing projects that now crowded the skyline. Though parks and playgrounds were still within reach of virtually every city residence, their decrepit condition and increasingly unsafe and inaccessible designs made them a pervasive symbol of urban decay.

This tragic period of decline in New York City parks was, nonetheless, punctuated by some remarkable signs of innovation and restoration in the 1960s and 1970s. Innovative designers such as

M. Paul Friedberg and Richard Dattner attempted to reinvent children's play environments with creative "adventure playgrounds." Their simultaneously modern and naturalistic designs sought to reinvent the Moses-era standards with more dynamic elements such as slides incorporated into landforms and climbing obstacles formed from abstract geometries. Seen through the lens of current safety and accessibility standards, both the adventure playgrounds and the Moses-era standards were equally inaccessible but nonetheless evidence of the city's commitment to an evolving understanding of how children play and develop.

Figure 2. Moses-era standard swing set (New York City Department of Parks and Recreation, circa 1935)

The idea of an accessible playground that would allow fully able and disabled children to play side by side was also born in the midst of New York City's fiscal crisis. In response to current studies and scholarship that focused on the need to "mainstream" the disabled, the Department of City Planning in conjunction with New York City Parks sponsored an international design competition in 1976 for a "Playground for All Children." The commission was awarded to Hisham Nasrat Ashkouri, who held a Masters in Urban Design from Harvard University and the Massachusetts Institute of Technology, as well as a Masters of Architecture from the University of Pennsylvania. While at the University of Pennsylvania, Ashkouri had studied under Louis I. Kahn, whose own architectural beliefs were manifested in Ashkouri's design. Kahn, in opposition to his traditional Beaux-Arts education, favored less regimented, more expressive forms with which he consciously orchestrated movement through space by creating "zones," areas distinct from one another according to their individual programmatic function. Ashkouri adapted these fundamental principles by basing his design on the notion of creating concentric areas of play. He divided the spaces according to the ability of the child; the center of the design was better suited for disabled children as it had more shade and protection, while free play environments existed in the radiating zones. Ashkouri labored to develop new play standards based on the Moses-era palette, and after more than eight years of design and testing, New York City's first "Playground for All Children" opened in Flushing Meadows Corona Parks (Figure 3).

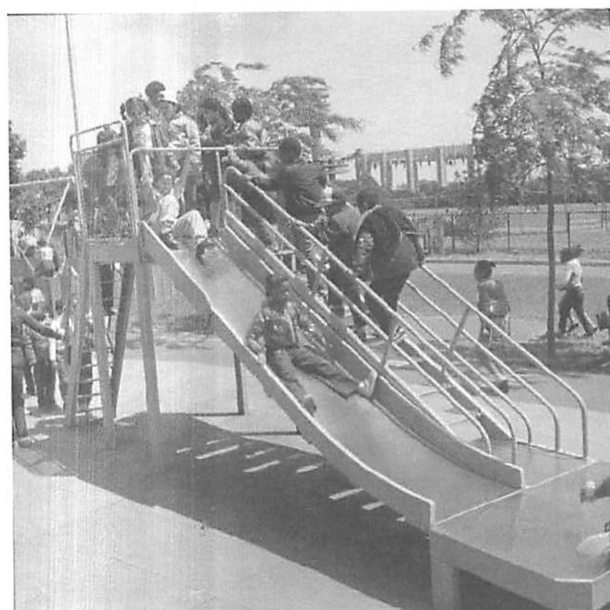

Figure 3. Slide at the Playground for All Children (New York City Department of Parks and Recreation, circa 1985)

The playground's huge success spawned three other fully accessible and integrated playgrounds in the Bronx, Staten Island, and Manhattan, and paved the way for contemporary playgrounds that must all meet minimum accessibility requirements (Figure 4).

Since the advent of the Americans with Disabilities Act (ADA) of 1990, New York City has been on a deliberate and steady schedule of renovating the massive build-out of the Moses era according to current accessibility standards. It is a daunting undertaking that has involved billions of dollars and hundred of projects. Even with this enormous investment, the effort to transform an immense mid-twentieth century urban system—with notable nineteenth-century landmarks—into a fully accessible resource has only begun. Much of the investment to date has involved the most mundane but essential of tasks: for example, providing an accessible route into and out of individual parks. Though much of New York City's topography was

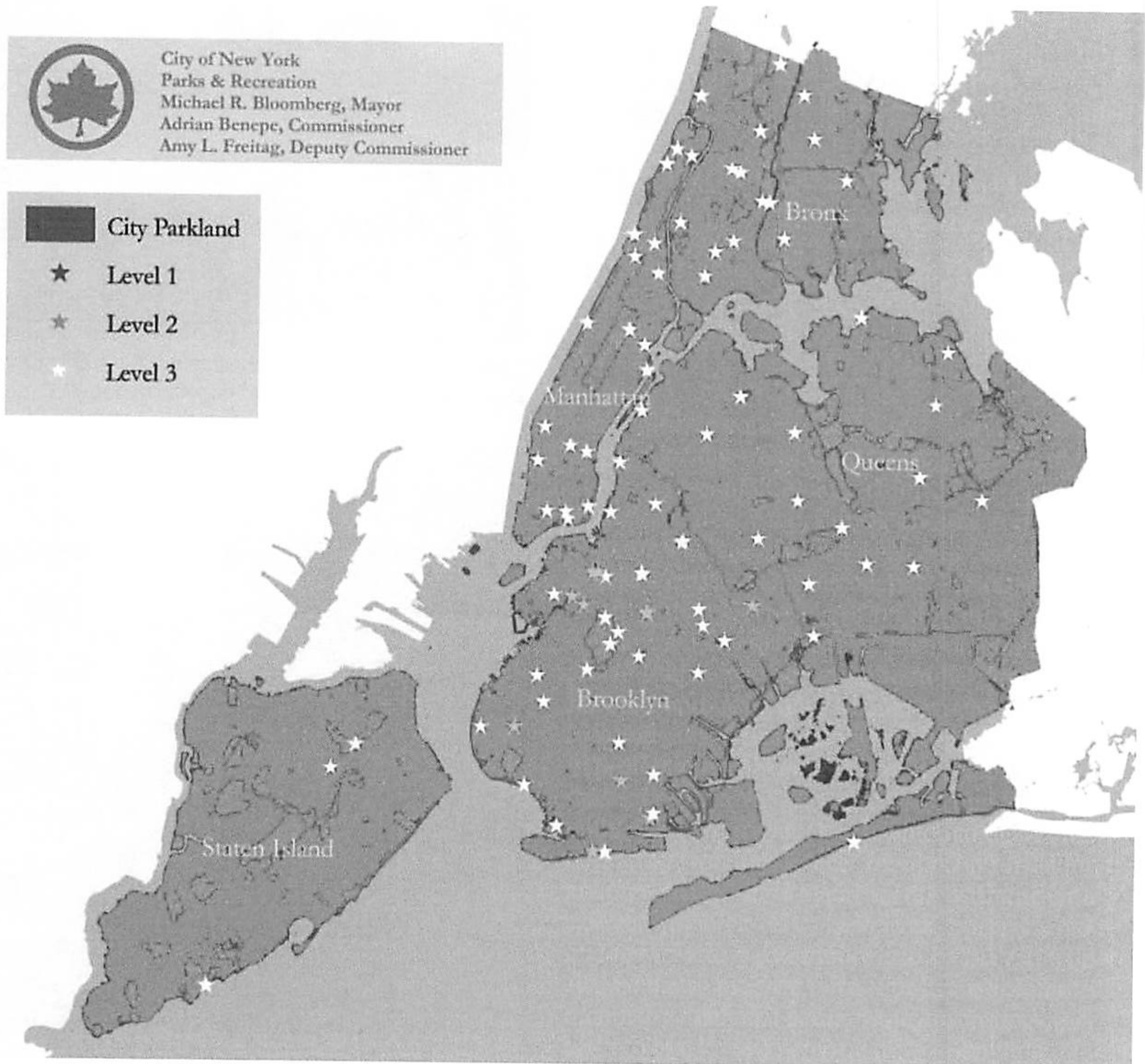

Figure 4. Accessible playgrounds in New York City (New York City Department of Parks and Recreation, 2005)

tamed by urban development, many of the parks remain perched on high-tops and hillsides or with an intentionally rustic (and consequently inaccessible) design. Eliminating stairs and adding ramps and adequate clearance has been a tremendous undertaking. New forms of play equipment, including full body swings, are added when and wherever existing equipment and budgets can accommodate them. Old Moses-era standards including benches and tables have been redesigned to accommodate people with disabilities, in many cases by making the designs more comfortable for all users. For example, an accessible drinking fountain, designed in 1991 by parks designer Emmanuel Thingue, has become a favorite for all parks, not only because of its accommodation of people in wheelchairs, but also because it is a modern yet contextual addition to Olmsted-era parks (Figure 5).

New York City Parks has quickly come to understand that meeting the minimum standard of access is not sufficient for many of the parks. New York City's bid to host the 2012 Olympic Games, and by extension the Paralympic Games, facilitated collaboration with disabled athletes and advocacy groups that fostered improvements to new and existing recreation infrastructure. A new $60 million indoor ice rink and pool, which could host Olympic water polo, will be built in Flushing Meadows-Corona Park with accessible ice to accommodate sled hockey. The facility is scheduled to open by fall 2007. This consideration is largely thanks to the efforts of Paralympian Victor Calise,

Figure 5. Accessible drinking fountains (New York City Department of Parks and Recreation, 1991)

Figure 6. Olmsted steps in Riverside Park (New York City Department of Parks and Recreation, 2005)

a staff member at the United Spinal Association, who brought designers and athletes together to ensure that minor changes to technical elements would allow this growing sport to be fully accommodated in New York City parks. Calise has held workshops with New York City Parks and other agencies throughout the city to educate designers on the needs of disabled athletes, demonstrating that the wide variety of equipment used by the disabled, such as wheelchairs with canted wheels, cannot pass through minimum ADA standard width openings. Without this direct contact with disabled athletes, the parks could meet the ADA code but make it impossible for athletes to enter and use these spaces.

The effort to make New York City's landmark structures accessible has its own set of difficulties. In most cases, access can be achieved with minimal disruption to historic fabric. For example, the Central Park Conservancy's addition of a simple ramp adjacent to the carved stone steps leading to Belvedere Castle makes this high point of Central Park fairly accessible. Other landmark sites, including the parks' historic homes and the Central Park Arsenal, were made accessible in accordance with the standards established by the New York City Landmarks Preservation Commission through substantial investment from private partners like the City Parks Foundation. Even small structures, including a 1920s bandstand on the Grand Concourse in the Bronx, are being renovated to accommodate disabled users. In this case, a limited use, limited occupancy lift will allow a musician to reach the stage without the addition of a ramp that would diminish the historic character of the structure.

Landmark parks that retain much of their Olmsted- and Moses-era character, such as Riverside Park, offer extreme challenges to designers and planners who seek to make these historic landscapes accessible. Margaret Bracken, landscape architect for Riverside Park, undertook its analysis to determine the most rational and practical accommodation for accessibility without disrupting the historic step ramps of the Moses era and the magnificent grand masonry steps that survive from the Olmsted design (Figure 6).

Her analysis focused efforts on the more extreme elevations of the northern end of the parks where new ramps and entrances will provide loop routes for people using wheelchairs. The realization of projects like this shows how the preservation of the past and the needs of the present and future can be simultaneously and successfully met.

New York City Parks has a long way to go to meet the accessibility expectations of its users, but a great deal has been accomplished to date. While the renovation of parks and playgrounds has absorbed the majority of invested time and money over the past two decades, accessibility of buildings and waterfront areas has become a primary concern of the current commissioner. Additionally, recent reviews by regulatory agencies have encouraged New York City Parks to concentrate even greater efforts on public information and signage, which has resulted in a massive undertaking along miles of park paths and roadways throughout the five boroughs.

New York City Parks has many of the same challenges faced by America's other great nineteenth and twentieth century park systems in cities such

as Chicago, Philadelphia, and Boston. These landscapes represent a remarkable inheritance that has quickly fallen behind contemporary use demands, and there is no quick or easy fix for making these systems accessible. New York City has been fortunate to have the support of generous private partners, such as the Central Park Conservancy and the Prospect Park Alliance, as well as a steadily growing economy and a supportive mayor who understands the need for park investment as a key "quality of life" measure. In particular, new partnerships with organizations and individuals within the disabled communities are a critical link to smart, strategic investments in access. The New York City Mayor's Office for People with Disabilities, under the able leadership of Matt Sapolin, has been a lynchpin in efforts to gain greater awareness and sensitivity to all New York City's park users. Every day brings the realization that there is more to do to fulfill Olmsted's democratic vision: "The primary purpose of the Park is to provide the best practicable means of healthful recreation for the inhabitants of all classes."[3]

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Notes

1. Ethan Carr, "Three Hundred Years of Parks" (City of New York Parks & Recreation: 1986), 31.

2. Compiled by Patricia Watkins Alesi, Department of Landscape Architecture and Regional Planning, University of Massachusetts, 2003–2004. Under the direction of Professor Ethan Carr.

3. Frederick L. Olmsted, *Forty Years of Landscape Architecture: Central Park*, 1st ed. (Cambridge, Massachusetts: The MIT Press, 1973), 406.

Bibliography

Caro, Robert A. *The Power Broker: Robert Moses and the Fall of New York.* New York: Vintage Books, 1975.

Carr, Ethan. "Three Hundred Years of Parks." City of New York Parks & Recreation: 1986. Pamphlet.

Olmsted, Frederick L. *Forty Years of Landscape Architecture: Central Park.* 1st ed. Cambridge, Massachusetts & London, England: The MIT Press, 1973.

Solomon, Susan G. *American Playgrounds: Revitalizing Community Space.* 1st ed. Lebanon, New Hampshire: University Press of New England, 2005.

Tools for Developing Acceptable Code and Safety Solutions for Unique Historic Recreational Buildings

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Because strict application of codes written for new construction can require substantial alteration, unique code and safety solutions are often necessary to preserve the character of historic buildings. Historic structures, in particular those constructed for recreational purposes, often defy current code classifications of construction and occupancy, and contemporary approaches to safety can be impractical or technically infeasible. Unique approaches and solutions can provide the technical justification required by appeal boards and code officials who are granted discretion by legislation or within the framework of the code to accept alternate solutions that provide an equivalent or reasonable level of safety.

Background

Prior to the 1990s, three model codes provided the basis of most building regulations in the US: the *BOCA National Building Code*, the *Uniform Building Code*, and the *Southern Building Code*. Special purpose codes and standards, such as the *National Electric Code* and *NFPA 13: Installation of Sprinkler Standards* published by the National Fire Protection Association (NFPA), were also referenced by these codes or independently available for adoption by a jurisdiction. These documents had evolved from the earliest codes in the country (the 1913 *Life Safety Code*, the 1927 *Uniform Building Code*, the 1927 *Building Exits Code*, the 1945 *Southern Building Code*, and the 1950 *Basic/National Building Code)*, typically in reaction to major catastrophic events. For example, requirements for outswing doors in public facilities evolved from forensic assessments following the 1903 Iroquois Theatre Fire in Chicago. In another case, the NFPA's Committee on Tents, Grandstands, and Air Supported Structures was formed in response to a 1944 circus tent fire in Hartford, Connecticut.

In 1994, the International Code Council, Inc. (ICC) was created to produce a single set of model codes that would be the basis of code enforcement nationwide. The initial council members were the publishers of the three prevalent model codes and the NFPA. Eventually the NFPA withdrew from the council and published, in 2003, its own building code, *NFPA 5000 Building Construction and Safety Code*. Chapter 15, Building Rehabilitation, of *NFPA 5000* is similar in concept and text to the ICC's 2003 *International Existing Building Code* (IEBC). These codes incorporate the proportional approach embodied in the ground breaking 1997 *Nationally Applicable Recommended Rehabilitation Provisions* (NARRP) published by the U.S. Department of Housing and Urban Development (HUD), and the 1998 New Jersey *Uniform Construction Code Rehabilitation Subcode*. In contrast to previous approaches to existing buildings, these docu-

Table 1. Assembly Sub-classifications (IBC)

	Description	Examples
A-1	Intended for production and viewing of performing arts or motion pictures, usually with fixed seating	Motion picture theatres; symphony and concert halls; television and radio studios admitting an audience; theatres
A-2	Intended for food and/or drink consumption	Banquet halls; night clubs; restaurants; taverns and bars
A-3	Intended for worship, recreation or amusement and other assembly uses not classified elsewhere in Group A	Amusement arcades; art galleries; bowling alleys; churches; community halls; courtrooms; dance halls (not including food or drink consumption); exhibition halls; funeral parlors; gymnasiums, indoor swimming pools and tennis courts (without spectator seating); lecture halls; libraries; museums; waiting areas in transportation terminals; pool and billiard parlors
A-4	Intended for viewing of indoor sporting events and activities with spectator seating	Arenas; skating rinks; swimming pools; tennis courts
A-5	Participation in or viewing outdoor activities including, but not limited to:	Amusement park structures; bleachers; grandstands; stadiums

ments seek to encourage rehabilitation by establishing proportional relationships of code-imposed requirements to owner-elected improvements as a means of relaxing the requirements imposed on new construction. For example, rehabilitation projects of limited scope are generally permitted to retain existing conditions, execute repairs in kind, and address only the most critical hazards, while more stringent requirements are imposed on extensive rehabilitation projects initiated by the owner. Historic buildings are specially treated by specific provisions that modify requirements imposed on other existing buildings, as addressed later in this paper.

Although the IEBC is largely a stand-alone document, it requires coordination with two of the ICC's other thirteen published codes, the *International Building Code* (IBC), and the 2003 *International Fire Code*. For the last decade the ICC codes have gained increasing momentum in acceptance throughout the country. Thirty-four states have adopted the IBC for statewide application, the IBC and other ICC codes have been adopted by many local jurisdictions, and the IEBC has been adopted statewide in seven of the twenty-one states in which it is in use. These statistics do not reflect those states where the IEBC has been modified to meet local or regional concerns, or where jurisdictions permit the use of IEBC as an acceptable alternate approach that complies with the intent of the prevailing code. Additional adoptions of the IEBC in local jurisdictions and by state governments are anticipated in the near future.

Construction and Occupancy Classification

Codes classify buildings as a function of construction materials and occupancy, with the most stringent requirements imposed on those considered to present the greatest potential hazard. Construction classification is a function of the fire-resistance rating of building elements. Within the IEBC, Types I and II construction are noncombustible structures differing in the number of hours (one, two, or three) that the structural frame, bearing walls, and floor construction will resist failure in a fire situation. Type III construction has noncombustible exterior walls, Type IV has heavy timber members, and Type V refers to all other structures, typically those with wood interior and exterior elements. Most historic recreational properties such as bowling alleys or movie theatres were built for traditional uses and can be readily defined as to their construction classification. Challenges arise when the older construction materials and assemblies are not rated by current sources, or where minor dimensional or material variations result in a numerically higher classification construction, implying greater hazard and consequently more restrictive code provisions.

Classification by occupancy can be even more problematic for historic recreational buildings. Most codes classify occupancies as belonging to one of the following: A-Assembly, B-Business, E-Educational, F-Factory, H-Hazardous, I-Institutional, M-Mercantile, R-Residential, S-Storage, and U-Utility. These categories are further subclassified to reflect the character of the occupancy and its inherent hazard and risk. For example, within Group R are transient lodgings such as hotels or boarding houses, buildings with less than two permanent residential dwelling units, and even residential care/assisted living facilities with less than sixteen occupants.

Most historic recreational buildings are classified as Assembly; further sub classification within this group is shown in Table 1. Although the risks associated with public assembly occupancies are well established, one limitation is the inability to further sub classify according to actual use, size, and hazard. For example, an A-3 designation applies to a large urban museum as well as to the small open air, farm museum complex with buildings as small as 100 square feet. (Note that, generally, less severe requirements are imposed on smaller assembly occupancies, since building or spaces used for assembly purposes by less than fifty persons are considered to be a Group B Business occupancy.)

Codes are continually modified to include increasingly stringent requirements for assembly occupancies, and it is likely that a requirement for sprinkler systems in all spaces with more than fifty occupants will become increasingly commonplace. In some cases the physical changes necessary to accommodate sprinklers and other requirements adversely impact historic fabric and character. They may also impose a financial burden on historic projects, with a dubious cost to benefit value when considering the actual circumstances and inherent risks of the individual building. The recognized importance of a practical, reasonable approach to code enforcement is in part the rationale for the special provisions for museums and similar historic occupancies and for code officials having specific areas of discretion when working with historic structures.

Mechanics of the Proportional Codes

Codes are applicable and enforceable when adopted by a state or local jurisdiction. Jurisdictions can adopt a model code as published or modify it to address local issues or priorities. Often, the administrative procedures are modified to comply with local law and procedures and the technical provisions of the model code are left untouched.

The initial chapters of the IEBC and the other proportional rehabilitation codes provide administrative procedures, definitions, and classifications of work by type and extent of the proposed undertaking. Chapters 4 through 8 of the IEBC define five classifications of work and establish increasingly stringent requirements (Table 2). Requirements are largely cumulative in nature: for example, Chapter 7, Alterations—Level 3, requires compliance with the unique requirements of that chapter and those established in Chapters 4 through 6. A building may have different classifications of work in different areas, as determined by the scope of owner-elective work.

The provisions for Chapter 8, Change of Occupancy, are generally the most stringent, an approach held over from the earliest rehabilitation codes where such changes were required to meet standards of new construction. As mitigation, the IEBC incorporates recent rehabilitation code philosophy, one that establishes that hazardous conditions should be corrected and that the rehabilitation should not render the building less safe. It also recognizes that changes of occupancy can represent an equivalent, increased, or decreased level of hazard. Thus, requirements imposed by this chapter are based on the relative increase or decrease in hazard level, as determined by numerical movement in three specific tables comparing the hazard categories and classifications of Life Safety and Exits, Heights and Areas, and Exposure of Exterior Walls.

Chapter 9, Additions, generally specifies that additions meet new construction standards; Chapter 11, Relocated or Moved Buildings, primarily addresses site and structural requirements, and Chapter 12, Compliance Alternatives, provides an optional approach for quantitatively establishing safety based on nineteen factors such as the presence or quality of emergency lighting and sprinkler systems.

Chapter 10, Historic Buildings, modifies the provisions of Chapters 4 through 8. To use this chapter, the structure must meet the definition of a historic building, in some cases have a special report prepared by a design professional, and, for some provisions, have the explicit approval of the code official. Other provisions are as-of-right and do not require discussions or negotiations. The historic building provisions vary according to classification of rehabilitation work: some apply to all work, some only to the minimal code requirements established for buildings undergoing repair, and others to buildings undergoing alteration or change of occupancy. Table 3 identifies the building features and characteristics that are given special consideration in Chapter 10.

Pursuing Unique Solutions

Unique solutions outside of the prescriptive provisions of the code may be permitted by code text that grants specific areas of discretion to the code official or by the overarching permission to use alternative materials included in the administrative chapter, such as in Section 104.11 of the IBC:

Table 2. IEBC: Organization and Classifications of Work

Chapter	Title	Scope
1	Administration	Addresses general requirements related to applicability of the IEBC, duties and responsibilities of the code official, permits, construction documents, fees, inspections, certificates of occupancy, service utilities, boards of appeals, violations, stop work orders, unsafe buildings and equipment, emergency measures and demolition
2	Definitions	Defines terms specific to the IEBC. Other applicable definitions included in the IBC
3	Classification of Work	Provides definitions for the classifications of work: Repairs, Alterations—Level 1, Alterations—Level 2, Alterations—Level 3, Change of Occupancy, Additions, Historic Buildings, and Relocated Buildings
4	Repairs	Provisions for rehabilitation work involving the patching or restoration of materials, elements, equipment, or fixtures for the purpose of maintaining these in good or sound condition
5	Alterations—Level 1	Provisions for rehabilitation work involving the removal and replacement or covering of existing materials, elements, equipment or fixtures with new that serve the same purpose
6	Alterations—Level 2	Provisions for rehabilitation work involving the reconfiguration of space, addition or elimination of doors or windows, reconfiguration or extension of any system, or installation of additional equipment
7	Alterations—Level 3	Provisions for rehabilitation work that exceeds 50 percent of the aggregate building area
8	Change of Occupancy	Provisions for rehabilitation work involving a change in the purpose or level of activity within a building
9	Additions	Provisions for an extension or increase in floor area, number of stories, or height of a building or structure. Requirements apply only to the new portion of the building: work in existing areas to remain must comply with Chapters 4 through 8, as applicable
10	Historic Buildings	Provisions for designated historic buildings that relieve or modify requirements of the proceeding applicable chapters
11	Relocated Buildings	Provisions for work involving the relocation or moving of a building
12	Compliance Alternatives	A quantitative method of determining building safety

Table 3. Historic Feature and Characteristics Addressed by IEBC Chapter 10

Fire Suppression	Stairway Railings	Natural Light
Means of Egress	Guards	Accessibility
Door Swing	Exit Signs	Unsafe Structural Elements
Transoms	Automatic Fire Extinguishing Systems	Floor Loading
Interior Finishes	Building Area	
Stairway Enclosure	Location on Property	
One-hour Fire Resistance Rating	Occupancy Separation	
Glazing/Corridors and Doors	Roof Covering	

> 104.11 Alternative materials, design and methods of construction and equipment. The provisions of this code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or methods of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of this code, and that the material, methods, or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.

Additionally, many jurisdictions have processes to grant modifications, appeals, waivers, or variances, providing that the underlying goal of life safety is met. Such modifications may be handled by personnel administering the code, elected or appointed jurisdictional bodies, or a special review panel such as a state variance board. Numerous tools exist for negotiating acceptable solutions within the parameters of the code or within an appeal context.

Resource Documents. Like IBC Section 104.11 above, most codes permit the use of other resources to justify a proposal that uses alternate materials or approaches. Those resources of the greatest assistance to historic structures include the *Guidelines on Fire Ratings of Archaic Materials and Assemblies*, first published by HUD in 1980 as part of its Rehabilitation Guidelines series, and most recently included as an appendix to *NFPA 914 Code for Fire Prevention of Historic Structures*. This document is one of the few resources that provides the fire ratings for older building materials and assemblies necessary for determining construction classification of buildings and for establishing the acceptability of retaining historic materials and assemblies.

Other Codes and Standards. Solutions established in other codes, in particular those with national representation and established by consensus processes or adopted by other jurisdictions, may also be considered by the code official or review board when developing acceptable alternate approaches. For this purpose, no rehabilitation document is more important than *NFPA 914 Code for Fire Prevention of Historic Structures*, which provides a unique approach complementing the technical prescriptive provisions of the prevailing code by permitting performance based approaches and engineered solutions, and by addressing hazard mitigation through the construction period and daily operations. Table 4 further illustrates the scope of NFPA 914.

Professional Expertise. Use of the IEBC's Chapter 10 Historic Buildings provisions requires the involvement of design professionals, architects and engineers with specific historic preservation expertise will bring to a project experience in the resolution of conflicts between preservation standards such as the Secretary of the Interior's Standards for Rehabilitation and the code. The involvement of a fire protection engineer may also provide the opportunity to develop solutions based on a historic building's unique circumstances. The fire protection engineer may provide limited performance based assessments of a single space, material, or assembly, or conduct a full performance design for the building using sophisticated mathematic and modeling techniques. Chapter 4, Process, of NFPA 914 addresses the importance of

Table 4. NFPA 914: Code for Fire Prevention of Historic Structures

Chapter 1	Administration
Chapter 2	Referenced Publications
Chapter 3	Definitions
Chapter 4	Process
Chapter 5	Prescriptive-Based Option
Chapter 6	Performance-Based Option
Chapter 7	Fire Precautions During Construction, Repair and Alterations
Chapter 8	Inspection, Testing and Maintenance
Chapter 9	Fire Prevention and Fire Protection
Chapter 10	Special Events
Chapter 11	Management Operational Systems
Appendix A	Explanatory Material
Appendix B	Planning and Design Appraisal
Appendix C	Survey Criteria for a Historic Structure
Appendix D	Fire Safety Inspection Forms
Appendix E	Fire Protection System Maintenance Checklist
Appendix F	Basics of Fire and Fire Protection Systems
Appendix G	Resources
Appendix H	Secretary of the Interior's Standards
Appendix I	Guideline on Fire Ratings of Archaic Materials and Assemblies
Appendix J	BSU Timber Panel Door Standards
Appendix K	Referenced Publications
Appendix L	Bibliography/Related Publications

the collaborative process whereby design professionals join code and safety officials and historic preservation advocates to identify a project's goals and objectives and, ultimately, to evaluate the acceptability of numerous options.

Hazard Mitigation. NFPA 914 recognizes that the most important aspect of fire safety is minimizing the likelihood of a fire start. This is achieved through code-imposed physical requirements and, arguably, more effectively through the manner in which the building is managed and used on a daily basis. Fire safety should be a management priority and a responsibility of key staff. Fire safety procedures are never more critical than during construction, when a building's normal safety procedures are often abandoned, when contractor's personnel and flammable materials pervade the site, and when the location of work and potential hazards moves daily with the construction activity. During such times, and for overall fire safety, close coordination with the fire service should occur so that in case of a fire event, a familiarity with the site can enable rapid mobilization.

Closing

Although historic buildings have long relied on code-related solutions negotiated between the code official, design professional, and owner, current codes provide additional opportunities to develop unique and tailored designs that reflect the nuances of a particular building and project, whether it be the reuse of a gymnasium or rehabilitation of a resort complex. The design professional's knowledge of the opportunities that exist within both the technical and administrative provisions of the code is essential, and it is increasingly common for such expertise to be accepted by code officials. The development of acceptable solutions based on principles of reasonableness must be seen as a collaborative and not an adversarial effort.

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Bibliography

International Code Council, Inc. *International Building Code*. Country Club Hills, Illinois, 2003.

International Code Council, Inc. *International Existing Building Code*. Country Club Hills, Illinois, 2003.

National Fire Protection Association. *NFPA 914 Code for Fire Protection of Historic Structures*. Quincy, Massachusetts, 2001.

National Fire Protection Association. *Building Construction and Safety Code NFPA 5000*. Quincy, Massachusetts, 2003.

Iron Structures in Public Parks
Conservation and Restoration Challenges

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The United Kingdom urban parks movement in the mid-nineteenth century countered the mass industrialization and growth of cities by using some of the wealth generated to establish municipal parks, often supported by altruistic donations from city fathers. In the 1990s there was a growing realization that these urban parks and the historic structures within were in generally poor condition.

In 2001, the Urban Parks Forum published a survey of parks in the care of local authorities that identified over 27,000 parks in the United Kingdom covering 143,000 hectares. Historic parks in particular accounted for 296 million visits per annum. An especially alarming statistic generated by the survey was the percentage of park features that had been lost, many of which were made or comprised of cast or wrought iron. The features shown in Table 1 are from a sample of 2,150 historic parks. Those that were lost, unused, or abandoned at the time of survey were made of iron, in whole or part. The maintenance demands of glasshouses (greenhouses) have led to many of these to fall into disrepair. Others have been restored for their intended purpose, or for multi function use.

The loss of iron structures in public parks may be attributed to neglect, vandalism, and inappropriate "restoration." A significant amount of public ironwork in particular was given up for the war effort, although it would appear that this was largely undertaken in order to engender a sense of participation since the wrought and cast iron used was either not of appropriate quality to be reused, or the volume given up exceeded demand.

Bandstands and fountains have been particularly vulnerable to deterioration or loss due to their high maintenance costs, with over half the stock of each being lost to use. This figure is likely to be higher since the survey assumed that those completing the forms were fully aware of all structures previously lost. In the author's experience, this is often not the case.

The primary force in funding the regeneration of urban and public parks in the last decade has been the Heritage Lottery Fund. Established in 1994 to distribute funds generated from the National Lottery, the Heritage Lottery Fund has dispersed over $6 billion to heritage projects in the United Kingdom, with $750 million awarded to public parks, squares, and historic cemeteries. While this has undoubtedly had a significant impact on the restoration of iron structures, much remains to be done.

Table 1. Loss of Iron Structures in Public Parks

Data adapted from Public Park Assessment, survey of local authority owned parks focusing on parks of historic interest, May 2001, Urban Parks Forum.

Feature	Total Number of Features	Lost	Unused	Abandoned	Total Lost	Percent of Total
Glasshouses (Greenhouses)	410	236	7	41	284	69.3
Bandstands	438	203	27	22	252	57.5
Fountains	449	141	26	59	226	50.3
Shelters / Pavilions	1,792	443	23	48	514	28.7
Ornamental gates	1,430	350	33	10	393	27.5
Bridges	1,041	72	9	17	98	9.4

The use of cast and wrought iron in the decorative and built fabric of public parks was prolific and often of exemplary quality. Iron may be found in gates, railings, fountains, bandstands, shelters, glasshouses, and many other features.

A significant architectural iron foundry industry developed in Scotland during the nineteenth century to meet the growing demand for sanitary goods, and later for decorative castings. The discovery of black band ironstone by Mushet in 1802 in conjunction with the development of the hot blast by Neilson in 1828 meant that the Scottish ironmasters could produce pig iron at a lower cost than their counterparts, and that the pig iron grade they produced was particularly suited to light architectural work due to its naturally high phosphorus (fluidity) and graphite (surface finish) content.[1] The growth in this field is evident in the number of companies specializing in such work. The Glasgow Post Office Directory for 1891 lists more than two hundred iron founders with architectural output alone.

Perhaps the world's most prolific architectural iron founder was Walter Macfarlane's Saracen Foundry in Glasgow (1850–1967). From an early beginning as a jeweller, Walter Macfarlane built the world's largest architectural iron foundry, capitalizing on the increasing market for such iron goods. In 1871, a new Saracen Foundry employing 1,800 was constructed on the green field site of Possilpark, which was transformed into a major suburb of Glasgow (Figure 1). The Saracen Foundry incorporated an impressive showroom where visitors could view the company's castings.

The Sun Foundry of George Smith (1858–circa 1899) was a competitor of Walter Macfarlane & Co., both of whom specialized in fountains and bandstands in particular. The Milton Ironworks of McDowall Steven (1834–1964), was an evolution of the earliest architectural iron founders with links to Carron Ironworks.

The last major architectural iron foundry, The Lion Foundry Co. (1880–1984) was established in Scotland by three workers from the Saracen Foundry. Aside from gates and railings, they specialized in park shelters and bandstands, later moving to the production of building facades as demand for park structures subsided. All of these firms manufactured an impressive array of park structures, which were for the most part exported

around the globe. Ironically, there are no architectural iron founders in Glasgow at present.

Planning and Conservation Today

The treatment of existing structures in a sensitive and practical manner depends on a good understanding of how the materials in question degrade and interact. An appreciation of the original manufacturing and construction processes employed can contribute greatly to the conservation and restoration of these structures. The treatment of extant structures requires philosophical fortitude, resourcefulness, and technical understanding. Principles of reversibility and minimal intervention are often difficult to reconcile with the technical demands of the materials, and there has been little formal research in the field. The author proposes that the sequential methodology described below be adopted for the restoration and conservation of iron structures.

Research

Understanding how the structure has been manufactured and assembled is particularly useful in considering any potential work whether it be repairs and restoration, dismantling, or relocation. Manufacturers' catalogues and trade literature are a particularly useful source of information. Archival photographs and postcards are often available, as park features were often recorded in this manner (Figure 2). Construction drawings and general layouts for projects are often held by local authorities. Makers' marks can often be found on cast iron items, with registration marks detailing the month and year of production. Wrought iron may be stamped with the manufacturer's details, and the iron bar may incorporate a merchant bar stamp. Material samples can provide positive identification of materials.

Assessment and Recording

A visual inspection on site may suffice or the structure may require a level survey (to measure any structural movement) or intrusive investigation. Good quality photographic recording is invaluable in any such effort. Identification of missing or damaged components should be undertaken based upon archival information and other extant structures. Fixings (fasteners) and constructional details should be examined and understood. Depending on the significance of the structure itself, photogrammetric survey or high quality drawn survey may be merited. Often, the full extent of repairs required is not immediately evident until dismantling and cleaning has been performed (particularly for cast iron structures). Therefore, a provisional agreed-upon sum for repairs should be incorporated within the contract sum.

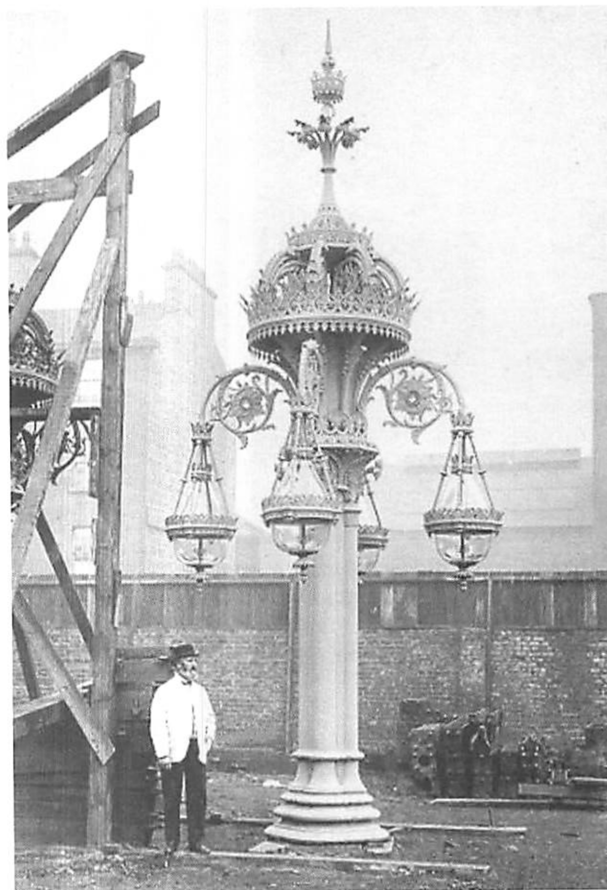

Figure 1. Walter Macfarlane, Junior, in the yard of Saracen Foundry circa 1900. Most products were trial assembled prior to shipping across the world. (Scottish Ironwork)

Paint sampling, with attention to areas that might be highlighted or gilded (column heads, fountain details), can help to determine the historic color. Victorian ironwork was often initially highly decorative in its finish but later overpainted in single colors as maintenance demands became too onerous. If the existing coatings are to be removed, an original sample of the scheme should be left for future reference.

For large structures such as glasshouses, databases can be employed to track and create object histories for the many thousands of components. This

Figure 2. Trade catalogues and archival images can provide valuable sources of information for conservation work. This illustration was used to recreate a destroyed Saracen Foundry shelter in Oldham. (Heritage Engineering, Glasgow)

method can also reference digital photographs to create a high quality conservation record (backed up by hard copy). Any dismantling of the structure should employ an effective recording technique coupled with the use of metal tags to identify individual components.

Materials

There is presently no commercial production of wrought iron in Europe or North America. The author is currently investigating manufacture in China and India as potential material sources, with some thought to establishing limited production in the United Kingdom by the conservation community. Until such production might be established, the use of recycled materials remains the only option. Other alternatives such as pure iron and Cor-Ten steel have been promoted as alternatives, but the lack of silicate slags do not allow for like replacement. The forgeability and corrosion resistance (due perhaps to the silicate slags which provide its fibrous nature) would still appear to make wrought iron the material of choice.

Grey iron is readily available, but sourcing high quality pattern making for architectural works is a significant problem in the United Kingdom, as is finding iron founders with the necessary skills and experience. Replacement castings should be moulded traditionally in green sand rather than modern foundry sands—the finish is often better in skilled hands and stimulating demand will help to perpetuate the craft skill. It is good practice to ensure that any new components for an existing structure are marked with the maker's name and dated for future reference (Figure 3).

Conservation and Restoration

Wrought and cast iron have been processed from ore in a reduction reaction. The resulting processed iron material seeks to return to a state of dynamic equilibrium or steady state, which is the ore-based form, by means of an oxidation reaction (corrosion). To effect this transition, the metal requires oxygen and moisture. Thus, the preservation of the iron form relies on sealing the iron.

Cleaning iron structures may be undertaken by a variety of means. Decisions about appropriate treatments should be considered in relation to the structure and material. Blast cleaning is less suitable for wrought iron than for cast iron as it removes the previously formed mill scale or stable oxide layer. Flame cleaning is particularly useful for fine repousée wrought ironwork, whereas a dry blast medium (using an inert grit or bead) works well for large columns and spandrels in cast iron. Microabrasive cleaning such as the JOS system (calcite particulate suspended in water) is useful for high quality work. The author has had some success with on-site cleaning using high pressure water blasting technology adapted from offshore oil production processes. Removal of putty from glazing bars or particularly heavy paint may require some hand tooling or pneumatic equipment. The skill of the operator in minimizing impact to the structure by controlling the blasting variables is of crucial importance. It is also critical to first undertake a series of test cleaning methods to ascertain the gentlest means possible to achieve the desired result without damage.

A painted finish is the most common form of protection applied. There is a philosophical consideration to be addressed here, since the application of a new paint system ideally requires bare metal, yet the original and subsequent decorative schemes form an integral part of the object's history. Much depends on the condition of the original (usually oil based) coating system, and consideration should be given to retaining elements of the original decorative scheme. As a porous material, cast iron acts as a moisture sink,

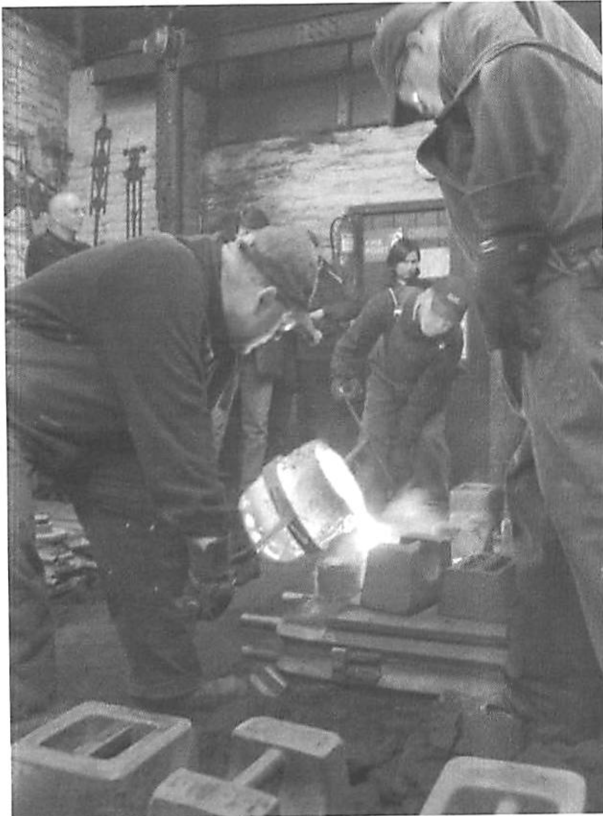

Figure 3. Casting grey iron into green sand molds at Beaverbank Foundry, Edinburgh, in 2004 (Copyright, D.S. Mitchell)

and the cleaning and coating of cast iron should be undertaken in a controlled environment in order to minimize relative humidity. For this reason cast iron structures are often best treated in a workshop environment. Similarly, the paint system chosen should allow for some moisture permeability. Some hard shell epoxy systems prevent this and cause subsequent corrosion problems beneath the coating layer. The thickness of the final paint system should be a balance between preserving the iron itself and guarding against a loss of detail by overpainting.

The author has used ferrous metal systems comprising zinc rich primers, micaceous iron oxide build coats, and proprietary gloss finishes, which have proven to be preferable on balance to epoxy systems. Traditional oil based systems also provide a good substrate for gilding. Gold leaf is always preferable to gold paint alternatives, which invariably discolor to brown.

The repair of wrought and cast iron is technically and ethically complex. It requires that a balance be struck between non-intervention and the maintenance of structural integrity—objectives that can be diametrically opposed. Repairs are by nature intrusive to some extent, but the preservation of historic fabric should always be the primary factor. The most successful philosophy is to approach the project with a variety of repair techniques, and consider each circumstance on an individual basis (Figure 4).

Electrode and gas weld repairs to cast iron are notoriously variable in consistency, but some good results have been achieved using high nickel electrodes. Plated repairs across fractures can be aesthetically unpleasing unless undertaken out of sight. Cold metal stitching, adapted from traditional engineering, has been utilized on ornamental ironwork with varying results. If undertaken poorly, it can have a negative visual impact. One United Kingdom ironwork specialist has successfully developed a weld technique using aluminium bronze as a substrate in an argon shield. Pinning of fractured ironwork with dowels and epoxy has been employed. Fiberglass repairs, while contentious, can be a reversible and successful approach. Repairs at the forge for wrought ironwork are to be recommended and can be most successful in skilled hands. Epoxy resin repairs can prove useful in building up corroded materials to prevent ponding of water on depressed surfaces.

The corrosion of wrought iron fixings and joints in cast iron structures is a common problem, and again poses a technical and ethical debate where replacement is required. Replacement in kind is an option, although an expensive one since the fixings will need to be hand made. Stainless steel is a common materials choice and works well if a sufficiently high grade is used, and phosphor bronze can be used in the right circumstances. Insulation between dissimilar metals is of critical importance and can be effectively achieved at little expense in most circumstances. There is a school of thought that galvanized fixings should be used since they will sacrificially corrode, with the fixing failing rather than the historic fabric.

The degree of intervention required to a structure where components are missing should be established at an early stage. Stabilization should only be considered for highly decorative wrought ironwork where the original morphology is unclear. Aesthetic demands may prompt missing components to be remanufactured, particularly where they are positively identified through archives or locations

Figure 4. Conservation challenges indeed—wrought iron delamination in a marine environment, Stornoway, Western Isles (Copyright, D.S. Mitchell)

of other extant examples. Any pieces manufactured should match the originals in materials, detail, and manufacturing process. The temptation to use silicone as a jointing medium should be resisted. Polysulfide mastics are a good alternative and pose less health risks. Traditional lead pastes have a track record of several hundred years and can be used without significant health issues.

Some structures, such as fountains, gates, and bandstands, to varying degrees lend themselves to pre-assembly in a workshop environment. The risk of damage to finished ironwork during handling requires careful attention. All fixings and repairs should be well planned beforehand in order that finished paint surfaces are not broken. Adequate packaging and handling of iron structures in transit benefits the client, contractor, and structure alike.

Replication

When undertaken, a reconstruction should match the design, materials, and philosophy of the original structure where possible. This is perhaps the most important means by which we can stimulate and perpetuate a demand for skills and materials. The author has experienced difficulties in remaking such structures, due to the demands of contemporary structural standards and in meeting access requirements.

A fountain canopy (Figure 5) was reconstructed to a Saracen design in Dun Laoghaire, Ireland. Though the original had been largely destroyed, a decision was made to use the materials and techniques employed on the original canopy to gain an understanding of the manufacturing process. Timber patterns were used with castings in grey iron, moulded in green sand. An original example in Glasgow served as a reference point. The project was challenging to the pattern maker and iron founder alike, but the result perhaps reflects the zenith of the historic craft.

In the early 1990s, a group of enthusiasts began to document in paper records the locations of iron structures made or found in Scotland, then within the United Kingdom, then further afield. A collection of archive images, postcards, and company literature was used as a means of identifying structures and manufacturers. The statutory lists of Historic Scotland were used as a basic framework but were quickly found to be lacking depth. The renewed interest in iron park features stimulated by the Heritage Lottery Fund programs encouraged the restoration of existing iron structures and often the reinstatement of bandstands and fountains. The ability to provide accurate archival information to assist in the restoration and conservation process prompted much interest and led to the establishment of www.scottishironwork.org in September 2003. The site provides an online database of iron structures made or found in Scotland, as well as manufacturing information and technical guidance. Structures that have been lost are also recorded to provide a reference point for those who might wish to reconstruct them in the future. Condition is recorded and where possible the responsible authority is notified when a listing is made. This effort has prompted moves towards restoration in a number of instances. At present, 120 bandstands have been recorded, with the database providing a means of profiling these according to the manufacturer's pattern or design number. In recent years lost bandstands originally manufactured in Scotland have been reconstructed following original designs in London, Middlesbrough, and Newcastle. The web site has served 38,000 sessions since its inception, and has answered approximately 400 technical and historical enquires to date. Such an online resource for iron structures may have applications in other countries to raise the profile of these important structures and promote sound conservation practice.

Figure 5. Dun Laoghaire Fountain Canopy, Dublin (Heritage Engineering, Glasgow)

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Notes

1. Samuel Smiles, *Lives of the Engineers*, vol. 3 (London: 1862).

Bibliography

Glasgow Post Office. *Glasgow Post Office Directories.* Glasgow, Scotland: 1830–1900.

MacLean, Angus. *Local Industries of Glasgow and the West Coast of Scotland.* Glasgow, Scotland: 1901.

Photo-Biographical Publishing Co. *Glasgow Contemporaries at the Dawn of the Twentieth Century.* Glasgow, Scotland.

Robertson, Graeme E. *Cast Iron Decoration: A World Survey.* London: Thames & Hudson, 1977.

Smiles, Samuel. *Industrial Biography, Ironworkers and Toolmakers.* London: 1879.

Trade Catalogues

Walter Macfarlane & Co Ltd, n.d., Saracen Foundry, Glasgow

George Smith & Co Ltd, n.d., Sun Foundry, Glasgow, Clippens and Alloa

Lion Foundry Co Ltd, n.d., Kirkintilloch

McDowell Steven & Co Ltd, n.d., Milton Ironworks, Glasgow and Falkirk

Metal Finishes and Coatings

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Metals are often major components of park structures, amusement parks, sports venues, and most other facilities where people play. Finishes and coatings protect the metals from deterioration, prolonging the lives of these facilities and helping to ensure that structural components do not fail. Where the metals are exposed, finishes and coatings also provide the desired appearance.

From the time humans began extracting metals from ores and alloying metals, they have been confronted by the changes metals undergo when exposed to the atmosphere. All metals commonly used in buildings and structures react when exposed to moisture, gases, and particles in the environment. The nature of the reaction between each metal and the atmosphere depends on how completely the metal is exposed to the air, the character of the metal surface, temperature, atmospheric pollutants, character of precipitation, how freely and frequently (if at all) water washes the surface, and the percentage of time that the metal remains wet.[1] On some metals, this reaction results in fairly stable and relatively impermeable surface layers—such as the green copper chloride and copper sulfate layers on copper and the clear chromium oxide layer on stainless steel—which greatly slow, and in some cases prevent, further interaction between the base metal and the environment. On other metals, exposure produces relatively unstable, flaky, porous layers—such as the iron oxides and hydroxides formed on ferrous metals—that do not protect the metal and, by collecting and holding moisture on the surface, can actually accelerate its deterioration.[2] Stable, relatively impermeable, uniform protective coatings are often referred to as patinas or natural conversion coatings. Unstable, permeable, uneven, unsightly coatings are referred to as corrosion, tarnish, deterioration, and rust.

For millennia, humans have attempted to prevent metals from deteriorating both by developing new metals and alloys with increasing corrosion resistance and by applying coatings that protect metals from contact with the atmosphere.[3] Although many of the traditional metallic coatings and some traditional paints are still used to protect metals from deterioration, some metallic coatings and a number of the most successful traditional paints are no longer in general use because they contain ingredients that are hazardous to humans or damage the environment.

The earliest protective coatings were undoubtedly greases, oils, and waxes, which are still used today—fats protect cast-iron cookware and oil and grease protect operating machinery. These coatings prevent or limit corrosion by forming a barrier, or at least a partial barrier, between the metal and the

atmosphere. Other types of barrier coatings include natural conversion coatings, enhanced natural conversion coatings, chemical conversion coatings, metallic coatings, and paints and finishes.[4] Some of these coatings also provide cathodic protection by becoming sacrificial anodes in galvanic systems, ensuring that the metals being protected become cathodes.[5] Coatings providing cathodic protection may or may not serve as barriers between the metal and corrosive agents in the atmosphere.

Metallic Coatings

For centuries, metals have been protected by thin coats of other metals. Metals used for coating include copper and copper alloys (brass, bronze, and nickel silver), tin, terne (tin-lead alloy), lead, zinc, nickel, aluminum, cadmium, chromium, silver, and gold. Metal elements may be coated by dipping into molten metal, electroplating, rolling using heat and pressure, spraying molten metal, depositing metal vapor, applying adhesive metal powder, applying metal leaf, and applying metallic paints. Metals often receive coats of two or more different metals to provide the desired protection and appearance. Ferrous metal hardware might be coated with copper to provide a smooth surface to receive further coating, nickel to provide a suitable substrate for the final coat, and a final silver finish.

Many of the traditional metallic coatings applied to ferrous metal—including tin, terne, and copper—are effective only as long as they form continuous, undamaged barriers. As these metals are nobler than ferrous metal, once the barrier is abraded or scratched and an electrolyte is present, the exposed base metal deteriorates. For this reason, traditional tinplate and terneplate roofing sheets were painted on all surfaces, including those that would be concealed, before installation.[6] Zinc, aluminum, and cadmium, three metals that are less noble than iron and steel, provide cathodic protection as well as barrier protection when applied as nonporous coatings.

Zinc is the most common protective metal coating for ferrous metal. The ferrous metal can be coated by hot-dip galvanizing (dipping objects into a tank of molten zinc or running coil stock through a tank of molten metal) or by electroplating, also known as electrogalvanizing (depositing metal using an electric current). Hot-dip galvanizing by dipping provides a relatively thick zinc coating; coil coating provides a significantly thinner coating; and electrogalvanizing provides a coating that is thinner still. Dipping ferrous metal in molten zinc does not simply provide a pure zinc layer on the base metal, as is the case with electrogalvanizing. When the ferrous metal is dipped into molten zinc, the chemical reaction provides a series of alloy layers between the ferrous metal surface and a nearly pure zinc top layer, each successive layer containing a greater proportion of zinc than the previous one.[7] Although the zinc coating applied during electrogalvanizing is relatively thin, an electroplated coating on a properly prepared substrate is soundly adhered and flexible enough to resist cracking when sheet metal is formed after galvanizing. Preparing ferrous metal surfaces to receive the zinc coating requires cleaning with a hot alkali solution to remove dirt, grease, and oil; using an acid bath or airborne abrasive cleaning to remove rust and scale; and fluxing the surface both to prevent oxides from forming and to promote bonding.[8]

Molten zinc, aluminum, or a zinc-aluminum alloy (commonly 85 percent zinc and 15 percent aluminum) can also be sprayed onto ferrous metal surfaces using compressed air, a process called thermal spray coating.[9] This process can be carried out on the site as well as in the shop and can be used in circumstances where hot-dip galvanizing is inadvisable, such as coating large cast-iron panels that might warp if submerged in molten zinc. The metal surface to be coated must be cleaned to the level of near-white blast cleaning or better and have a roughness, called an anchor pattern, of two to four mils to ensure a mechanical bond. The sprayed metal is normally applied six to eight mils thick. The quality of the thermal spray coating depends heavily on the applicator's experience and skill. Because thermal spray coatings are porous, they provide galvanic protection but not full barrier protection. They are often painted to achieve barrier protection as well. However, unpainted six-mil-thick thermal spray coatings have successfully prevented steel from corroding in salt-rich environments.[10]

Metallic zinc, in the form of small flakes or particles, can be mixed with a binder to form a paint, which can be applied as a protective coating on ferrous metal surfaces. The binder can be either inorganic or organic; in either case, the dry film should be greater than 65 percent metallic zinc. Inorganic zinc products typically have a silicate

binder, which reacts slightly with the substrate. These paints form porous coatings, which do not provide a moisture barrier. Salts that crystallize on the surface of the coating can form a barrier over time. Surfaces to receive inorganic zinc primers should be cleaned to near-white or white metal blast cleaning to prevent separation between the metal substrate and the zinc in the coating, which would inhibit protective galvanic action. Inorganic zinc coatings are tough and relatively abrasion resistant. They function well without topcoats.[11]

Organic zinc primers can use any of the modern polymers (e.g., epoxy, urethane, or vinyl) as binders. These nonporous paints provide barrier protection but, as the zinc is isolated from the metal substrate by the binder, are less effective as galvanic protection. Surfaces to receive these paints should be prepared to the level of commercial blast cleaning, which is a lesser requirement than that for surfaces to receive inorganic zinc primers. As application and topcoating are easier, organic zinc primers function better as base coats of coating systems than do inorganic zinc primers.[12]

Conversion Coatings

Rust conversion coatings are products that chemically react with adherent rust to form a sound substrate for paint. Phosphoric-acid-based coatings react with ferrous oxide to form a stable gray film of ferrous phosphate. Tannic-acid-based coatings react with rust to form a stable blue-black film of iron tannate. In preparation for rust conversion coatings, surfaces should be cleaned free of all contaminants and loose rust, leaving clean, sound substrates.[13]

Surfaces of new iron and steel elements or of existing iron and steel elements from which all corrosion and contaminants have been removed can be prepared for painting by applying a chemical that reacts with the metal to produce a thin, well-adhered surface coating known as a chemical conversion coating. Although these coatings provide varying amounts of corrosion protection and abrasion resistance, their chief function is to provide a superior substrate for paint. Chemicals used on ferrous metals, including phosphoric acid and its salts, produce iron, zinc, or manganese phosphates.[14]

Paints

Most paints consist of vehicles, solvents, pigments, and additives and can be classified based on their vehicles, which include oil, alkyd, acrylic, epoxy, urethane, silicone, fluorocarbon, coal tar, chlorinated rubber, and cement.[15] A paint system consists of the total series of coats or layers applied to the metal, usually one or more coats of primer, one or more intermediate coats, and one or more topcoats. Systems designed for maximum protection often include two coats of primer. Sometimes the system has only primer and topcoat. Structural elements protected from exposure often receive only a primer. The entire paint system must be flexible enough to expand and contract with the metal as the metal moves with changes in temperature.[16] The individual coats must serve different functions as well. The primer must thoroughly wet the substrate, firmly adhere to it, and prevent, or at least inhibit, corrosion at scratches and other faults in the coating. Each of the succeeding coats must bond to the previous coat and provide the appropriate proportion of the desired coating thickness. The topcoat, exposed to the atmosphere, must protect the surface from the surrounding environment and provide the desired appearance.

One of the most widely used traditional paints for cast iron, wrought iron, and steel was a primer of red lead ground in linseed oil, which forms protective lead soaps on the metal surface. This primer, followed by two coats of linseed-oil-based paint, provided a tough, elastic coating with superior corrosion protection.[17] Because lead is toxic to humans, this paint is no longer in general use. Another traditional paint consisted of micaceous iron oxide pigment ground in oil. This inert pigment consists of thin flakes of iron oxide, which align with the substrate forming a barrier coating. Paints formulated with this pigment, which can be incorporated in different vehicles, both traditional and elastomeric, are still applied as anticorrosion coatings for iron and steel.

Today, there are many different types of paints for ferrous metals, including those based on the vehicles listed above. Discussing the merits of all of these products is beyond the scope of this paper. However, some modern paint systems have performed well in protecting ferrous metal. One such system consists of the traditional sequence of three coats—a primer, an intermediate coat, and a finish coat. The primer is selected depending on

the amount of surface preparation possible. If the surface can be cleaned to near white metal, an inorganic zinc primer will provide superior protection. Less well-cleaned surfaces should receive an organic zinc primer. If it is not possible to provide even that level of surface preparation, an amine-cured epoxy or a polyamide-cured epoxy can be used. The intermediate coat over either an inorganic or an organic zinc primer should be an amine-cured epoxy; the intermediate coat over an epoxy primer should be a urethane. The finish coat should be urethane.

One modern paint that is widely used on shop-painted ferrous metal elements, which are baked after the coating is applied, is based on polyvinylidene fluoride (PVDF), a powdered transparent fluoropolymer resin, which is dispersed in a solvent with pigments. The pigments, which must withstand baking, are usually ceramic. In addition to high temperatures, they stand up well to chemicals and weathering. The paint is either spray-applied or applied by immersing the metal in a coating bath. When the coated element is baked, the particles dissolve and coalesce, forming a tightly adherent uniform barrier. Polyvinylidene fluoride coatings perform well when compared to other coating systems.[18]

Surface Preparation

The performance of a coating depends not only on the quality of the material and its suitability for the function for which it was selected but also on the preparation of the substrate. Often, limitations on the extent of surface preparation affect the selection of the coating. The ideal substrate is clean—free of contaminants that might adversely affect coating adhesion—with a roughness or anchor pattern appropriate to the selected coating to ensure mechanical bond. Metal surfaces can be prepared by removing corrosion and contaminants using airborne-abrasive cleaning, thermal cleaning, chemical cleaning, power-tool cleaning, and hand-tool cleaning. Following cleaning, a surface may be chemically treated to produce a conversion coating for improved adhesion.

Standards for different levels of surface preparation, ranging from removing loose rust and dirt using hand tools to removing all surface corrosion and contaminants using aggressive airborne abrasive blasting, have been developed by The Society for Protective Coatings and by NACE International.[19] Whatever the level of mechanical cleaning, oils, grease, and other substances that might interfere with the adhesion of a protective coating must be removed using an appropriate solvent. Workers, others that might be affected by cleaning operations, and the environment itself must be protected from harm caused by hazardous materials used and released during the cleaning process.[20]

When painting existing ferrous metal elements that cannot be dismantled and returned to the shop for surface preparation and painting, the degree to which the surface can be cleaned is often limited by site conditions. Constraints may include regulations on abrasive cleaning and use of volatile organic compounds, the need to protect adjacent materials, and ease of access. After the surface has been cleaned the primer should be applied before flash rusting, which can occur within hours, and before the surface is contaminated by dirt from surface preparation of adjacent metal, other construction operations, or the atmosphere. Coatings should be applied only when the temperature of the metal surface, the temperature of the surrounding air, the temperature of the paint, and the humidity are within the ranges recommended by the coating manufacturer and the metal surface is at least five degrees above the dew point.[21]

Selecting and Specifying Coatings

The selection of coatings for metals should be based on all of the factors affecting the metal and its environment including the type of metal, the location (whether it is an interior or exterior surface and, if the latter, whether it is in a rural, urban, or industrial environment), adjacent materials, desired appearance, desired performance, level of surface preparation that can be expected, whether the work is to be done on the site or in the shop, legal restrictions on volatile organic compounds, initial cost, and life-cycle cost.[22]

Coating specifications should include material type and quality; qualifications of the firm(s) preparing the surfaces and applying the coating; qualifications of personnel applying the coating; requirements for mock-ups, quality control panels, and field samples; requirements for surface preparation; conditions under which the coating is to be applied (allowable ranges of temperature and

humidity and requirements for control of dust); application method and procedure; coating thickness; curing conditions and duration; quality control requirements (provisions for evaluating surface preparation, material composition, dry film thickness, and adhesion); and procedures for repairing damaged coatings and replacing noncompliant coatings.

Conclusion

Metals are widely used in historic buildings and sites designed for play. The maintenance and restoration of these historic resources require that the metals used in them be properly identified and their conditions evaluated. In some cases, metals may form their own protective coatings by reacting with the atmosphere; in other cases, original protective coatings may require only repair or replacement in kind; and in still others, severely deteriorated elements may require major repair or replacement. Many times, however, it may be necessary to provide an appropriate new coating to prolong the life of a metal element, to renew its appearance, or both. Those responsible for maintaining and restoring metal on historic resources should evaluate the factors that affect the selection, application, and performance of coatings on metal; select an appropriate coating; and specify proper surface preparation and coating application. Metal that is properly protected from corrosion can remain functional and decorative indefinitely.

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Notes

1. Leygraf and Graedel, *Atmospheric Corrosion*, provides in-depth analyses of the causes and effects of atmospheric corrosion on metals.

2. Metals undergo many types of corrosion, including general or uniform corrosion, pitting corrosion, stress-corrosion cracking, corrosion fatigue, intergranular corrosion, filiform corrosion, crevice corrosion, galvanic or bimetallic corrosion, fretting corrosion, erosion corrosion, and selective leaching or demetalification. Atmospheric corrosion is generally uniform corrosion or pitting corrosion. Extensive information on the different types of corrosion can be found on several web sites, including www.corrosion-doctors.org. NACE International (formerly The National Association of Corrosion Engineers, www.nace.org) publishes books and journals containing information on all types of corrosion. Gayle, Look, and Waite, *Metals in America's Historic Buildings*, and Weaver, *Conserving Buildings*, discuss metal corrosion specifically in the context of metals in historic buildings.

3. Gayle, Look, and Waite, *Metals in America's Historic Buildings*; Walker, *Corrugated Iron and Other Ferrous Cladding*; and Zahner, *Architectural Metals*, discuss at length types of coatings for metals.

4. Examples of natural conversion coatings include, in addition to chromium oxide on stainless steel mentioned above, aluminum oxide on aluminum, and titanium oxide on titanium. Providing an electrochemically thickened aluminum oxide coating on aluminum, an enhanced natural conversion coating, is called anodizing. Metallic coatings are discussed below.

5. Galvanic corrosion occurs when two dissimilar metals are in electrical contact in the presence of an electrolyte. In this system, which functions in the same way as a battery, the metal that is lower in the galvanic series (baser metal) will become the anode, and the metal that is higher in the galvanic series (nobler metal) will become the cathode. The anode will deteriorate. Removal of any of the requirements for corrosion (dissimilar metals, electrical connection, or electrolyte) prevents galvanic action and protects the metal. Coating metal with a less noble metal, which protects the substrate by becoming the anode and corroding sacrificially, is called sacrificial anode cathodic protection. For the galvanic series see Gayle, Look, and Waite, *Metals in America's Historic Buildings*, 134.

6. Gayle, Look, and Waite, *Metals in America's Historic Buildings*, 104, 105.

7. *Zinc Coatings*, 7.

8. *Zinc Coatings* provides an evaluation of different types of zinc coatings including hot-dip galvanizing and electrogalvanizing.

9. The metal to be deposited can be supplied as a wire or a powder and can be melted using a gas flame or electric arc. In one of the most common procedures, zinc-aluminum alloy wire is fed to a nozzle where it is melted by an oxyacetylene flame and propelled towards the metal surface by compressed air.

10. Thermal spray coating has proven to be an effective method of protecting bridges and other highway structures from corrosion. The Society for Protective Coatings (SSPC), American Welding Society (AWS), and NACE International (NACE) have developed a joint standard for thermal spray coatings: SSPC-CS 23.00/AWS C2.23M/NACE No. 12, *Specification for the Application of*

Thermal Spray Coatings (Metallizing) of Aluminum, Zinc, and Their Alloys and Composites for the Corrosion Protection of Steel.

11. Weismantel, *Paint Handbook,* 4-53–4-54.

12. Weismantel, *Paint Handbook,* 4-17.

13. Binnie, "Commercial Rust Converters."

14. Stoye, *Paints, Coatings and Solvents,* 196–198.

15. Paint includes liquids and powders containing pigments that on application and curing form opaque films with protective and/or decorative properties. There are many different ways of classifying paint ingredients. Not all paints contain solvents.

16. A 10-foot-long ferrous metal element expands and contracts approximately 5/64 inch with a change in temperature of 100 degrees Fahrenheit. Metal exposed to the environment may experience an air temperature range of 120 degrees Fahrenheit during the course of a year and an even greater internal temperature range caused by solar radiation. The coating must be flexible enough to accommodate this movement.

17. Gale, Look, and Waite, *Metals in America's Historic Buildings,* 137.

18. Stoye, *Paints, Coatings, and Solvents,* 28.

19. The Society for Protective Coatings was formerly the Steel Structures Painting Council [www.sspc.com]. The surface preparation standards can be referenced in specifications to establish the desired level of surface preparation.

20. Possible hazardous materials include lead dust and fumes, fumes from organic solvents, and particles of abrasives and of coatings and metal removed by the abrasives.

21. The adhesion of paint to metal can be adversely affected by rust not visible to the unaided eye and by condensation on the metal.

22. Volatile organic compounds (VOCs) are compounds that contain the element carbon in their molecular structure and that vaporize easily at room temperature. These compounds participate in atmospheric photochemical reactions. The VOC content of a coating product is the weight of volatile organic compound content per volume of coating (grams per liter or pounds per gallon). Current federal VOC emission standards for architectural coatings were enacted in 1998. The allowable VOC content varies with the type of coating as defined in the regulations (e.g. flat coatings, non-flat coatings, lacquers). Some jurisdictions have enacted regulations with VOC limits lower than those of the federal standards.

Bibliography

Binnie, Nancy. "Commercial Rust Converters: Surface Preparation for Rusted Iron." Ottawa: Canadian Conservation Institute, 1 April 1992. http://www.cci-icc.gc.ca/about-cci/cci-in-action/view-document_e.aspx?Type_ID=8&Document_ID=32.

Gayle, Margot, David W. Look, and John G. Waite. *Metals in America's Historic Buildings: Uses and Preservation Treatments.* Washington, D.C.: Preservation Assistance Division, National Park Service, U.S. Department of the Interior, 1992.

Hornbostel, Caleb. *Construction Materials: Types, Uses and Applications.* 2nd ed. New York: John Wiley & Sons, 1991.

Hornsby, M. J. *Hot-dip Galvanizing: A Guide to Process Selection and Galvanizing Practice.* London: Intermediate Technology Publications, 1995.

Leygraf, Christofer, and Thomas Graedel. *Atmospheric Corrosion.* New York: John Wiley & Sons, 2000.

Stoye, Dieter, ed. *Paints, Coatings and Solvents.* New York: VCH, 1993.

Walker, Bruce. *Corrugated Iron and Other Ferrous Cladding.* In association with Christopher McGregor and Gregor Stark. Technical Advice Note 29. Edinburgh: Historic Scotland, 2004.

Weaver, Martin E. *Conserving Buildings: Guide to Techniques and Materials.* With Frank Matero. New York: John Wiley & Sons, 1993.

Weismantel, Guy E., ed. *Paint Handbook.* New York: McGraw-Hill, 1981.

Zahner, L. William. *Architectural Metals: A Guide to Selection, Specification, and Performance.* New York: John Wiley & Sons, 1995.

Zinc Coatings. Englewood, Colorado: American Galvanizers Association, 2000. http://www.galvanizeit.org/resources/files/AGA%20PDFs/T_ZC_00.pdf.

63rd Street Beach House

Repair and Matching for Historic Concrete

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The 63rd Street Beach House, also referred to as the 63rd Street Bathing Pavilion, is located on the Lake Michigan shore just south of downtown Chicago, Illinois. Built in 1919 and designated a City of Chicago Landmark in 2004, the beach house was influenced by the nearby South Shore Country Club (Marshall and Fox, 1906) and Daniel H. Burnham's buildings for the Chicago parks (Figure 1).[1]

The beach house fell into disrepair in the second half of the twentieth century. In response to the building's deteriorated condition, in the 1990s the Chicago Park District initiated a project to assess and restore it. A condition assessment and inspection was undertaken beginning in 1997. The objective of this phase was to establish both the physical condition of the beach house and to prepare a series of options related to rehabilitation. Subsequently the Park District undertook a rehabilitation program in 1998–1999. The rehabilitation of the 63rd Street Beach House presented a variety of philosophical and technical issues, similar to those faced by many historic buildings being updated for modern public use. This paper focuses on the concrete restoration portion of the project, which involved field trials, a cleaning program, and repair of the concrete facade.

History

The 63rd Street Beach House in Jackson Park overlooks the Lake Michigan shoreline and an expanse of sandy beach. The pavilion is an important visual landmark in Jackson Park, one of Chicago's larger parks designed by Frederick Law Olmsted and named after President Andrew Jackson. The original plan for a bathing pavilion, developed by Olmsted and Calvert Vaux in 1871, was not implemented because the park plans were among those lost when the Great Fire of that year destroyed the Chicago South Park Commission administrative offices.

In 1890, Olmsted recommended the site of the unfinished Jackson Park for the World's Columbian Exposition, slated for Chicago in 1893. Olmsted, his assistant Henry Codman, Daniel Burnham, and John Wellborn Root were active in the design of the fair grounds. The World's Columbian Exposition in Chicago was a catalyst in the City Beautiful Movement, although most of the buildings of the fair's "White City" were not intended to be permanent. Following the Columbian Exposition, the firm of Olmsted, Olmsted, and Eliot continued planning Jackson Park, following Olmsted's original 1871 plan of lagoons with islands, peninsulas, and landscaped shoreline.

Figure 1. The lake side of the beach house probably in the 1940s (Chicago Park District, Department of Special Collections)

Figure 2. The lake side of the beach house after the rehabilitation project in 1995 (Leslie Schwartz Photography)

One of the significant architectural features of the park design was the 63rd Street Beach House. Designed by the South Park Commission's in-house architects, the pavilion was modeled on designs by D.H. Burnham and Company for other earlier buildings in Chicago's South Side parks.

The beach house exemplified the increased popularity of sports and recreation—especially swimming and boating along oceanfronts and lakeshores—in late-nineteenth century America. In Chicago, the popularization of lakeshore activities, including swimming, was made possible by major engineering improvements in 1899 when the city completed construction of a drainage canal, which changed the flow of the Chicago River so that sewage no longer emptied into Lake Michigan. In 1905, the City of Chicago's Special Park Commission took over management of municipal beaches and began planning for bathing pavilions to provide changing rooms, rest rooms, and other facilities for park visitors. In 1916, the Clarendon Municipal Beach opened in Lincoln Park, just north of downtown Chicago, featuring an impressive bathhouse designed in a Neoclassical style with two towers similar to the eventual design of the 63rd Street Beach House. The Clarendon Municipal Bathhouse, much altered now, has been converted to a community center.

Olmsted envisioned a bathing beach and pavilion at Jackson Park as early as 1895. Finally, in 1917, the South Park Commission architects developed plans for the pavilion. A ten-acre beach extension was filled in between 1916 and 1917, before the pavilion construction. Construction was slowed by restrictions on building materials during the First World War. The beach house was finally opened on 14 June 1919 at a construction cost of $173,000.[2]

The new pavilion measured 460 feet long by 145 feet wide. Its construction featured poured in place exposed aggregate concrete walls and green tile roofing. The symmetrical plan was organized around two enclosed courtyards, and featured a two-story loggia, open arched second story, and two towers with Neoclassical pilasters and brackets, wide eaves, and pyramidal roofs. Smaller towers flanked the principal entrance, and on the beach side a promenade overlooked the lake. Indoors, facilities included dressing rooms, showers, and lockers to accommodate about 2,000 women and 4,000 men.

Taking inspiration from the White City at the Columbia Exposition, the facades were expressed in the exposed aggregate concrete that became known as "marblecrete" or "popcorn concrete." The South Park Commission employed this type of concrete in many of its parks buildings because the material was inexpensive and facilitated rapid construction and easy replication of details and ornament.

Although the beach house is a recognized visual landmark and historic feature of the park, it fell into disrepair through exposure to the elements and reduced maintenance. Concrete decorative

Figure 3. Wall construction of the Beach House with lift lines between concrete placements. Note the intentional inconsistency of the placement and variable aggregate exposure. (Wiss, Janney, Elstner Associates, Inc.)

Figure 4. Severe deterioration of a concrete ornamental bracket below a balcony. The deterioration was due to corrosion of embedded reinforcing steel. (WJE)

features were the most severely deteriorated, especially areas of fine architectural detail that had eroded and in some cases dislodged and fallen off.

In the late 1990s, the Chicago Park District implemented an $8 million rehabilitation program to return the beach house to its intended function. In this project, the concrete was repaired, the original tile roof restored, and the large open-air courtyards restored (Figure 2). The following discussion addresses the investigation and work methods used for repair of the exterior exposed aggregate concrete on this interesting structure.

Technical Considerations

The original architectural concrete used for the exterior walls of the beach house was composed of 2 parts portland cement to 3 parts sand and 9 parts broken stone. This composition represents a mix proportion of 1:1.5:4.5 for the architectural concrete. A commonly used concrete mix today is closer to 1:2:3. For the reinforced concrete section of the building, the original specified concrete mix was 1:2:4, which is much closer to a modern mix.

The original specification described the required concrete placement as follows:

> It shall be mixed comparatively dry, with just enough water to make it hold together when a ball of the fresh concrete is squeezed by hand, and so when tamped in the form no free water or free mortar flushes to the surface. The concrete shall be deposited in even horizontal layers not exceeding eight inches . . . the exposed concrete shall be left just as they are when the forms are removed . . .[3]

This type of placement technique resulted in concrete that had significant exposed aggregate, air voids throughout the matrix, and an overall appearance that was intentionally to be inconsistent.

The exterior walls of the beach house are primarily unreinforced concrete, although localized areas are reinforced. The walls were placed in horizontal lifts (Figure 3). The top of each wall was covered with a cement mortar layer to provide greater water resistance. Reinforcing steel was used in structural applications around openings in walls, columns, arches, slabs, and beams. By the 1990s, many of these areas exhibited deterioration due to corrosion of embedded steel resulting in cracking and spalling of the concrete (Figure 4). Paste erosion was more severe in areas exposed to weather than in protected areas. Paste erosion resulted in aggregate becoming loose and eventually falling away. Other problems included a variety of conditions such as non-matching and failed previous concrete repairs, graffiti, and soiling of the concrete surfaces.

Technical considerations included designing appropriate repairs for the cracked and spalled concrete and the corroded reinforcing steel; matching the original aggregate and the paste color; creating an intentionally inconsistent appearance

through placement techniques and the repair concrete mix design; cleaning the existing concrete, including removal of graffiti; and replication of architectural details.

The conservation and effective repair of the beach house concrete is dependent on an understanding of the nature of the material, the pathology of deterioration, and the available repair technology and craftsmen. The challenge of this project was to execute repair work that would perform well and match the appearance of the original, existing materials. The following discussion summarizes the phases of the concrete repair project, including the investigation, laboratory analysis of materials, development of the concrete repair mix, trial repairs, and the repair program.

Investigation

The purpose of the investigation was to determine the causes of the deterioration and to develop a plan for the rehabilitation of the facades. The primary types of distress found in the beach house were cracking and spalling of the concrete, paste erosion, and freeze-thaw distress. The investigation consisted of a review of available documentation; an initial visual inspection; a hands-on, close-up examination; and sample removal and laboratory analysis of the construction materials.

The goal of the investigation phase was to evaluate existing conditions and distress. Many of the original drawings and the original specifications were available for review in the collection of the Chicago Park District. It is rare to have access to the original specifications, and they were a very valuable resource. Visual examination of the facade was performed from grade and the loggia, and samples of the concrete were removed at selected locations.

Previous repairs had been performed on the building but were not documented in the building records. These repairs appeared to have been undertaken several times over the life of the building. During the detailed examination, the investigators made inspection openings to assess the condition of these repairs and to determine the repair techniques used.

From these examinations, investigators found that crack repairs had consisted of application of a mortar slurry and hand placed aggregate over the cracks. The repair material did not match the original concrete paste in color or depth of aggregate exposure. The previous repairs were found to be cracked, delaminated, and debonded from the original concrete. In some locations, severely deteriorated original architectural concrete walls had been replaced with a ready-mix concrete with a formed finish as a temporary solution. The previous repairs were very noticeable and had a negative aesthetic effect on the building's overall appearance.

Laboratory Analysis

After the field investigation and as part of the repair design, the removed materials were analyzed to determine material components, composition, and causes of deterioration. Laboratory studies of the concrete included petrographic evaluation following ASTM C856 and tests to determine air content, water-cement ratio, cement content, general aggregate identification, carbonation depth, and chloride content.

The petrographic evaluation provided a general identification of the original concrete's components and aggregates. This information was needed to develop a mix design for the repair concrete. The petrographic studies revealed that the original concrete was made with a crushed limestone aggregate that has been used in the Chicago area for many years. The fine aggregate was found to be composed of siliceous sand that is probably also local.

Deterioration of concrete in building facades is generally related to two principal causes: corrosion of embedded steel or deterioration of the concrete itself. In Chicago's climate, freeze-thaw damage also occurs when concrete is critically saturated with water and then exposed to freezing temperatures resulting in expansive forces from cyclic freezing water. This destructive process led to deterioration of the concrete and was most severe at lift lines, joints, architectural details, and other areas with more exposure. Modern concrete utilizes entrained air (the incorporation of microscopic air bubbles), to provide protection for the concrete against damage due to cyclic freezing action. The use of air-entrained concrete in a structure from the early 1900s would not be expected. Air entrainment, did not gain popularity

in buildings until the middle of the twentieth century, particularly with increasing use of concrete in high-rise construction.

Corrosion of steel can occur where embedded reinforcing steel is not protected by the concrete's normal alkaline environment. Carbonation, which results from the reaction of carbon dioxide with calcium hydroxide and moisture in the concrete, causes a reduction in alkalinity (pH). When carbonation extends to the level of the reinforcing steel, the concrete no longer provides a protective alkaline environment and therefore no longer protects the steel from corrosion. As expected, carbonation was found to be a major factor in deterioration in the samples evaluated.

Corrosion of embedded reinforcing steel also occurs in the presence of sufficient chloride ion, and exposure to water or high humidity levels. Protection of the reinforcing steel is directly related to depth of concrete cover.

Laboratory analysis of the concrete samples confirmed the specified low cement content and a variable, moderate to moderately high, original water-to-cement ratio. In addition, microscopic examination revealed that the variation in the amount of exposure of the aggregate particles on the surface was due to differential dissolution of exposed cement paste. The more that water from rainfall scrubs the surface of concrete, the more the cement paste is dissolved and washed away, exposing the aggregate. This weathering process is typical of concrete surfaces.

Rehabilitation Strategy

The goal of the project was to repair the exterior concrete, address deterioration of other exterior elements of the facade, and reduce the rate of future deterioration of exterior building materials. The primary objective of the repairs was to use materials and techniques that would be sympathetic to the existing facade and perform well. Finally, the repair design needed to meet the intentionally high installation tolerances used in the original construction. The concrete was installed in a variable fashion without straight lift lines to match the original concrete.

In order to achieve these goals, the project was organized in three phases: development of trial repair materials and procedures; performance of repair work at a trial area on the building; and performance of repair work on the rest of the building facade. Trial mixes and repair techniques were evaluated to determine how to best match the original appearance while providing a durable repair. The implementation of repairs at one trial area permitted technical and aesthetic evaluation of the final product and an assessment of the scope of work and the contractor's procedures. Information gathered in the first two phases was invaluable in refining the requirements for the project.

Repair Program

Phase 1 focused on developing a mix design for a repair concrete to match the original. The first challenge was to identify aggregates, sand, and cement in the original concrete. Laboratory analysis revealed that the coarse aggregate was a crushed stone composed primarily of dolomitic limestone and the fine aggregate was natural sand. The cement was buff/white in color. The coarse aggregate consisted of flat, elongated pieces placed in a horizontal pattern during original construction. This type of aggregate is not often used today and is difficult to locate. The buff-colored cement, not commonly used or produced today, was more difficult to obtain that typical white or grey cement.

Testing during the project helped in maintaining consistency in the repair materials. The testing parameters were developed during the trial repair phase so that they could be evaluated and adjusted prior to implementation of full-scale repairs. Initial parameters developed for laboratory or field testing, included slump (ASTM C143, *Test Method for Slump of Portland Cement Concrete*), air content (ASTM C231, *Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method*), and compressive strength ASTM C39, *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*. Slump (measured by ASTM C143) is a measure of the concrete's workability and consistency, which determines its ability to be consolidated properly within the forms and repair areas. A slump test is performed by placing fresh concrete into a cone, removing the cone, and measuring the vertical distance the concrete settles. During original construction, the architectural concrete was placed with no slump to achieve the desired appearance. The repair concrete was placed utilizing a similar technique.

All concrete repair materials were placed into formwork with a minimum depth of approximately 3 inches. Trowel-applied thin patches, repair materials installed without forms, were not used. Formed patches with greater depth from the exposed surface provided more room for proper placement of the repair concrete and resulted in a more consistent and a more durable repair. The formed patches were anchored to the original concrete with reinforcing steel. For architectural concrete, this required the addition of reinforcing steel that was anchored into the original adjacent concrete within the patch area. In areas of reinforced concrete requiring repair, the original reinforcing steel was exposed by excavation of existing unsound and sound concrete to a minimum depth of 3 inches. This removal process exposed the original reinforcing steel and allowed installation of new reinforcing steel within the patch to provide more substantial mechanical attachment to the structure. The repair concrete was air entrained by the addition of an admixture during the mixing process and the air content was measured.

Three types of repairs were performed: architectural concrete walls, reinforced concrete with a formboard finish, and precast ornamental concrete.

Numerous small samples were prepared in forms, separate from the building. The samples used a variety of mixes, with different proportions of buff-colored cement and aggregate components, and different placement and finishing techniques. It was difficult to match the appearance of the existing concrete because of the varying degrees of paste erosion and resulting aggregate exposure, inconsistent lift lines, and architectural details. Early mock-up samples during the selection of aggregate and depth of aggregate exposure are shown in Figure 5. Several finishing techniques and procedures were developed to allow the contractor to selectively vary the exposure of aggregate in the concrete to match the appearance of the original adjacent concrete. Some of the surface finishing techniques evaluated included the application of a surface retarder, low pressure water blasting, and hand brushing. When a spray-applied surface retarder or brush-applied form retarder were used, care had to be used to prevent the resulting appearance from being overly uniform or having too much aggregate exposed in comparison with original concrete. The most

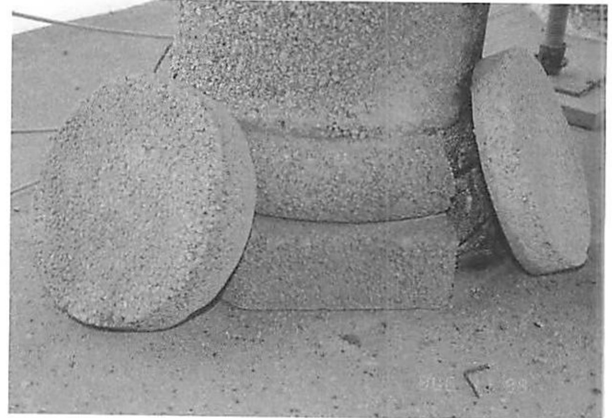

Figure 5. Concrete samples of various coarse aggregates and different exposure levels (WJE)

Figure 6. Craftsman placing and finishing repair concrete in a mock-up area. The craftsman developed techniques to maintain an inconsistent aggregate exposure to match the variability in the original adjacent concrete. (WJE)

Figure 7. Placement of architectural concrete along the projecting edge of the upper terrace. The concrete was placed against formwork with a concrete retarder and then hand finished to match original concrete. (WJE)

effective finishing techniques involved a combination brush application of a retarder onto forms, very light water spraying, and hand brushing. Once the finishing techniques were refined, the proportions of aggregates and the buff/white cement mixture were adjusted.

Previous crack repairs using a repair mortar material were unsuccessful in bridging cracks and in preventing moisture from entering the concrete. As a result, the original concrete surrounding the repair continued to deteriorate and in reinforced concrete areas the embedded reinforcing steel continued to corrode and deteriorate. The new repairs used a concrete that was similar to the original material and visually blended to the surrounding concrete.

After the repair mixes and finishing procedures were finalized, a mock up repair was performed in an accessible and unobtrusive portion of the building (Figure 6). Refinements to the mix and placement procedure were made during the mock-up. For example, placement of the one mix design during the sample preparation was unsuccessful because the water content was too high and the concrete flowed too readily, resulting in better consolidation of the concrete within the patch than was needed; less consolidation was desired to match the original concrete while still providing a durable repair.

Surface preparation is one of the most important components of any concrete repair. The steps followed at the beach house are fairly typical of concrete repair work. However, the removal of concrete was slightly more aggressive within the patch area, to provide better encasement of the reinforcing steel within the patch and to improve the performance of the patch. In some cases, removal and replacement of entire concrete elements was needed (Figure 7). Precast concrete was used in some areas where the architectural detail would not allow for in place repair (Figure 8).

Conclusion

During the sample repairs, procedures and materials were adjusted to achieve a concrete repair that matched the adjacent original concrete in appearance and met the established criteria for good concrete repair practice. The process of investigation, laboratory analysis, trial samples, mock-ups,

Figure 8. Replacement precast concrete bracket that was installed below the balcony (WJE)

and full-scale repairs allowed refinement of the repair design, maintaining consistency of installation procedures while achieving the desired varied appearance, and implementation of quality-control measures as the project progressed. A preservation approach was used to guide technical and engineering decisions, resulting in repairs that perform to modern practice standards and are aesthetically successful.

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Notes

1. *63rd Street Bathing Pavilion: Landmark Designation Report.* Chicago, Illinois: Staff of the Commission on Chicago Landmarks, June 2004; revised September 2004.

2. "Chicago Municipal Improvements: The Bathing Pavilion at Jackson Park," *American Architect* 116, 8 October 1919, 461–465.

3. *Specifications for a Bathing Pavilion in Jackson Park for the South Park Commissioners, Chicago, Illinois.* Bids received 4 April 1917.

Soldier Field
Protection Methods for Historic Concrete

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Soldier Field, designed by Holabird and Roche and constructed between 1922 and 1926, is a concrete stadium located along Chicago's lakefront. The stadium is operated and maintained by the Chicago Park District. Its original structural system consisted of reinforced-concrete treads and risers, or stepped slabs spanning the concrete raker beams, which in turn spanned reinforced-concrete columns founded on timber piles (Figure 1).

The facade is assembled from hollow cast stone blocks, and the 136 columns that line the east and west colonnades were constructed of hollow cast stone rings stacked in segments. Formulated to resemble granite, the cast stone for Soldier Field was one of the first and most prominent works of the Benedict Stone Company, a firm founded in 1919 by James Benedict of New York. From 1919 to 1930, this company supplied cast stone for more than a hundred buildings from Illinois to New York, as well as in Canada and Australia.[1]

The structural frame, coffered ceilings, and colonnade roofs were cast in place. The formwork for the visible elements of the colonnades was lined with a 2-inch thick layer of architectural concrete formulated to resemble granite. Before this architectural concrete layer set, the interiors of the forms were filled with structural concrete backup. The result was two-layer, monolithic cast-in-place construction. The concrete was site-batched, raised vertically in tall scaffold towers, and then delivered by long, angled chutes down to the point of placement, sometimes as high as 110 feet above grade (Figure 2).

At a construction cost of $13 million, the stadium was completed and dedicated in 1926 in honor of the soldiers of the First World War. Figure 3 shows the nearly completed west colonnade. Over the years the stadium has been used for myriad public events, including football, boxing, soccer, midget-car races, concerts, and other assemblies. Currently the stadium is the regular season home of the Chicago Bears national football team.

Working for the Chicago Park District, Wiss, Janney, Elstner Associates, Inc. (WJE), assisted with the design of major strengthening repairs that were part of the substantial renovation of the stadium in the late 1970s. WJE has inspected the stadium and recommended repairs as appropriate nearly every year since. The renovation and partial reconstruction of Soldier Field, designed by others, was completed in 2003. The interior of the original stadium was replaced with a new stadium structure—but the facade, colonnades, and exhibition halls at the stadium perimeter were retained and

renovated. WJE was a consultant on the repair of the historic concrete portions of the stadium that were retained but was not involved in the redesign of the new stadium elements.

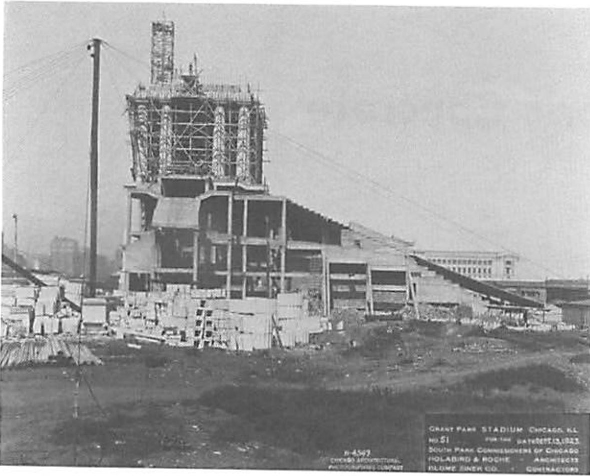

Figure 1. Soldier Field, Chicago, cross section through structure and seating, 1923. Note that the stadium is identified as Grant Park Stadium; it was renamed Soldier Field within a year. (Chicago Park District Special Collections)

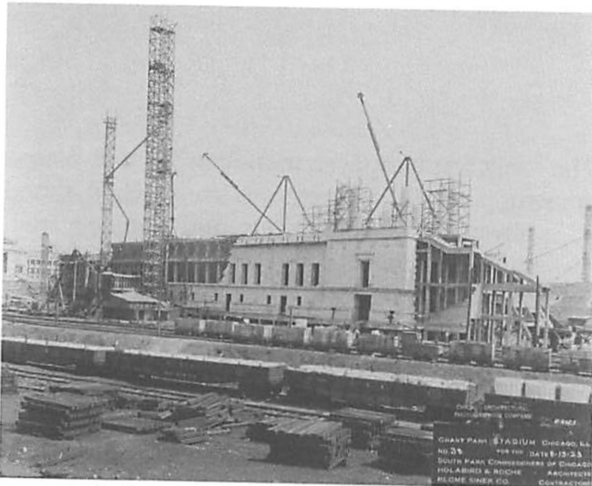

Figure 2. Concrete batching and delivery underway, 1923 (Chicago Park District Special Collections)

Figure 3. Completed west colonnade, 1924 (Chicago Park District Special Collections)

Concrete Durability Challenges

High chloride content in the concrete in the coffered ceilings. Over the years the heavily reinforced-concrete beams in the colonnade's coffered ceilings delaminated and spalled due to corrosion of the embedded reinforcing steel (Figures 4 and 5). The distress was attributed to the high chloride content of the architectural face mix. High chlorides were not present in the structural concrete backup. Calcium chloride was apparently added to the face mix during original construction, either to facilitate the two-layer placement or to accelerate the set of the concrete during winter construction. Corrosion of reinforcing steel is a well known electrochemical phenomenon, in which iron is oxidized at an "anodic" location on the steel and oxygen is reduced at a "cathodic" location on the steel.[2] Under normal conditions the high alkalinity of concrete (12.5 to 13.5 pH) produces a protective layer, or passive film, on the embedded reinforcing steel, which mitigates the corrosion reaction. However, when chloride ions are present, the steel reacts readily with the chloride ions, water, and oxygen to form ferrous oxide and ferric oxide, commonly known as rust. Corrosion of the steel results in a significant volumetric increase, which can cause the surrounding concrete to crack, delaminate, and eventually spall.

Deep carbonation in the exhibition hall concrete. The overhead concrete in the exhibition halls, particularly the main transfer beams, has also deteriorated over the years due to reinforcing steel corrosion (Figure 6). However, the deterioration in the exhibition hall concrete can be attributed primarily to deep carbonation, not high chlorides, in the concrete. Carbonation is a natural process in which carbon dioxide in the air reacts with calcium hydroxide in the concrete to form calcium carbonate and water. When concrete carbonates to the level of embedded reinforcing steel, the alkaline environment around the reinforcement, which normally protects the steel, is disrupted. If sufficient moisture and oxygen are present, corrosion of the embedded reinforcing can occur. The depth of carbonation in the exhibition hall concrete ranged from 1 to 3 inches, which is at or beyond the level of the reinforcing steel.

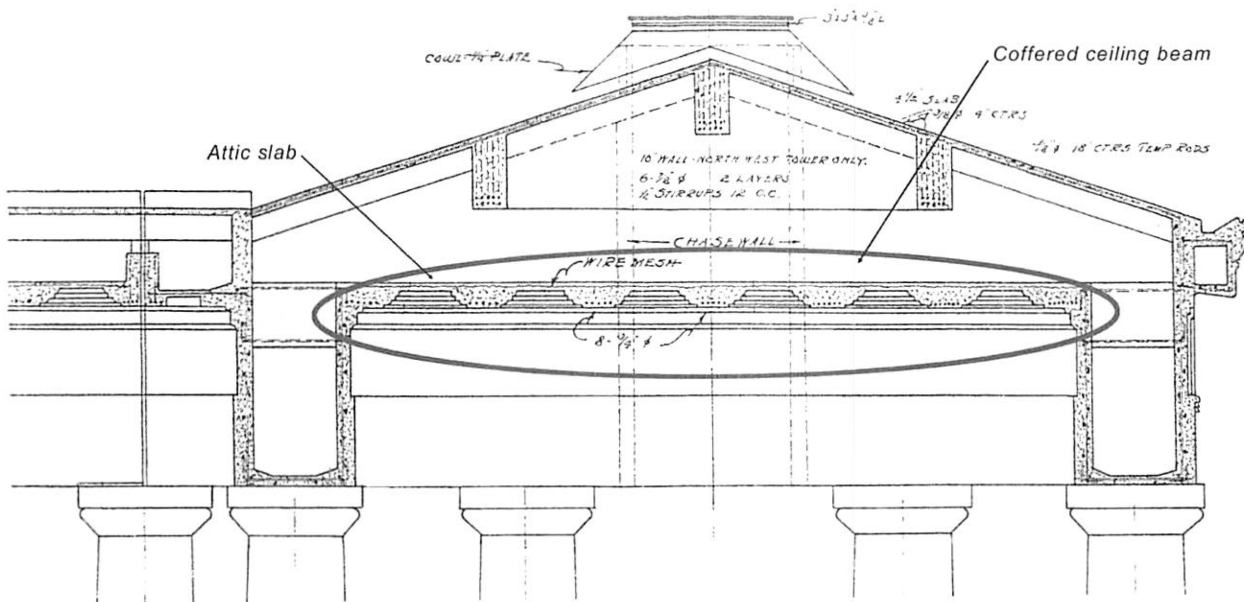

Figure 4. Cross section through colonnade roof, with circle added to indicate coffered ceiling (From original drawings for stadium by Holabird and Roche, dated 2 February 1925)

Maintenance Approach

Despite the high chloride levels and deep carbonation, limited exposure of the concrete to moisture slowed the reinforcing-steel corrosion and resulting concrete deterioration at Soldier Field. Both the coffered ceilings and the exhibition halls are sheltered from direct exposure to the weather, so available moisture is limited to ambient humidity and occasional condensation on cold surfaces.

To respond to the potential hazards of concrete spalling overhead, the Chicago Park District adopted a maintenance approach in which the overhead concrete surfaces were inspected close up every year and loose pieces were removed. With repairs limited to chipping and patching, reinforcing steel corrosion and concrete deterioration would continue indefinitely. This maintenance approach was labor intensive, costly, and disruptive to stadium operations. Knowing that schemes for reducing the concrete deterioration could reduce maintenance and improve stadium operations, the park district commissioned an investigation of corrosion mitigation schemes for the coffered ceilings and exhibition halls just prior to the 2003 stadium renovation.

Corrosion-Mitigation Systems Considered

Various types of corrosion-mitigation technologies are available, depending on the nature of the deterioration to be addressed, the owner's limitations regarding initial cost and maintenance requirements, and accessibility and geometric constraints at the structure. The following sections provide a brief description of the most commonly available corrosion mitigation options. The basic operation of the various systems is diagrammed in Figure 7.

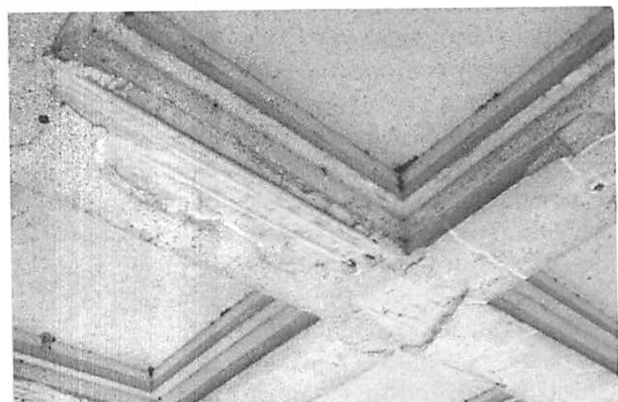

Figure 5. Typical concrete spall in coffered-ceiling beam in the colonnade. The corroded reinforcing steel was coated with epoxy paint for short-term protection. (WJE)

Impressed-current Cathodic Protection. Impressed-current cathodic protection (CP) involves connecting an inert anode to an electrically continuous reinforcing steel mat and applying a constant electrical current, via a DC rectifier, between the anode and the steel. The anode is typically a titanium mesh, ribbon, or probe that is applied over the concrete surface or implanted in the concrete. The applied current forces the entire reinforcing-steel mat to become the "cathode" in the electrochemical cell and therefore not corrode. The anode is consumed gradually over time, but a specially coated titanium anode can last twenty years or more. Impressed-current cathodic protection is the most effective means of mitigating steel corrosion and has been used in practical structural applications since the 1970s. However, impressed-current cathodic protection systems are typically the most costly to install and require substantial ongoing monitoring, adjustment, and maintenance to ensure a proper voltage output (protection current) over time.

Sacrificial Anode Cathodic Protection. Sacrificial anode cathodic protection systems, sometimes called galvanic cathodic protection systems, are similar to impressed-current cathodic protection systems, except that the electric current is not applied but rather flows naturally by galvanic action. An electrically active metal, typically zinc, is used as the anode and is connected electrically via wires to the embedded reinforcement. Common anodes include zinc coatings sprayed onto the concrete surface as in arc-sprayed zinc, zinc sheets fastened mechanically to the concrete surface, and zinc pieces embedded within the concrete. The anode is sacrificial in that it is consumed over time, while the reinforcing steel, functioning as the cathode in the electrochemical cell, is protected. The main advantages of this technique are maintenance-free operation (since it operates by its own galvanic action), minimal preparation prior to installation, and lower initial cost. Since the anode is consumed over time, periodic reapplication is required. The use of sacrificial anode cathodic protection dates back to the 1800s; today many industries utilize the concept of sacrificial anode cathodic protection for the protection of steel exposed to corrosive environments.

Chloride Extraction. Chloride extraction is a recent technology developed for repairing chloride contaminated bridge decks, which removes chloride ions from concrete electrochemically.[3] Much like impressed-current cathodic protection, the installation involves an external anode (typically a metallic mesh), a dike or porous covering containing an electrolyte, and a rectifier. A strong electrical current is applied from the anode to the reinforcing steel for a period of anywhere from a few days to several weeks. To maintain charge neutrality, free chloride ions in the concrete migrate away from the reinforcing steel and toward the anode. After the process the external anode and electrolyte are removed. Drawbacks of this process are the possible staining of the concrete surface and the difficulties in applying and containing the electrolyte, particularly overhead.

Realkalization. Realkalization is an electrochemical process to restore the alkalinity (i.e., raise the pH) of the concrete around the reinforcing steel, thus restoring the protection that was lost by carbonation. The technique employs the same principles as impressed-current cathodic protection, except that the electrical current is much higher and is applied only temporarily, typically for several days. The electrolyte is an alkaline solution such as sodium carbonate. As the current is applied, the alkaline solution is driven into the concrete, and an electrolysis reaction occurs around the reinforcing steel. These actions increase the pH of the concrete around the reinforcement, thus restoring the protective alkaline environment for the reinforcement.

Corrosion Inhibitors. Corrosion inhibitors are chemical formulations added to concrete in an attempt to reduce corrosion of reinforcing steel. Inhibitors can be admixed into concrete or sprayed over the concrete surface. Three major formulations are available: calcium nitrites, typically admixed, which react with ferrous ions to form a protective ferric oxide film on the steel surface; organic amines and esters, typically admixed, which reduce permeability and chloride ingress and form a coating on the steel surface; and vapor-phase amine alcohol inhibitors, typically surface applied to the concrete, which penetrate by vapor diffusion and form a monomolecular protective layer on the steel. These materials are relatively easy and inexpensive to install and require no maintenance. On the other hand, there is wide disagreement in the professional community regarding their effectiveness. Few well documented field studies exist, particularly for surface applied

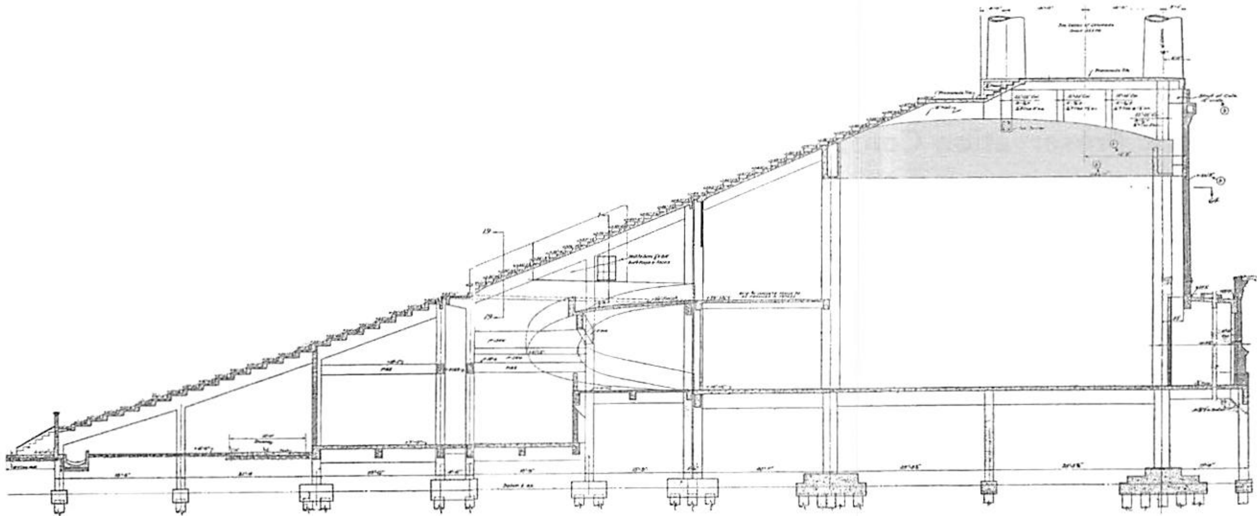

Figure 6. Cross section below colonnades, with shading added to indicate transfer beams over exhibition halls (From original drawings for stadium by Holabird and Roche, dated 2 February 1925)

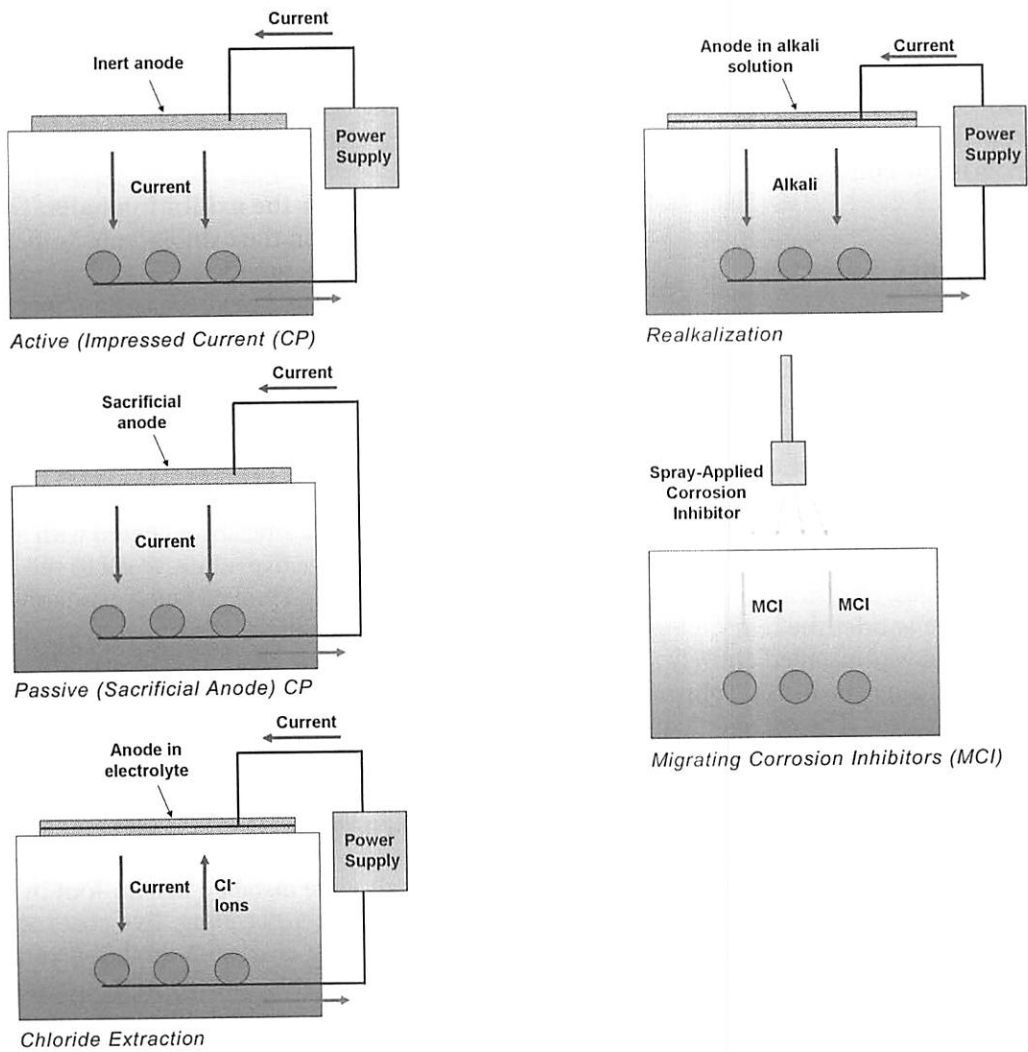

Figure 7. Corrosion mitigation options (WJE)

(migrating) inhibitors, and some studies have shown that the inhibitors provided no benefit in reducing reinforcing-steel corrosion.[4]

Historic Preservation Considerations

For historic structures the impact of the mitigation system on the historic fabric must be considered. As with other repair work on historic structures, the following key questions must be answered relative to each corrosion mitigation system:

- Do the proposed repairs retain rather than replace the original historic fabric?
- Do the repairs alter the appearance of the original material?
- Are the repairs reversible?
- Is the repair a proven technology?

Based on these historic preservation considerations, as well as the technical merits of each system relative to their use at Soldier Field, the most appropriate mitigation systems were selected for field trials in the coffered ceilings and exhibition halls.

Trial Treatments Selected

Treatments for the colonnade coffered ceilings. Two systems were selected for field trials in the coffered ceilings: a sacrificial-anode cathodic protection system and corrosion inhibitors. The zinc anodes for the sacrificial-anode cathodic protection system were embedded in holes drilled at a uniform spacing into the top of the colonnade beams from the attic space (Figure 8). At the bottoms of the holes, electrical connections were made between the anodes the reinforcing steel. The zinc-anode system was installed entirely from the attic and does not alter the historic appearance of the ceilings from below. The corrosion inhibitors are very cost effective and do not significantly alter the appearance of the ceilings. On the other hand, the inhibitor treatment is irreversible and unproven; therefore, careful evaluation of the effectiveness of the treatment in field trials is required.

An impressed-current cathodic protection system would afford the greatest protection but was not selected because it had the highest cost and maintenance requirements. Also, installing the

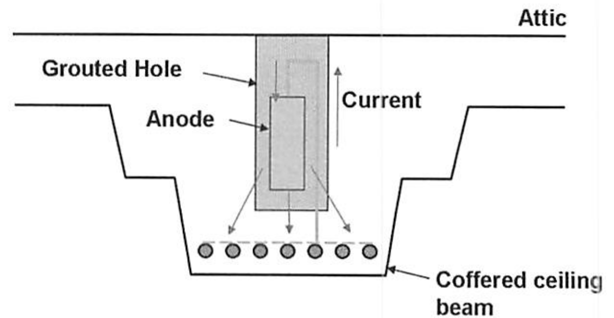

Figure 8. Schematic cross section showing typical zinc anode installed in coffered ceiling beam (WJE)

anode on the bottom surface, either in mesh or ribbon form, would alter the appearance of the ceilings. Placing the anode on the top of the ceiling would not afford as much protection, although drilled-in probes could be used. Zinc coating systems were not selected because they would significantly alter the appearance of the original concrete. Chloride extraction was ruled out because of the difficulties in accessing the underside of the ceilings and in applying and containing the electrolyte.

Treatments for the exhibition halls. The overhead concrete in the exhibition halls includes less prominent structural features that are more readily accessible, painted in all areas, and obscured in some areas. Four different mitigation options were selected for field trials: realkalization, zinc-hydrogel-sheet sacrificial-anode cathodic protection, arc-sprayed-zinc sacrificial-anode cathodic protection, and corrosion inhibitors. The zinc-hydrogel system involves adhering and mechanically fastening a zinc sheet coated with an ionically-conductive adhesive gel to the concrete surface. The arc-sprayed zinc system involves applying a metallic coating of zinc to the concrete surface. The zinc coatings have a uniform, dull gray color, which can be painted to match the adjacent painted concrete surfaces. The zinc coatings can also be removed in the future, if needed.

Test Areas

Field trials were installed in a 40-foot by 20-foot area of the coffered ceiling. Two coats of a vapor-phase migrating corrosion inhibitor were applied to one-third of this area. To study the effect of admixed corrosion inhibitors, a vapor-phase inhibitor was also admixed into prototype patches in this portion of the trial area. In another third of

the area two groups of zinc anodes were installed, one group spaced at 22 inches and another group spaced at 32 inches. The balance of the test area served as a control.

In the exhibition hall each of the four selected systems was executed on a separate 10-foot length of a main transfer beam. Before the systems were installed, the existing thick coatings of paint on all four beams were removed by sandblasting. Two coats of migrating corrosion inhibitor were applied to one beam. Realkalization was performed on another beam. A third beam was coated with arc-sprayed zinc and a fourth beam was fitted with zinc-hydrogel sheets. Specialty contractors assisted with these installations.[5]

Test Results

Baseline rate of corrosion. The baseline rates of corrosion measured in the colonnade ceilings and exhibition hall beams before any of the mitigation systems were installed were very low. Typical baseline corrosion rates measured in this study were around 0.02 mpy, and the highest value was 0.07 mpy. These values are several times less than a typical high rate of corrosion (say, 0.5 mpy) that might be measured in a concrete parking garage exposed to high amounts of moisture and chlorides.

Sacrificial distributed zinc anodes in colonnade ceilings. Test data collected from the sacrificial distributed zinc-anode cathodic protection system installed in the colonnades indicated that the system was effective in reducing the corrosion of the reinforcing steel located near the anodes, although the degree of protection of the reinforcement was sensitive to the anode spacing. The galvanic current density (i.e., the "protection current") at a corrosion probe located within 12 inches of an anode was nearly 10 ¼A/cm², a level that would afford good protection to reinforcing steel. However, a corrosion probe located 3 feet away from the nearest anode showed minimal current density, indicating essentially no protection to the reinforcing steel.

The mean galvanic current between the zinc anodes and the adjacent reinforcing steel is shown in Figure 9. The current exhibited typical cathodic protection characteristics, that is, a large initial current output followed by a smaller current that can fluctuate with time. The measurements taken during a rainy period indicated a moderate spike in current, demonstrating that the system can deliver more current and thus greater protection with increased moisture in the concrete.

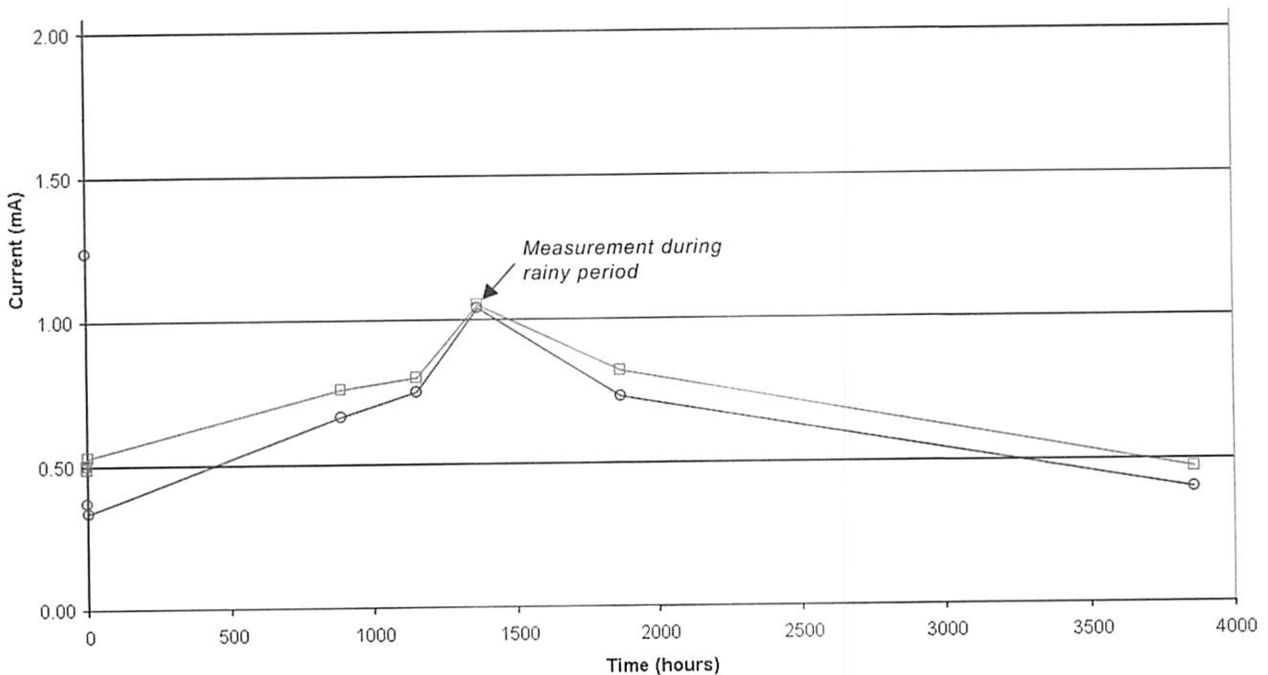

Figure 9. Change of average galvanic current output with time for two groups of zinc anodes installed in coffered ceilings (WJE)

Testing Equipment and Techniques

After baseline measurements were taken and the instrumentation and mitigation systems installed, the performance of each system was monitored for six months (Table 1). The equipment and testing techniques are described below.

Corrosion rate instruments. The instantaneous rate of corrosion, a kinetic property indicating how fast corrosion is occurring at the time of measurement, was measured at various locations in the test areas using a GECOR-6 corrosion-rate instrument. Measurements were made in terms of current density (¼A/cm^2), which can be converted to metal loss in mils per year (mpy). The GECOR-6 is a self-contained, hand-held device that uses the principle of linear polarization resistance. Electrochemical testing equipment made by Gamry Instruments (Gamry PCI4 Potentiostat/Gavanostat/ZRA) was also used to measure corrosion rates at corrosion probes embedded in the colonnade ceiling. A titanium-mesh counter electrode mounted to the concrete surface over the probes was connected via wires to the equipment in the attic space to allow remote measurements.

Corrosion probes. Two types of corrosion probes (devices embedded in concrete to measure the in situ corrosion rate) were used in the field trials. One type was fabricated from 3-inch lengths of #3 reinforcing bars fitted with PVC caps and lead wires. These probes were inserted into holes drilled into the concrete and then grouted. The probes were also cast into the prototype admixture patches in the colonnade ceiling. The second type of corrosion probe was created by saw cutting 6 inch long segments of existing reinforcing bars and making electrical connections to the cut segments. This type of probe destroys the structural continuity of the bar but has the advantage of monitoring an actual reinforcing bar with minimum disturbance to the surrounding concrete. To evaluate the performance of the mitigation systems, wiring circuits with toggle switches and electrical panel boards were devised and installed to allow measurement of electrical currents and potentials between the corrosion probes and the various components of the mitigation systems.

Half-cell potentials. Half-cell potentials (HCPs) were measured using a copper-copper sulfate reference electrode placed in contact with the concrete surface at regular spacing on the coffered ceiling and exhibition hall beams. The difference in electrical potential between the reference electrode and the adjacent reinforcing steel indicates the probability of corrosion actively occurring in the reinforcing steel.[6] To minimize the effect of surface carbonation on the readings, the measurements were taken in drilled holes.

Carbonation testing. In the exhibition hall beams, where carbonation is the primary cause of the steel corrosion, carbonation testing was performed on core samples removed at random locations. The cores were cut along their length, dried, and sprayed with a phenolphthalein solution. When exposed to phenolphthalein, uncarbonated concrete turns pink, whereas carbonated concrete presents no color change. Carbonation testing was performed on cores removed before and after the realkalization treatment.

Table 1. Field Testing Performed to Verify Field Trials

	Colonnade Coffered Ceilings		Exhibition Hall Beams			
Tests / Measurements*	Corrosion Inhibitors	Distributed Zinc Anode CP System	Corrosion Inhibitors	Realkalization Treatment	Arc-Sprayed Zinc CP System	Zinc-Hydrogel Sheet CP System
Corrosion Rate	•	•	•	•	•	•
Corrosion Probes and Electrochemical Data	•	•	•		•	•
Anode Current Output		•			•	•
Protection Current Density		•			•	•
Depolarization					•	•
Half Cell Potentials	•	•	•		•	•
Inhibitor Penetration Depth	•		•			
Carbonation Depth Before/After Treatment				•		

* Baseline petrographic examination, carbonation testing, and chloride content analysis performed on core samples from each area

Calculations performed by the manufacturer indicated that the zinc in the discrete anodes would be consumed in nine to fifteen years. This service life could be extended by providing additional zinc in the anodes, installing more than one anode per drilled hole, or decreasing the anode spacing.

Cathodic protection of exhibition hall beams. Both the arc-sprayed zinc and zinc-hydrogel sacrificial-anode cathodic protection systems installed in the exhibition halls exhibited satisfactory performance during the trial period. Both systems delivered reasonable amounts of protection current to the reinforcing bars and corrosion probes. The zinc-hydrogel system delivered greater current than the arc-sprayed zinc system, suggesting that the zinc-sheet system would afford greater protection, but also that it would be consumed somewhat more rapidly than the arc-sprayed zinc. Both systems require moisture in the concrete to operate. The zinc-hydrogel attracts moisture due to its inherent hygroscopic properties, while the arc-sprayed zinc requires periodic spraying with a humectant to keep it functioning properly in dry environments. In other applications of zinc-hydrogel, concerns have been expressed about the hydrogel drying out over time and losing its bond to the concrete surface, in which case the long-term effectiveness of the system is suspect. Further field observations are needed to address these concerns.

Depolarization, a measurement of the electrical potential (voltage) shift brought about by the applied current in a cathodic protection system, is used to evaluate the effectiveness of cathodic protection systems. According to a National Association of Corrosion Engineers criterion, the level of cathodic protection current in reinforced concrete structures is adequate if the amount of depolarization is at least 100 mV in a four-hour period.[7] Measured depolarization of both zinc systems in the exhibition halls exceeded loo mV, demonstrating that both were adequately protecting the reinforcing bars.

Baseline half-cell potential data in the exhibition halls were numerically very positive due to the dryness of the concrete and concrete carbonation. The half-cell potentials shifted to very negative potentials upon application of the cathodic protection systems, indicating the effectiveness of the installed systems at mitigating the corrosion process.

Realkalization of exhibition hall beams. Carbonation depths measured on cores taken from the beams in the exhibition halls prior to the realkalization treatment ranged from 1.0 to 3.5 inches, with reinforcing steel cover of 0.5 to 1.5 inches. After the realkalization treatment was completed, cores taken from the treated beam showed that significant restoration of alkalinity in the concrete around the reinforcing steel had occurred. However, some small regions of concrete near the bars remained carbonated, indicating incomplete and non-uniform effectiveness of the realkalization process. The realkalization contractor believed that more effective treatment could be achieved by a fairly minor adjustment in the treatment process, namely providing a separate applied current circuit to the bottom versus the sides of the beams, since the sides of the beams have significantly less steel than do the bottoms. Nonetheless, this testing indicated that careful quality control should be performed in the field to determine the effectiveness of realkalization treatments.

Effect of corrosion inhibitors. In the corrosion inhibitor trial areas, evaluation of system performance was limited to measurement of corrosion rates. As described above, the baseline corrosion rates at this structure were so low that any changes in the rates that might have been brought about by the corrosion inhibitors could not be discerned within the measuring accuracy of the test equipment. The length of the test program was also limited and may not have been long enough to detect the maximum effect of the corrosion inhibitors. Therefore, the test results for the corrosion inhibitors were judged to be inconclusive. Limited current density data from the corrosion probes installed in the patches with admixed corrosion inhibitors suggested that the admixed inhibitors provided some benefit in reducing the corrosion. Laboratory tests performed on concrete samples removed from the areas treated with migrating corrosion inhibitors indicated that the inhibitor had penetrated the concrete to the depth of the reinforcing bars, and prior studies have shown that inhibitors that penetrate to the reinforcement can reduce corrosion.

Cost Analysis

To compare the various systems for full-scale use at Soldier Field, a life cycle cost analysis was developed. The cost for each system over the span of twenty years was compared to the option of continuing with annual inspections and periodic patching without a corrosion-mitigation system. For each system costs included not only initial installation but also maintenance of the system. A reduced amount of periodic concrete patching was also included during the twenty-year period.

The life-cycle costs of the various mitigation systems and concrete maintenance strategies were not drastically different. By a small margin the most cost effective repair approach for the coffered ceilings was found to be the installation of the sacrificial distributed zinc-anode cathodic protection system, followed by a reduced level of future inspections and repairs. The most cost effective approach for the exhibition hall concrete was not to install any corrosion mitigation measures at this time but rather to continue with annual inspections and periodic patching of the overhead concrete. For a modest additional life cycle cost, corrosion mitigation measures could be implemented in the exhibition halls and thereby reduce future maintenance and disruptions to the facility. The life-cycle costs of both zinc-coating systems and the realkalization treatment were similar.

Conclusions and Recommendations

1. The baseline rate of reinforcing steel corrosion measured in these studies was very low. This slow corrosion rate is consistent with the historical observations at the stadium: concrete deterioration has developed slowly in small, localized areas over the years. If the exposure conditions remain the same, the rate of corrosion and the rate of development of concrete distress should remain low.
2. Although treatment of the concrete with corrosion inhibitors had the lowest initial cost among the options considered, no definitive benefit of the corrosion inhibitors could be discerned in this limited study. The data implied that corrosion inhibitors admixed into patching concrete provided some benefit in reducing reinforcing steel corrosion. Testing showed that the migrating corrosion inhibitors did reach the reinforcing steel, and prior studies have shown that inhibitors that penetrate to the reinforcement can reduce corrosion. However, since no definitive benefit of the inhibitors could be shown in this study, they were not recommended for full-scale use at Soldier Field without further testing.
3. Based on the measured performance of the trial installation and the cost analyses, the study recommended installing the sacrificial distributed zinc-anode cathodic protection system throughout the colonnade ceiling beams, followed by a reduced level of future inspections and repairs. This system is appropriate as a preservation measure in that it retains the historic fabric, does not alter the appearance of the colonnades, and is based on proven technology. The system can be installed and monitored from the attic space above the coffered ceilings, so disruption to the stadium is minimal. Installation in two stages was recommended. The first phase would involve installation of the anodes in half of one colonnade, and the details of the system performance would be monitored and verified over three to five years. Using the performance results from the first phase, the second phase would be designed and implemented in the remaining colonnade areas.
4. Performance of the field trials and the cost analysis indicated that the most cost effective repair approach for the exhibition halls was not to install any corrosion mitigation measures but rather to continue with annual inspections and periodic patching of the overhead concrete. On the other hand, the owner was advised that for only a modest additional life-cycle cost, a corrosion mitigation system could be successfully implemented in the exhibition halls. Such a system would reduce concrete deterioration, reduce future maintenance, and reduce disruption to the facility. Either of the zinc-coating systems or the realkalization treatment verified by careful quality control testing would afford good protection to the reinforcing steel.

Current Status

Patching of the deteriorated concrete in the colonnade coffered ceilings and exhibition halls was performed as part of the stadium renovation completed in 2003. However, due to time and budget constraints in the renovation, corrosion

mitigation systems were not installed. For the colonnade ceilings, the owner is planning to implement the first phase of the recommended corrosion mitigation system, specifically the sacrificial distributed zinc-anode CP system, in the near future. For the exhibition halls, based on the results of the life-cycle cost analysis, corrosion mitigation systems will likely not be pursued.

General Implications

Besides the specific implications for Soldier Field, this study demonstrated the following broader implications:

1. New technologies in corrosion mitigation can be applied with appropriate sensitivity as preservation measures for historic concrete structures. This sensitivity involves understanding the many options that are available and choosing wisely among them based not only on technical issues but also on historic considerations. For new technologies well-devised and well-executed field trials should be carried out to substantiate the performance before full-scale implementation.
2. Sacrificial anode cathodic protection systems using distributed zinc anodes are a promising technology that can solve problems related to treatment in areas of difficult access and complicated configurations, which are common in historic structures. In certain situations, the anodes can be installed without altering the appearance of the structure. Performance of these systems is sensitive to anode spacing, moisture conditions, and other environmental factors.
3. More field test data are needed to substantiate whether or not corrosion inhibitors are effective at reducing corrosion, and their use should be considered experimental until their performance is verified.
4. Sacrificial anode CP systems using zinc coatings can be very effective and relatively economical. They do alter the appearance of the concrete, which may not be appropriate in some situations, but they can be painted.
5. Realkalization is a new technology that can be effective for mitigating steel corrosion in carbonated concrete, bearing in mind that the process can be untidy (because of leakage of the electrolyte), can stain the concrete, and needs to be verified by quality control testing.
6. For each potential application, a life-cycle cost analysis should be carried out to evaluate the cost benefit of implementing a corrosion-mitigation system. In some cases conventional concrete repair techniques alone may be more cost effective.

Finally, because of the complexities and multiple disciplines involved, successful implementation of corrosion mitigation technologies for historic concrete structures requires a team of experts. This team should include preservation architects and engineers, materials conservators, corrosion engineers, instrumentation and testing experts, and representatives of the system manufacturers. Working together, these experts can devise corrosion mitigation strategies that are appropriate for each unique application.

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Seung Kyoung Lee, PhD, is a former corrosion engineer in the materials group of Wiss, Janney, Elstner Associates, Inc. He is currently with the Federal Highway Administration in McLean, Virginia. Dr. Lee's areas of practice include investigation of corrosion-related distress and development of corrosion mitigation schemes. He is certified by the National Association of Corrosion Engineers as a cathodic protection specialist.

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Notes

1. Brenda M. Doyle, "The Benedict Stone Collection," *Blueprints* (Fall 1991). *Blueprints* is the web newsletter of the National Building Museum in Washington, D.C.; http://www.nbm.org/blueprints/90s/fall91/page2/page2.htm

2. Corrosion-engineering textbooks provide detailed descriptions of the chemical reactions involved in the corrosion process. One that specifically addresses corrosion of reinforcing steel in concrete is John P. Broomfield, *Corrosion of Steel in Concrete: Understanding, Investigation and Repair* (London: E. & F.N. Spon of Chapman and Hall, 1997).

3. National Association of Corrosion Engineers International Task Group 054 on Electrochemical Chloride Extraction and Realkalization of Reinforced Concrete, "Electrochemical Chloride Extraction from Steel Reinforced Concrete, A State-of-the-Art Report" Technical Committee Report, NACE International Publication 01101, (Houston, Texas: NACE, 2001).

4. Michael M. Sprinkel, Virginia Transportation Research Council, in cooperation with the U. S. Department of Transportation Federal Highway Administration, "Final Report: Evaluation of Corrosion Inhibitors for Concrete Bridge Deck Patches and Overlays," VTRC 03-R14, June 2003.

5. These contractors were Cathodic Systems, Inc., Juneau, Wisconsin; Corrosion Restoration Technologies, Inc., Jupiter, Florida.; Sika Corporation, Lindhurst, New Jersey; Takao Nagai Associates, Ltd., Villa Park, Illinois; and Vector Corrosion Technologies, Winnipeg, Ontario.

6. *ASTM C 876-91 (Reapproved 1999), Standard Test Method for Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete.*

7. "Cathodic Protection of Reinforcing Steel in Atmospherically Exposed Concrete Structures," NACE Standard RP 0290 (Houston: NACE, 2000).

Current Technologies in Facade Cleaning and Graffiti Removal

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Recreational structures, whether they are beach houses, park buildings, pools, playground amenities, amusement park facilities, or stadium complexes, typically require cleaning for the same reasons as other properties—to improve aesthetics, remove airborne contaminants, prepare surfaces for repair, and as part of cyclical maintenance activities. However, recreational structures often require specialized approaches to cleaning for a number of reasons. The special materials and forms used in recreational structures for functional or decorative effect may make cleaning of exterior facades a particularly challenging task. Some recreational facilities are particularly vulnerable to graffiti because of their use by large numbers of visitors and because usage varies from extensive in certain times of the year to unused (and therefore sometimes unmonitored) in other seasons. Recreational structures in harsh environments such as coastal locations may require special cleaning, for example to remove airborne salts. Water features at some facilities require special treatment to address organic growth. Finally, for historic recreational structures or structures in historic settings, special constraints may apply to the cleaning processes used.

Approach

The Secretary of the Interior's Standards for the Treatment of Historic Properties specifically address the appropriate philosophical approach to facade cleaning: "Chemical or physical treatments, if appropriate, will be undertaken using the gentlest means possible. Treatments that cause damage to historic materials will not be used."[1] This statement is useful guidance for any cleaning project. Among the guidelines that accompany the Secretary of the Interior's Standards are the following recommendations for exterior masonry:

> Clean masonry only when necessary to halt deterioration or remove heavy soiling . . . Carry out masonry surface cleaning tests after it has been determined that such cleaning is appropriate. Tests should be observed over a sufficient period of time so that both the immediate and the long range effects are known to enable selection of the gentlest method possible . . . Clean masonry surfaces with the gentlest method possible, such as low pressure water and detergents, using natural bristle brushes.[2]

The Secretary of the Interior's Standards and other guidelines address when and whether to clean, as well as how to clean. If cleaning cannot be performed without damage to the substrate, the option remains of not cleaning at all. Proper cleaning can significantly contribute to the appearance and

Figure 1. Successful cleaning can remove harmful deposits and enhance the appearance of historic buildings. (Wiss, Janney, Elstner Associates, Inc.)

Figure 2. Inappropriate cleaning can irreparably damage building materials, such as the etching of this brick facade. (WJE)

longevity of facade materials (Figure 1), while improper cleaning can result in damage and accelerated deterioration (Figure 2).

A typical methodology for facade cleaning (Figure 3) begins with establishing criteria for the cleaning project and understanding the nature and condition of the masonry substrate and the soiling to be removed. Next, the advantages and disadvantages of possible cleaning systems are explored, and selected cleaning approaches are evaluated through small-scale trials. Contract documents are developed for project specific cleaning; large-scale cleaning mock-ups are performed and evaluated; and cleaning procedures are refined. Lastly, quality control oversight by a professional should be provided throughout the cleaning project.

The purpose of the cleaning effort may be to remove deleterious contaminants or failed coatings, to prepare the substrate for further treatment or repairs, or simply to improve the appearance of the building or structure. If the accumulated soiling represents a character-defining patina, it may be desirable to preserve rather than remove it. The preferred level of cleanliness is defined prior to and during the cleaning process by evaluation of trial samples. Other issues to be addressed in establishing cleaning criteria, developing project documents, and through performance of trial repairs include protection and disposal requirements; site, temperature, and other environmental constraints; special application requirements; availability of the required materials, equipment, and skilled personnel; and cost.

Soiling may consist primarily of atmospheric pollutants such as carbon deposits from vehicular traffic, other contaminants, staining related to components of the substrate, undesirable surface treatments or coatings, biological growth, or a combination of these factors. The nature and condition of the substrate defines general limits on the types of cleaners that can be considered for use. For example, a fragile surface typically cannot be cleaned with moderate or high pressure water or micro-abrasive systems. A stone substrate containing ferrous mineral inclusions, such as certain types of sandstone, may be subject to staining if cleaned with strong acidic chemicals. Light colored stone substrates, for instance white marbles, are vulnerable to staining if cleaned with water having high iron content, even without the use of chemical cleaners.

A wide range of cleaning systems is presently available. Research, laboratory and/or on site trials, and testing of more than one system is usually required before one or more systems is selected for the cleaning project. Trials provide an opportunity to confirm that the proposed cleaner will not damage the substrate by staining, discoloration, etching, or erosion, and also help define the acceptable limits of cleaning. Although a cleaner substrate may be desired aesthetically, a clean appearance must be balanced against possible damage. Over-cleaning can result in increased future dirt accumulation, absorption of moisture, and surface deterioration. In addition, some cleaning systems can present a potential source of damage to building elements and materials other than those being cleaned, as well as to nearby

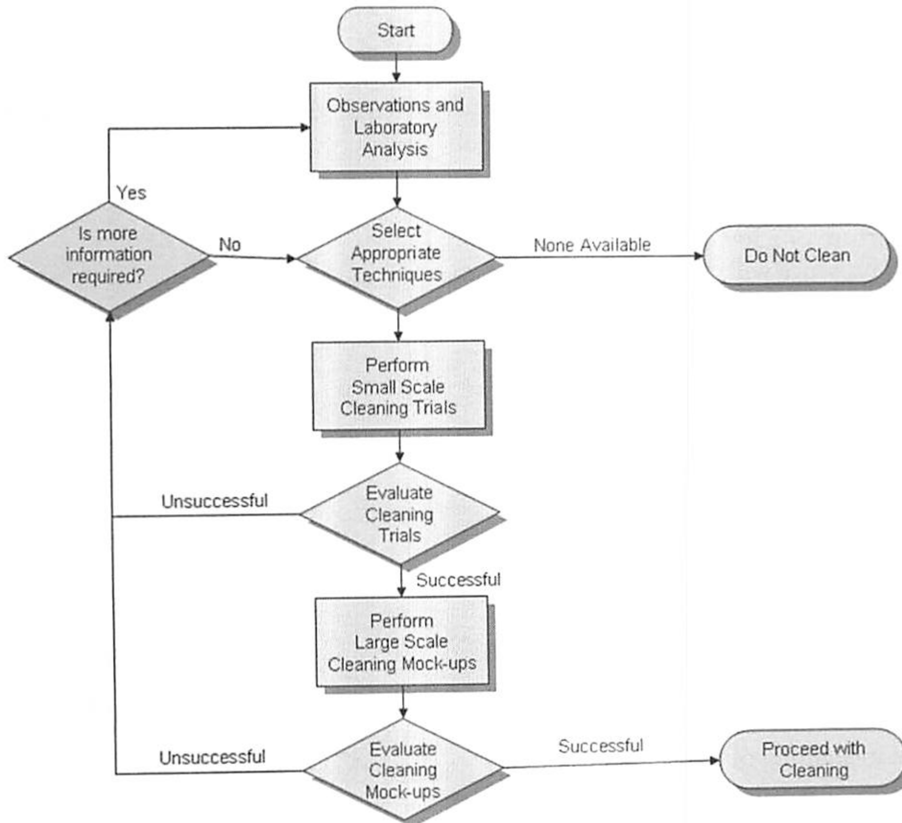

Figure 3. This flowchart shows the typical decision-making process for cleaning historic building facades. (Joshua Freedland and Lisa Chan, WJE)

structures and the environment. Some cleaning systems also present a hazard to workers, other persons, and animals in the work area.

Thorough examination of the substrate and evaluation of the proposed cleaning system help determine the extent of the work to be performed, as well as how the work will be carried out. Sample test areas implemented prior to the work serve as a reference to refine the specified cleaning process, and mock-ups performed at the beginning of work establish a standard for the remainder of the cleaning work. Finally, involvement by the conservation professional, either in performing the work or reviewing and observing the work in progress, ensures continued quality control during the cleaning.

Facade Cleaning Systems

Facade cleaning techniques generally fall into four categories: water/steam, abrasive, laser, and chemical. Depending on the nature and condition of the substrate, and on the character of the soiling to be removed, one system or a combination of systems may be appropriate for a specific cleaning project.

Water cleaning techniques work by softening or dissolving loosely bonded dust, dirt, soot, and other deposits (Figure 4). The process involves soaking, mist spraying, or brushing the surface, followed by rinsing to remove residual dirt. Depending on the substrate, the definition of low, medium, and high pressures varies widely. For stone or brick masonry, gentle water cleaning methods based upon intermittent misting or continuous soaking involve very low pressures (less than 50 psi), followed by a low (100 to 200 psi) or medium (200 to 400 psi) pressure water rinse. Moderate to high pressure water washing (400 to 800 psi) is generally safe for use on harder stone or concrete.[3] However, water washing at these moderate to high pressures can erode soft or fragile stone surfaces. In comparison, pressures of well over 30,000 psi are considered safe for use in cleaning some metal elements on buildings and other structures, and have been successfully used to remove coatings without damage to sound, high strength concrete substrates.

The effect of the water spray or stream on the substrate is related to the application pressure, volume of water, aperture of the nozzle, and

distance of the nozzle from the wall surface. Low pressure water cleaning techniques usually involve continuous or intermittent water spray through multiple fan nozzles attached to a rack suspended adjacent to the wall surface being cleaned. High pressure water cleaning is typically performed from a single nozzle with a very narrow fan spray, as a narrower aperture or a lower water volume at a given application pressure will generally result in higher pressure as water reaches the wall. Problems associated with improper or uncontrolled water cleaning include water infiltration through open joints, cracks, or through the face of porous masonry materials. If water infiltration is a concern, then dry cleaning systems may need to be considered. Water cleaning should not be performed in cold weather, as damage can occur to masonry substrates from cyclic freezing and thawing of entrapped moisture. In addition, water used in cleaning should be checked to confirm that it is free from impurities or minerals that can stain the substrate. For example, even a very small amount of iron in the water used for cleaning or rinsing can result in staining of a white marble substrate.

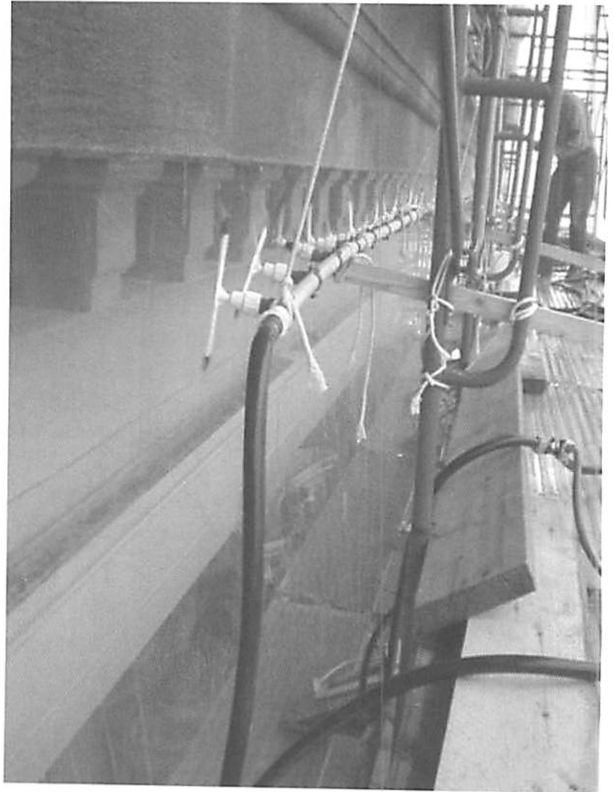

Figure 4. Low pressure water cleaning in progress (WJE)

Steam cleaning offers the advantage of using less water than other water cleaning techniques. This process is therefore especially useful if the volume of water needs to be limited. Steam cleaning systems, once considered hazardous to workers, have become more readily available during the past decade as improved equipment provides better control and safety.[4]

Abrasive and microabrasive systems clean by abrading or eroding the surface; however, the extent to which the surface is affected varies widely depending on the nature of the substrate and the aggressiveness of the system used. Traditional abrasive cleaning systems using ground walnut shells as the blast media are still commonly used to clean metals. Mechanical cleaning methods using high-pressure sand or grit blasting (common through the 1960s), are no longer used for historic masonry because of the likelihood of damage to the substrate. During the past few decades, new microabrasive systems have come into use. Unlike older abrasive methods, when undertaken with proper controls these new techniques can remove contaminants from delicate surfaces, including masonry, without significantly damaging the substrate (Figure 5).

Figure 5. Microabrasive cleaning in progress (WJE)

Abrasive and microabrasive systems vary in the type of materials, specialized nozzles, and other equipment used in application, as well as whether the system involves water for cleaning and rinsing. Most microabrasive systems have in common the use of very fine particulates (less than 90 microns in diameter) such as crushed dolomitic limestone for cleaning. The particulates are applied at very low pressures (typically 25 to 75 psi maximum). The cleaning process is adjusted by varying the particulate according to type, hardness, size, and shape, and by modifying the nozzle size, application pressure, and flow rate.[4] The particulate varies with different systems and may include soft dolomitic particles, hard alumina, or even sodium bicarbonate (baking soda). The latter medium has been found to be problematic because baking soda and water form a paste that is difficult to remove. In addition, sodium bicarbonate is a salt and if not thoroughly removed by rinsing can damage masonry. Cleaning with frozen carbon dioxide (CO_2) or "dry ice" pellets, accelerated with compressed air to a high velocity, has been used with success to clean metal but does not appear to have had widespread success in facade applications or with masonry materials.

Laser-based cleaning systems, already used for cleaning monuments and artwork, have gained increased recognition over the last two decades for their successful use in building cleaning, particularly for ornamental and sculptural facade elements. Laser cleaning systems apply a laser beam in a pulse frequency with controlled power output. Handheld devices can focus the laser beam to a fine point, thereby adjusting the intensity of the laser impact over the surface. The use of laser cleaning systems is labor intensive and time consuming, and therefore does not appear to have widespread potential for use on recreational structures except where sculptural elements or artwork are involved.

Chemical cleaning systems react with the soiling or the substrate to loosen or dissolve soiling. Because many chemical cleaners are used with water, appropriate water pressures and prevention of leakage through open joints also need to be considered with chemical approaches. In addition, many chemical cleaners contain strong alkalis or acids that are hazardous to humans and animals and can damage the materials being cleaned as well as other building elements, site features, plants, and the environment. Chemicals spread by wind drift can damage adjacent vehicles and buildings. Special collection and disposal procedures may be required to control runoff from chemical cleaning.

Chemical cleaning compounds can be alkaline or acidic cleaners, or organic solvents. These products may be available in liquid, gel, or poultice form. In addition to the composition of the cleaning product, other factors include dilution (if liquid), application technique, and dwell time (the period for which the cleaning compound is allowed to remain on the surface), which can vary from less than five minutes to more than twenty-four hours. Manufacturer's literature generally provides a description of the cleaning product and information on application procedures. However, detailed information about product composition is usually only available through the Material Safety Data Sheet (MSDS), which provides specific information on material composition, protection, and other health and safety issues. Even the MSDS may not provide complete information about the cleaner since the document typically only reports what is required by law. When specifying chemical cleaners, it is important to review current product information, as formulations change over time.

Commonly used alkaline cleaning compounds include trisodium phosphate (TSP) and sodium hydroxide, which may be used alone or as a pre-wash in combination with a mild acid after-wash. In this case, the alkaline pre-wash reacts with the soiling, and the acidic after-wash neutralizes the pre-wash. Many cleaning products contain acids, some of which may remove soiling from some substrates but cause damage to others. Chemical cleaners may pose a health hazard regardless of their environmental effect or chemical description. Hydrochloric and hydrofluoric acids are not only hazardous but can significantly damage building materials. Hydrofluoric acid dissolves silica and other siliceous components such as are found in many types of stone. Ammonium bifluoride and sodium bifluoride can etch glass and, in the presence of water, form hydrofluoric acid. Hydrochloric (muriatic) acid can also damage masonry and adjacent facade components. These acids can cause severe staining of some substrates and remove painted finishes. Proprietary cleaning products containing milder acids such as phosphoric, sulfamic, gluconic, acetic, or citric acid tend to be potentially less harmful to users and to the substrate; however, even milder acids may cause staining to some substrates. Small-scale samples

Figure 6. Chemical cleaning was used on this terra cotta and granite facade in Chicago to remove general surface dirt from water runoff and air pollution. At left, the original appearance of the facade. At center and right, field samples of two different chemical cleaning products. An examination of the sample at center with a field microscope suggested that damage to the terra cotta substrate could occur; therefore, the product used for the sample at right was selected to clean the building. (WJE)

are particularly important as an initial step with chemical cleaning products to confirm that the chemicals in the cleaner will not react with the substrate and cause staining or other damage (Figure 6).

Many chemical cleaning products also contain a surface active agent (surfactant), which acts as detergent, wetting agent, and emulsifier, or a chelating agent such as ethylenediaminetetra-acetate (EDTA), which is capable of holding metal ions. Certain chemical cleaners are particularly effective on specific stains. For example, cleaners containing oxalic acids are effective in removing some types of ferrous staining. Chemical cleaners in poultice form, in which the cleaning solvent is mixed with an inert absorbent material such as attapulgite (an expansive clay) or latex, are particularly effective on deep seated or difficult to remove stains.[6]

Removal of Graffiti and Coatings

Many of the methods discussed above can also be used for coating removal; however, not all of these systems are universally successful, especially where the existing coating is well bonded or has penetrated the substrate. Steam will sometimes remove an existing coating where water will not. Microabrasive systems are also not always effective in coating removal because the particulates used may simply rebound from some types of applied coatings without removing them from the substrate, or the pressures required to remove coatings may result in damage to the substrate. Microabrasive cleaners are generally more effective in removing coatings from metals than from masonry.

In general, where coatings are intact and well adhered to the surface, chemical coating removal systems are most effective in removing them from masonry. Most paint strippers available today are either alkali-based or solvent based. Alkali-based paint strippers may contain calcium hydroxide, sodium hydroxide, or potassium hydroxide. Solvent-based paint strippers may contain methyl chloride, benzene, and toluene, among other chemicals.[7] Each of these products is more effective on some coatings than others and each has different environmental and safety concerns; some of these components present a significant safety hazard for users. Precautions for the use of coating removal products are similar to those for chemical cleaners.

Some coating removal systems incorporate a paper mask supplied by the manufacturer. The stripping product, usually in gel or paste form, is applied to the substrate and covered with the paper. The coating remover is allowed to dwell for a period time, after which the paper is removed together with the remnants of cleaner and debris (Figure 7). Dwell times for coating removal products can be as long as twenty-four hours or more, depending on the coating removal product, substrate, and

number and thickness of coating layers to be removed. Some proprietary systems also come with special bags for disposal of the paper, cleaner, and debris.

Removal of Organic Growth

Biological growth on buildings ranges from plants such as ivy to microbiological organisms like algae, lichens, fungi, and bacteria. Organic growth can appear green, brown, or black, and is sometimes mistaken for accumulations of airborne dirt. Such growth is usually aesthetically undesirable and in some cases may increase the rate of deterioration of the substrate by preventing the evaporation of water. Cleaning techniques that remove soiling will often also remove organic growth, but the organic growth will likely recur unless the cleaner incorporates a biocide. Historically, biocides included copper and fluorides left in place on the masonry surface to inhibit the organic growth; these systems have not been used in recent years due to health concerns. The present approach is toward cyclical application of a cleaner containing a biocide.

An example of a biocide is a solution of detergent, sodium hypochlorite (household bleach) or calcium hypochlorite, and a trisodium phosphate-type cleaner; this cleaner is applied to a prewet surface, scrubbed, and thoroughly rinsed with low pressure water. A variety of proprietary biocide products are also available, some of which contain quaternary ammonium chlorides (found in medical disinfectants as well as in biocides for facade cleaning). Even with use of a biocide, organic growth will tend to reappear over time, particularly on porous substrates, in shaded areas, and in areas that remain moist over time. Reapplication of the biocide at regular intervals may be necessary. Long-term trials are necessary to evaluate the effectiveness of biocides for a given substrate. For larger scale organic growth such as ivy and overhanging trees or shrubs, seasonal pruning or removal may indicate if the growth is damaging to the substrate or interfering with drying or drainage of the building roof and walls.

Figure 7. Use of a chemical poultice to remove graffiti. (WJE)

Quality Control and Maintenance Cleaning

Quality control for cleaning projects is established in part through clear and project specific contract documents. Specifications are especially critical to cleaning projects, and provide an opportunity to cite reference standards such as the Secretary of the Interior's Standards as well as to define controls and limits on the work. In addition to materials and methods, issues addressed in the specifications include site and temperature constraints; handling, collection, and disposal requirements; other controls such as mineral content of water used in cleaning and rinsing; requirements for submittals, samples, and mock-ups; and evaluation processes required during cleaning. It may be necessary to specify more than one system for in situ trial cleaning samples by the selected contractor, to allow the entire project team (owner, architect, engineer, conservator, contractor, and others) to assess the effectiveness of the system, evaluate the proposed protection and disposal systems, and refine the cleaning procedures to be used. Protection requirements may be complex, especially for chemical cleaning systems that demand special protective measures for workers, others present on site, building elements, and site features. The project manual may also mandate specific contractor qualifications such as years of experience, references from past projects, and documentation of certified applicator status for those performing the work. As with any cleaning technique, the success of the application is dependent on quality control during application. Finally, field observation by the conservation professional is essential during the work to monitor the effectiveness and gentleness of the cleaning process.

Where cleaning is performed as a cyclical maintenance procedure, which is often the case with recreation structures and particularly where the focus of cleaning is graffiti removal, the effects of repeated cleaning on the substrate should be considered. For example, if a single cleaning

application results in minor erosion of the substrate, repeated cleaning by the same process over time can eventually cause noticeable loss of surface material. Such effects indicate that either less aggressive cleaning methods are needed or that cleaning should be performed only at very long intervals, even if noticeable accumulation of soiling occurs between cleaning programs.

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Notes

1. Kay D. Weeks and Anne E. Grimmer, *The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring & Reconstructing Historic Buildings* (Washington, D.C.: U.S. Department of the Interior, National Park Service, Cultural Resource Stewardship and Partnerships, Heritage Preservation Services, 1995).

2. Ibid.

3. Deborah Slaton, "Under Pressure," *Construction Specifier*, December 2000.

4. An example of a steam cleaning system is the Rotec steam system, distributed by Quintek of Niagara, Ontario, Canada.

5. Examples of microabrasive systems presently available include Rotec Vortex, distributed by Quintek of Niagara, Ontario, Canada; Facade Gommage, distributed by Thomann-Hanry, Inc., of Paris, France (which includes a containment system for particulate and debris); the JOS system, distributed by Stonehealth of Marlborough, Wiltshire, England; and Sponge-Jet, distributed by Sponge-Jet, Inc., of Portsmouth, New Hampshire.

6. Many proprietary chemical cleaners are currently available, and most suppliers provide product literature and MSDS on line. Because of the significant potential hazards involved in use of these systems, advice from specialists should be sought in evaluating chemical cleaning systems and interpreting MSDS. Examples of manufacturers currently providing a range of chemical cleaning products at this time include Prosoco, Inc., Kansas City, Kansas; Dumond Chemical, New York, New York; Diedrich Technologies, Oak Creek Wisconsin; FTB Technologies (Arte Mundit), Bouwelven, Belgium; and many others.

7. Solvent-based strippers may contain N-methyl pyrrolidone, methylene chloride, mineral spirits, alcohols, or other chemicals, and include aliphatic and aromatic hydrocarbons (such as petroleum distillates, mineral spirits, naphtha, benzene, toluene); chlorinated hydrocarbons (methylene chloride, ethylene dichloride, trichloroethane); citrus terpenes; esters (dimethyl adipate, dimethyl glutarate, ethyl acetate); alcohols; and ketones.

Bibliography

Ashurst, Nicola. *Cleaning Historic Buildings, Volume 1, Substrates, soiling and investigations, Volume 2, Cleaning materials and processes.* London, England: Donhead Publishing Ltd, 1994.

Grimmer, Anne. *Keeping it Clean: Removing Exterior Dirt, Paint, Stains and Graffiti from Historic Masonry Buildings.* Washington, D.C.: National Park Service, U.S. Department of the Interior, 1988.

Slaton, Deborah, and Kyle C. Normadin. "Masonry Cleaning Technologies: Overview of Current Practice and Techniques." *Cleaning Techniques in Conservation Practice*. Kyle C. Normadin and Deborah Slaton, eds. Shaftesbury, Dorset, England: Donhead Publishing Ltd, 2005.

Weaver, Martin E. *Conserving Buildings: A Manual of Techniques and Materials.* New York, New York: Wiley, 1997.

Weeks, Kay D., and Anne E. Grimmer. *The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring & Reconstructing Historic Buildings.* Washington, D.C.: U.S. Department of the Interior, National Park Service, Cultural Resource Stewardship and Partnerships, Heritage Preservation Services, 1995.

Maintenance Planning for Building Facades

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Owners of all types of buildings, including those used for recreation or leisure activities, can benefit by knowing when they should anticipate performing routine maintenance and repair. Such efforts help extend the service life of buildings and building envelope systems through planning and developing effective budgets. Advance maintenance planning should be considered routine for historically significant buildings. It is well established that a well maintained building envelope will last longer than one that is only repaired after distress conditions, such as water leakage, peeling paint, or mold, are observed. However, building owners and managers are rarely provided with the detailed information they need to maintain their buildings, either by the builder or the designer. Maintenance schedules are provided for less costly objects such as cars, office equipment, and many of the contents within a building—why not the building itself?

Many products and materials used to construct the exterior envelope of a building have known ranges for anticipated service life and required maintenance, based on the long historic use of these materials. Other materials or installations may not have as long a track record of use, but may have warranties from the manufacturer that provide some guidance on their anticipated life. Obtaining and compiling this information into a concise and easy to reference format can help guide the building owner or manager to anticipate when some intervention will be required for the building to continue to perform well.

This paper discusses a methodology for preparing maintenance documents. It also presents sample documents provided to owners describing anticipated service life for specific elements of building envelopes as well as a tabulation of the recommended maintenance and repair activities and time frames for commonly used materials and constructions.

What is Preservation? What is Maintenance?

The Secretary of the Interior's Standards for the Treatment of Historic Properties define *preservation* as "the act or process of applying measures necessary to sustain the existing form, integrity, and materials of an historic property. Work, including preliminary measures to protect and stabilize the property, generally focuses upon the ongoing maintenance and repair of historic materials and features rather than extensive replacement and new construction." The dictionary definition of *maintain* is "to keep in an existing state (as of repair)." As Stewart Brand points out, "Preservation IS Maintenance."[1]

However, designers and building owners generally approach preservation work as a typical design-bid-build process with a defined beginning and end. Brand asserts "building maintenance has little status with architects. They see the people who do the maintaining as blue-collar illiterates and the process of upkeep as trivial, not a part of design concerns."[2] The challenge then is for architects to recognize their role in the long-term maintenance and preservation of buildings during initial construction or implementation of major repairs, long before new distress develops and further intensive repairs are needed. The challenge for owners is to fit development of maintenance plans into their project budgets. When historic preservation professionals embrace the role of maintenance planner during the design and construction process, they are better able to assist the owners in establishing a sound program for a building's long-term preservation.

Proper routine maintenance can minimize, delay, or avoid the deterioration of building components and the need for intensive future repairs. With proper preventive maintenance, the cumulative costs of repair and maintenance work should be reduced over time, because deterioration tends to increase exponentially over time. A straightforward example is the painting of exterior wood elements. Frequent repainting imposes a small cost on a regular basis. Deferring painting can save a little money in the short run, but allows rot and decay to gain a foothold in the wood element. The spread of deterioration may eventually require a more drastic repair or even total replacement, exceeding the cost of the painting work that could have prevented the deterioration.

Maintaining existing building materials is inherently a more sustainable approach than allowing materials to deteriorate to the point where replacement is necessary; the energy and resources consumed by maintenance will be less than what would be needed to replace or reconstruct the building. Maintenance also helps preserve the historic integrity of significant buildings. If existing materials are regularly maintained and prevented from deteriorating, the integrity of materials and workmanship of the building is protected.

Recreational structures encounter many of the deterioration and maintenance issues common to other building types. However, there are some issues that make maintenance of these historic resources particularly challenging:

- They are vulnerable to wear and tear because of intensive use by large groups of people
- They may experience seasonal periods of inactivity (and lack of maintenance)
- They typically have higher exposure to vandalism or graffiti because of public access combined with periods of disuse
- Their design may incorporate uncommon decorative or fanciful elements that may prompt unusual maintenance needs

Maintenance Schedules

Once an owner acknowledges the need to plan in advance the maintenance of the building, the challenge becomes collecting, organizing, and presenting the recommended maintenance work in a form that will be useful for future budgeting and scheduling work. A maintenance schedule can provide the owner or manager with the information needed to perform specific maintenance tasks in a timely routine. The maintenance schedule can convey information on the anticipated performance of systems and materials from the builder or original designer.

The best time to develop a maintenance schedule is during the design process, when building systems and materials are best known and understood. The maintenance schedule can then influence life cycle cost decisions and the level of quality to be provided in the initial construction. For historic buildings undergoing a major work effort, including the development of a maintenance schedule as part of the design process is even more crucial, both to guide restoration detailing and material selection decisions and to determine realistic owner expectations regarding future maintenance needs once the repair work is "completed."

Typically, the following tasks are needed to develop a useful maintenance schedule:

- Identify systems, components, and materials
- Determine an estimated service life for each component
- Develop intervals of inspection, routine maintenance, minor repair, major repair, and ultimate replacement
- Provide general guidance on how to inspect, maintain, and repair each component

Service Life

Materials and systems do not last forever. Obtaining information on their life expectancy is an important step in developing a useful maintenance plan. A range of life expectancy for most building materials and systems are fairly well known. Product warranties can provide useful guidance on estimating service life. Life expectancy information can also be obtained from industry associations, professional organizations, and from one's own professional experience. Some useful industry organizations include:

- Brick Industry Association
- National Stone, Sand and Gravel Association
- Vinyl Siding Institute
- National Roofing Contractors Association
- Slate Roofing Contractors Association of North America
- Copper Development Association
- The Aluminum Association
- American Composites Manufacturers Association
- Insulation Contractors Association of America
- North American Insulation Manufacturers Association
- American Architectural Manufacturers Association
- Window & Door Manufacturers Association
- Association of the Wall and Ceiling Industry
- Ceramic Tile Institute of America
- Kitchen Cabinet Manufacturers Association
- National Kitchen & Bath Association
- American Society of Heating, Refrigerating and Air-Conditioning Engineers
- Air-Conditioning and Refrigeration Institute
- Mechanical Contractors Association of America
- Plumbing and Drainage Institute

One of the more ubiquitous building envelope materials, building joint sealant, requires routine maintenance, which is often not performed until after water leakage is observed in the building. ASTM C1299 provides useful information on expected service life for various types of elastomeric joint sealants.

Sample Maintenance Schedule

The sample maintenance schedule and associated task descriptions (refer to sidebar) were developed by the authors for a newly constructed condominium building in metropolitan Chicago. Note that a minimum level of inspection and maintenance is included at the most frequent interval for all elements, to ensure that unexpected problems or unique distress conditions are discovered promptly. Although a five-year baseline interval was adopted for masonry, other elements (such as flat roof areas) included recommendations for inspection activities that should be performed annually. Minor elements, such as the sealant joints, require repair work on a more frequent basis, while more intensive repairs to brick, cast stone, and limestone are expected to occur at longer intervals over the life of the building. However, the shorter-cycle maintenance work is required in order to achieve the long life expected for the major facade elements.

Generally, it is preferable to assign particular years to particular tasks, rather than just describing intervals. For example, rather than stating "joint sealants will require replacement at twenty year intervals," the direction "joint sealants will require inspection in 2006, 2011, 2016, and 2021, and replacement in 2011 and 2021" is more specific and useful to future planning.

Sample Maintenance Schedule

Masonry

Year	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
Pointed joints	IM	IM	IM	IM	IM	RP	IM	IM	IM	IM
Sealant joints	IM	RS	IM	RS	IM	RS	IM	RS	IM	RS
Brick	IM	IM	SBR	IM	IM	NBR	IM	IM	SBR	IM
Cast Stone/Limestone	IM	IM	SST	IM	IM	NST	IM	IM	SST	IM
Precast Balconies	SE*	SE	SE	SE	SE	SE	SE	SE	SE	CO

* Note: It is recommended that the balconies be coated every two years.

IM = Inspect and maintain. Inspect the masonry wall elements from grade using binoculars, from balcony areas, and from roof areas. Remove any loose spalls if present in brick, limestone, or cast stone. Fill any gaps or breaches in sealant joints. Add mortar to open mortar joints, if present.

RP = Repoint joints. If mortar is observed to be cracked, loose, or missing, repointing is required. To repoint, remove the existing material from the joints, taking care not to damage the brick, limestone, or cast stone units. Place Type N mortar into the prepared joint in three equal lifts. Tool the surface of the joint to a concave profile. Clean the facade with a mild detergent and water after pointing.

RS = Reseal joints. Remove all sealant joints and replace. Clean the joints of debris, dust, and existing sealant residue; prime joint surfaces; and install new sealant. Multiple colors of sealant should be used, matching the color of brick or cast stone masonry adjacent. Also, any cracks related to thermal and moisture expansion in the masonry should be identified. Remove the mortar from the cracked area. Clean the joints of debris and dust; prime the joint surfaces; and install a new continuous sealant joint.

SBR = Stabilize brick. At areas where cracked, spalled, or damaged brick units are observed, perform localized repairs. Repair movement-related cracks by routing the crack and installing bond breaker tape and sealant. Remove existing deteriorated sealant or mortar in previously repaired cracks and install new sealant. Remove all loose spalls within brick masonry.

NBR = Install new brick. At areas where cracked, spalled, or damaged brick units are observed, install new brick units. Remove the damaged brick units and install new units in full mortar beds matching the original units in size and color. At locations of embedded steel such as window lintels, dismantle brick as needed to expose the entire steel element, repair and recoat the steel element, and rebuild the brick masonry, using new brick units. Incorporate new flashing to protect the steel lintel. Anchor the new brick to the concrete block masonry behind using lateral wall ties.

SST = Stabilize cast stone or limestone. At areas where cracked, spalled, or damaged cast stone or limestone units are observed, perform localized repairs. Remove small spalls and delaminations. Repair movement-related cracks by routing the crack and installing bond breaker tape and sealant. Remove existing deteriorated sealant or mortar in previously repaired cracks and install new sealant.

NST = Install new cast stone or limestone. At areas where severely cracked, spalled, or damaged cast stone or limestone units are observed, install new cast stone or limestone units. Remove the damaged units and install new units in full mortar beds matching the original units in size and color. At locations of embedded steel such as window lintels, dismantle cast stone as needed to expose the entire steel element, repair and recoat the steel element, and rebuild the cast stone masonry, using new units. Incorporate new flashing to protect the steel lintel. Anchor the new units to the backup using lateral wall ties.

SE = Seal concrete balconies. Every two years in spring, apply a clear penetrating sealer on the deck surface of the precast concrete balconies. Clean and prepare the deck surface as recommended by the sealer manufacturer. It is recommended that this maintenance activity be implemented every two years in spring.

CO = Concrete repairs at balconies. Inspect the concrete balconies for cracks, spalls, and delaminations. Remove all unsound areas of concrete. At deep spalls, expose the embedded reinforcing steel, clean and coat the steel, and install a concrete patch. Alternately, replace to match any original balconies that show significant cracking or other distress.

The individual maintenance schedules and tasks for the various building components can be combined into and presented in a comprehensive report. The typical maintenance report would normally include:

- Description of the building
- Itemized list with description of materials, components, and systems included and installed on the building, including trade names, as well as components or systems not covered in the maintenance report (For example, interior finishes such as painted gypsum board or carpeting may be excluded.)
- Maintenance schedules and tasks for each material or component, organized by CSI divisions
- Descriptive narrative for each task or activity included in each schedule
- Reference product literature, catalog cut sheets, shop drawings, and other useful reference materials

Depending upon the size and complexity of the maintenance report, a three-ring binder format may be preferable to a permanently bound report, to allow for the insertion of future records or product data sheets when maintenance work is implemented.

Conclusions

Although we may all agree that "preservation IS maintenance," successfully implementing maintenance takes more than just saying "maintain the building." Maintenance schedules should be developed along with the design. Establishing and following a realistic plan or schedule that anticipates the need to maintain and replace building components can help trigger maintenance work in a timely and cost-effective manner.

Experience has shown that most buildings are under-maintained. While there is obviously no guarantee that a maintenance schedule will be followed by future owners or building managers, without such guidance the likelihood that effective and timely preventive maintenance will be performed is even less. Providing information that owners can use to guide future maintenance decisions is an important means of contributing to the long-term protection of buildings.

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Notes

1. Stewart Brand, *How Buildings Learn* (New York: Penguin Books, 1994), 110.

2. Ibid.