Best Practices

in Stone Building Preservation Management

Presented to San Antonio Missions National Historical Park
by The University of Texas at San Antonio Center for Cultural Sustainability

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Cover Images
The NPS-managed portions of (clockwise from top) Missions San José, San Juan, Concepción, and Espada. Photos by Tracie Quinn, Marcus Huerta, and Kelsey Brown.

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Key Points

OVERALL

- **Treatment objectives should be clarified and put in writing before any work commences** (See p. 7). These objectives are usually included in a Historic Structure Report crafted for the resource. Also, review the resource's historical significance, which can be found in National Register and/or UNESCO documentation. **Stakeholders and consulting parties should be engaged to discuss treatment objectives,** as well.

DIAGNOSTIC

- **Avoid expensive, high-tech diagnostic testing unless there is a specific question or problem to be investigated** (See p. 6). Take into consideration the presence of archaeological artifacts. Invasive or destructive investigation techniques are often undesirable or even prohibited (See Harvey, p. 36).

- "**Focus on determining underlying causes of observed distress or anomalous conditions**, rather than the distress itself" (See Harvey, p. 37).

- **Understand how moisture moves through a building.** Failure to do so can result in misdiagnosis, inappropriate interventions and unintended consequential damage (See p. 12). "A trial-and-error approach to interventions should be avoided" (See Henry, p. 52).

- **Cracks alone are generally not a concern,** but they can be evidence of potentially larger troubles (See p. 12).

- Best practices include **regular inspection by knowledgeable staff** looking for roof leaks or flaws in the drainage systems. (See p. 13).

SITE WATER MANAGEMENT

- Do not allow water to pond or dwell around or near structures.

- Limit irrigation around buildings.

- Do not allow water to pond on roofs for extended periods of time.

- Protect roofs and copings with waterproofing materials.

- Provide ventilation for attics, vaults, basements, etc. (See Itle & Murray, pp. 54–59).

Key Points (continued)

WALLS

- Always divert water as much as possible before it can enter the walls (See p. 13).

- **Be on the lookout for evidence of moisture infiltration.** For example, a spot of especially green grass near the foot of a building could be a sign of abundant soil moisture, which could be the source of rising damp (See Henry, p. 51).

- Caps are needed on free-standing walls without roofs. Typically, the cap is a hard mortar mix, though "a liquid-applied membrane may be an appropriate choice," as well (See Itle & Murray, p. 57).

- Make sure repair materials are compatible with the original (See p. 65).

CLEANING

- **Preservationists do not agree on the pros and cons of removing biofilm.** That being said, avoid cleaning products that are acidic or highly alkaline (See pp. 67–68).

- When cleaning, follow the principle of **"gentlest means possible"** (See p. 17).

- Prior to cleaning:

    - Be sure to learn more about the types of stones that make up a historic site—their physical properties and the minerals they contain. This information can be found in documents such as a Historic Structure Report or determined through laboratory testing.

    - Determine the building's current conditions—erosion, cracks, weathering, etc. (See Gale, p. 69).

    - Consult OSHA's Safety Data Sheets for any cleaning product being considered. Additionally, product manufacturers may provide upon request a reference lists of projects that used their product.

    - Test any new cleaning product before widespread use.

- Chemical consolidants should be reserved for severe stonework deterioration (See Gale, p. 69).

- **Remove graffiti as soon as possible.** Regarding graffiti control treatments, polysaccharide sacrificial coatings appear to be effectice. (See Gale, p. 69).

Key Points (continued)

MORTAR

- Because **no two buildings or sites at SAAN are exactly the same,** mortar repointing methods and mixes must be guided by lab analysis and approved in advance (See p. 17).

- **Repoint only when needed,** don't feel bound to a cyclical maintenance schedule (See p. 17).

- **Ensure lead masons hired by the park to do a repointing project boast five or more years of experience** (See Adler, p. 76).

- **Replacement mortar, "should be softer and should have higher water vapor permeability than surrounding masonry and historic mortar** … repair mortars used at SAAN should be a formulation of Natural Hydraulic Lime (NHL) and aggregate only" (See Adler, p. 75).

PLASTER

- Retain as much Spanish Colonial plaster as long as possible (See p. 18).

- "Repair mixes should be physically, chemically, and aesthetically compatible with the historic plasters; have low shrinkage and moderate strength; contribute negligibly to the soluble salts in the system; and be durable enough to withstand the weather but relatively easy to remove if the need arises (See Bass & Porter, p. 87).

- **Avoid binders that include Portland cement** (See Bass & Porter, p. 87)

RISK ASSESSMENT/MANAGEMENT, AND DISASTER PLANNING

- Preventive maintenance increases hazard resilience.

- Documentation is key, as cyclical documentation can show how well a treatment is working or how fast an area is degrading. Generally **more documentation is a better strategy than less.** Completion reports should be filed upon the conclusion of any capital improvement project (See p. 25).

- Be sure to seek and include public input in disaster planning/preparation and engage with the Texas Division of Emergency Management [TDEM] (See Meyer & Semien, p. 91).

- Large capital improvement projects at SAAN warrant the inclusion of a dedicated risk manager on the contractor's team managing a "project risk plan" (See Staley, p.103).

Introduction

The San Antonio Missions *Manual of Best Practices in Stone Building Preservation Management* was prepared by the University of Texas at San Antonio's Center for Cultural Sustainability (UTSA-CCS) to provide a framework for the ongoing care and management of the historic Spanish Colonial structures in the San Antonio Missions National Historical Park (SAAN). Based on assessments of the Missions' designations of historic significance, stated preservation objectives, and observed heritage values, this manual provides guidance to assist the National Park Service (NPS) in the management of the Missions as a National Historical Park and UNESCO World Heritage site.

The *Manual of Best Practices* details implementation priorities and treatment protocols for stone masonry at the SAAN sites, which includes four compounds and associated features. The first and second sections of the manual focus on treatment principles and essential building health, including structural issues and site water management. The third section of the manual addresses risk management of the park's cultural assets.

The fourth section of the manual focuses on heritage documentation and archives management. Section Four also includes interpretation issues as they relate to building preservation, plus the practices for care of collections and artifacts encountered during preservation projects. The fifth and final section is concerned with management of preservation issues which arise during actual treatment, including all types of maintenance, repair, conservation, and capital improvement projects.

The work is informed by and includes contributions of invited experts. These professionals were engaged to write white papers on distinct topics defined in advance by UTSA-CCS to support the manual, and then to present their work for discussion in a Symposium organized by UTSA-CCS and hosted by SAAN on 19–21 May 2021. The resulting ten academic white papers, submitted, reviewed, and revised prior to the Symposium, are appended to the manual as edited proceedings of the event.

Invited peer reviewers were engaged to participate in the Symposium and then issue comments on the entire manual.

ACKNOWLEDGEMENTS

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- **Dr. Tamra Walter,** Associate Professor, Texas Tech University. "Spreading the Faith: Missions and Presidios in Spanish Texas."

Section One | Preservation Treatment Principles

A. *THE SECRETARY OF THE INTERIOR'S STANDARDS FOR THE TREATMENT OF HISTORIC PROPERTIES*

All types of preservation and maintenance work are considered "treatments," and compliance with the *Standards for Treatment of Historic Properties* (36 CFR Part 68, 1995) is mandatory at San Antonio Missions National Historical Park (SAAN). The *Standards* define acceptable treatments for preserving, rehabilitating, restoring, and reconstructing sites of historical significance.

They are issued by NPS with accompanying Guidelines. In 2017, the *Standards* were revised and updated by Anne E. Grimmer to address newer building assemblies developed since 1995. Grimmer's 2017 effort expanded the Guidelines with new illustrations, also addressing fresh topics.

> The *Standards* 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. New exterior additions are not within the scope of this treatment; however, the limited and sensitive upgrading of mechanical, electrical, and plumbing systems and other code-required work to make properties functional is appropriate within a preservation project."

Figure 0.1: Definition of "preservation," from Grimmer, 2017, p. 27

Each of the four treatment types is defined in the *Standards* with a specific definition. All represent common-sense principles developed by the U.S. Department of the Interior, National Park Service, to help protect our nation's irreplaceable cultural resources by promoting consistent preservation practices. The *Standards* are applicable to all NPS properties listed on the National Register of Historic Places: buildings, sites, structures, objects, and districts. The *Standards* present approaches to maintaining, repairing, and replacing historic materials, as well as designing new additions or making alterations.

Regarding the historic buildings and structures of SAAN, the applicable treatment principle is "preservation." (See Figure 1.1). The preservation treatment is the one most widely employed at NPS historic sites, particularly at historic sites open for educational purposes or functioning as historic museum properties.

In addition to the *Standards for Treatment,* there are numerous publications by NPS Technical Preservation Services which provide reference standards for preservation treatments. Historic masonry is specifically addressed in *Preservation Briefs #1, #2,* and *#38.* Staff at SAAN who are responsible for stone building preservation should be familiar with these publications.

Preservation Brief 1, Assessing Cleaning and Water-Repellent Treatments for Historic Masonry Buildings, by Robert C. Mack, FAIA, and Anne E. Grimmer (2000), and ***Preservation Brief 38, Removing Graffiti from Historic Masonry*** by Martin E. Weaver (1995), were written over two decades ago. Yet, both *Preservation Briefs* remain valid. They offer generic advice applicable to all types of situations. The white paper by Fran Gale, "Stone Masonry Preservation 1—Chemical," appended to this manual, has been written specifically to the conditions and situations at SAAN. Gale's paper should be the principal reference source, used in conjunction with the broader and more general advice found in *Preservation Briefs 1* and *38.*

Preservation Brief 2, Repointing Mortar Joints in Historic Masonry Buildings by Robert C. Mack, FAIA, and John P. Speweik (1998), has been revised and updated since it was first issued in 1976. Like other *Preservation Briefs,* it is a solid reference standard, yet it is not specific to SAAN. Staff who are responsible for mortar preservation at SAAN should refer to *Preservation Brief 2* as supplemental to the specific advice in this manual of best practices, looking in particular to the appended white paper by Rachel Adler, "Considerations for Mortar Repair and Replacement at San Antonio Missions National Historical Park."

Table 0.1: Basic Principles and Ethics of Historic Preservation Practice
First, do no harm Routine and cyclical maintenance
Reversibility & re-treatability Take good care of the existing materials
Research methods; evidence-based Exemplary scholarship using credible sources
Sustainability/longevity/resilience Make choices to benefit future generations
Archive Properly catalogue and store records and artifacts
Participation/inclusion of stakeholders Document stories and viewpoints of people
Objectivity Planning and design without bias; full disclosure
Legibility & uniformity New work distinguishable, yet well-blended
Authenticity/honesty Do not manipulate the historical record
Fiduciary responsibility Design and build within the capacity of the context
Heritage documentation Survey, measure, photograph everything

B. PRINCIPLES OF HISTORIC PRESERVATION PRACTICE

Principles of practice guide the actions of site managers, consulting professionals, and topic experts involved in cultural resource management. This is especially true for preservation of monuments and public history sites, places like SAAN where people visit to be educated about the past. Regarding best practices for care of masonry walls, the relevant principles of preservation practice concern the field of architectural conservation, which is the preservation of buildings and structures.

Managers of SAAN should review and consult the principles of historic preservation practice during master planning endeavors, at inception of new projects, and prior to approval of reports or documents from architects, engineers, conservators, and contractors.

The key principles to guide SAAN projects are represented in Table 0.1 and listed below, 1–12.

1. **First, do no harm** is the Hippocratic Oath of the medical profession and it can be applied to cultural resources. In practice, this translates to "gentlest means possible," or "least intervention necessary," because actually, it is not possible to do zero harm to the walls. That's because some historic materials or assemblies, hopefully small quantities, are always altered or destroyed in the process of achieving conservation aims for masonry walls. The principle is to fully consider the long-term (think multi-generational) impacts of your present-day actions. Before implementing conservation treatments, consider the length of time the resource has survived and what can be done to perpetuate it without unnecessary changes that may possibly cause harm.

2. **Reversibility and re-treatability** principles refer to the desirable attributes of preservation treatments which will not prejudice or preclude future treatments. The history of masonry preservation treatments sadly offers multiple examples of treatments people believed were a good idea at the time, later discovered to be damaging. Anticipating the possibility this can happen again is prudent. This principle calls upon everyone to avoid permanent physical or chemical changes to a material or assembly. At the very least, caution should be used when deviating from straightforward solutions which are proven effective, and take measures to mitigate the potential harm which might result.

3. Principles of **research methods** include good scholarship and adherence to the process of scientific enquiry. Each academic or professional discipline has its own norms and standards, but the overall aim is consistent. All parties should follow established methodologies, cite sources, and maintain a retrievable record of research, data collection, and design

(treatment) choices.

4. **Evidence-based** treatment is critically important. This means case-by-case diagnosis to determine and treat the cause of a problem, not merely symptoms. Adherence to this principle often requires careful and exemplary diagnostic evaluation. Site managers should be suspicious of any treatment not in response to a known problem or threat. Always pause to consider the option of "no action" as preferable over speculative treatments that "probably can't hurt."

5. **Non-destructive evaluation** (NDE) is preferable to methods requiring disassembly, removal, or destruction, no matter how slight. Always strive to pursue NDE methods first, consistent with the principle of "do no harm."

6. **Sustainability** and also longevity, resilience, and durability, are generally good design principles for any type of construction or conservation project. However, these may be in conflict with principles of reversibility and do no harm. The project team must find the appropriate balance. In managing a cultural resource like the S.A. Missions, erring on the side of lower longevity (e.g., no Portland cement in historic mortar mix) in favor of less harm is often good practice.

7. **Archive** and maintain good records. This principle starts with good heritage documentation to establish a base-line record of conditions (exactly as prescribed in NPS-28), runs through all project documents, and includes project completion reports. Every bit of information may be essential to solving a future problem. All must be archived for easy retrieval when needed.

8. **Participation and inclusion** of stakeholders is a principle of practice which can require a lot of effort, yet reaps great rewards. Project results are improved by listening in the planning stages to what people value about a cultural resource.

9. **Objectivity** is attained by being open to new ideas and working without bias to the extent possible. Objectivity is related to the principle of disclosure necessary for transparency of decision-making. This includes consultants (and other parties to important decisions) on preservation of cultural resources publicly disclosing their credentials, associations, and prior work experience. Objectivity is necessary for successful inclusion of stakeholders and assessment of preservation design or treatment choices.

10. **Legibility** of treatments is a principle for better comprehension by careful observers and future caretakers. New work should have characteristics distinguishing it from historic periods. Changes, including conservation treatments to masonry walls, should be apparent upon close inspection. Attaining legibility of changes over time does not mean allowing visual discordance. The new work should not be so obvious it distracts from the visitors' experience. There is a corollary principle which tempers legibility—uniformity of appearance. Finding the right balance between legibility and uniformity will be informed by the "Treatment Objectives," discussed below.

11. People value **authenticity** at historic places. Visitors to historic sites never prefer reproductions over reality. An authentic thing is honest, not false. Visitors expect **honesty** in preservation of real, surviving heritage at historic places.

12. **Fiduciary responsibility** is simple common sense – design and build within the capacity of your context. Yet, historic sites are rife with examples of ambitious, innovative projects later exceeding the capacity of the place to support, operate, or maintain what was done. This happens when the planning team fails to consider and respect the long-term capacity of their context.

Principles described above are written into many guidelines, charters, and doctrines issued by international advisory bodies and individual nations. Notable among these are:

- International Charter for the Conservation and Restoration of Monuments and Sites, also known as the “Venice Charter,” 1964;
- UNESCO World Heritage Convention, 1972 (and subsequent Operational Guidelines);
- The Australia ICOMOS Charter for Places of Cultural Significance, also known as the “Burra Charter,” (1979—current revision, 2013); and
- Nara Document on Authenticity (1994).

C. ESTABLISHING TREATMENT OBJECTIVES

The overarching treatment objective at SAAN is the “preservation” treatment defined in the Secretary of the Interior’s *Standards for the Treatment of Historic Properties.* SAAN managers should regard this as a minimum standard. All projects must be planned, designed, and executed in compliance with the *Standards.* Yet there is wide latitude within the “preservation” treatment standard for a variety of outcomes. In practice, different resource at a complex site like the San Antonio Missions can and often should have slightly different treatment objectives.

Conservation of a 1950s wall feature may be handled quite differently from an 1860s convento or a 1760s plaster fresco, yet all three projects will meet the Standards for Preservation.

Furthermore, managers of SAAN will find specific problems often have more than one technically correct response. For example, an engineer might provide several good options for repair of a structural problem. Then a choice is necessary to pick the one most appropriate. What is the best practice to select the appropriate treatment? Ideally, the selected treatment will be in accord with past treatments consistently applied at the same resource over prior decades. How is this attained? The answer is found in the treatment objectives for the resource.

Best practice for care of historic resources like SAAN calls for the treatment objectives to be written and acknowledged in advance. Establishing treatment objectives can begin at any time. Often the topic is a section in a well-written Historic Structure Report. Figure 0.2 provides an example of a treatment recommendation found in the Historic Structure Report for the Mission San Jose convento. The treatment objectives need to be revisited when discussions commence or plans are made for individual preservation projects. If not already written, the first step is to consider the rationale and motivations for the specific project at hand. People often believe this is a simple step, maybe even not necessary, yet it is a prerequisite to establishing treatment objectives which will guide a project from start to finish and set the stage for future projects in decades to follow.

Excerpt of Treatment Objectives for Mission San José Convento

“Applying the preservation treatment to the Mission San José compound means the extensive reconstructions and restorations pursued in the 1930s under the leadership of Harvey P. Smith are to be conserved with the same degree of respect granted to earlier periods of construction. However, there are subtle allowances for modifications to the 1930s work when it is deemed harmful to surviving fabric from the Spanish Colonial era. Portland cement mortar, for example, is a distinctive characteristic of the work that is not replicated. Similarly, the 1930s work is generally treated with a little less reverence than the colonial materials …”

Figure 0.2: Treatment objectives for the convento structures at Mission San José, from Dupont, Lombardi, et al., 2019b, pp. 229–231.

The process can be guided by straightforward questions, and these same questions can be revisited as often as needed.

- Why preserve the site, building, or feature?
- What are the driving forces behind the project?
- What are the contemporary benefits of the historic fabric to be conserved?
- How will heritage be used, i.e., made to perform, for the good of visitors to the site?

The answers to these questions will illuminate principles and objectives guiding the work.

Another key to establishing the treatment objectives is to review the historical significance. The National Register statement of significance and UNESCO outstanding universal value should be reviewed and clarified (in writing) as they pertain to the resource or individual preservation project.

The integrity of the resource, including physical condition, plays a role in establishing the treatment objectives. Integrity as defined by NPS is the capacity of the resource to convey its significance. No masonry conservation project can proceed without a full understanding of the resource's integrity. Built features with high integrity also have a high percentage of surviving material from the period of significance. Treatment objectives explain, in writing, how integrity will be respected and enhanced, never diminished. Integrity relates to significance and it varies up and down from place to place across the SA Missions.

The masonry walls of the SA Missions have much variety concerning the periods of historic significance. Some features are pure 18th-century Spanish Colonial, others represent clumsy historic preservation efforts from the mid-20th century, and there is everything in between. All of it is historic, yet treatment objectives may need to establish appropriate priorities.

All are part of the education programs interpreting Spanish Colonial history. SAAN managers of course recognize that the construction date (and thus physical appearance) will not always coincide with the period of interpretation. Treatment objectives need to realistically address this matter, too.

If appropriate to the project, stakeholders and consulting parties should be engaged to discuss treatment objectives, as well. The objectives can be nicely informed and refined by public comments when circumstances warrant. The public involvement generally enriches understanding of contemporary values, providing information about what is most important to preserve.

Ultimately, all projects need a succinct statement of objectives to guide the people (NPS staff and professional consultants) who will design, specify, and execute the preservation treatment.

Even straightforward masonry repointing demands clarity or purpose for the craftspeople. People involved in a project should be provided information about the values and motivations driving their efforts and given the opportunity for discussion.

Common to all historic stone structures at SAAN is a passionate desire to see them unfinished and somewhat ruinous, as they have existed since the mid-19th century. The "preservation" treatment as a primary objective means maintaining a partially dilapidated condition.

In terms of pure conservation, though, the best long-term care of all walls would be to re-establish historic surface finishes wherever they are known to have existed. Yet, such a treatment would dramatically alter the appearance of the missions, obscure aesthetic qualities of the stone, and perhaps clash with the inclinations of mission descendants and heritage tourists alike.

> "It is well to bear in mind the saying: 'Better preserve than repair, better repair than restore, better restore than [re]construct…It is better to retain genuine old work of several periods, rather than arbitrarily 'restore' the whole, by new work, to its aspect at a single period."
>
> —The Advisory Board on National Parks, Historic Sites, Buildings, and Monuments, 1936

D. WORLD HERITAGE MANAGEMENT ISSUES

The San Antonio Missions are a UNESCO World Heritage cultural site, inscribed in July 2015 by a decision of the World Heritage Committee.

SAAN leadership participates on a local World Heritage Advisory Committee with all the other property owners to fulfill obligations of World Heritage management. The obligations are consistent with DO-28 and all standard NPS procedures, but do add a layer of additional responsibilities.

The 2014 World Heritage nomination document for the San Antonio Missions describes World Heritage management planning responsibilities.

“The purpose and mission of the World Heritage management plan is to preserve and protect the Outstanding Universal Value of the San Antonio Missions and all of the associated features (acequias, labores, rancho, etc.), and to work actively to ensure their continued relevance for Americans and for visitors from around the world.

The San Antonio Missions will continue to be managed in a way to preserve their cultural resources while respecting the living and religious traditions of the missions and ensuring they continue to be representative of cultural and religious traditions in San Antonio and South Texas.” (Management Plan, Appendix A, p.6)

All the expectations and requirements for protection and management of World Heritage sites are contained in the 1972 World Heritage Convention and further detailed in the World Heritage Operational Guidelines periodically revised and reissued by the World Heritage Committee.

E. DIRECTOR’S ORDER 28

Director’s Order 28 (a.k.a. DO-28 or NPS-28, as modified) provides guidance to SAAN park leadership regarding management of cultural resources like the masonry walls at the missions. Managers of SAAN must always conduct work in accord and compliance with DO-28. All aspects of the *Best Practices* manual are consistent with DO-28.

Cultural resources are “the material evidence of past human activities” (NPS, 1998, p. 9). Without the proper preservation of these nonrenewable resources, deterioration can lead to the loss of parks’ purpose. Once cultural resources are destroyed, they cannot be replaced. Therefore, the primary goal of cultural resource management is to “minimize the loss or degradation of culturally significant material” (NPS, 1998, p. 13). Through cultural resource management, there is research, planning, and stewardship that bring awareness to the finite nature of these material resources.

The Directive System provides comprehensive guidance to NPS managers and staff. National Park Service Director’s Orders remain in effect until amended or rescinded by the Director. NPS Management Policies guide research, planning, and stewardship actions to protect and manage cultural resources. The key program activities of NPS-28 include the management of ethnographic resources, archeological resources, museum objects, cultural landscapes, and historic and prehistoric structures (NPS, 1998).

DO-28 acknowledges research must be conducted to establish, fully understand, and preserve cultural resources. This is done through a process of identification, evaluation, documentation, and registering. Each cultural resource requires public history interpretation, as well. All of this is essential for park planning and operations, so that decisions are based on the inventory and data collected in research phases. It is the responsibility of NPS to identify and plan, at a local, state, and national level, for the protection of cultural resources and their significant value at each level.

Per DO-28, park planning for care of cultural resources should be interdisciplinary and inclusive. Stakeholders from neighboring jurisdictions and organizations, outside the park’s boundaries, are routinely involved since parks concern a larger cultural environment.

Stewardship by the NPS, according to the Management Policies, states that the protection and preservation of all cultural resources will be done to preserve their existing conditions. The first consideration of resource treatment should always be the “preservation” treatment as defined by the SOI’s *Standards.* Even though rehabilitation, restoration and reconstruction are legitimate treatments on cultural resources, these other treatments tend to involve higher levels of harm to finite material. Long-term preservation goals should typically serve as the basis of how to determine the treatment for cultural resources.

SAAN has “four plans that assist in guiding the management of the property. All four are current, and are implemented under the direction of the Park Superintendent” (National Park Service, 2014, p. 268). These include the *Resources Management Plan* (2001), the *General Management Plan and Development Concept Plan* (1982), the *Comprehensive Interpretive Plan* (2002), and the *Park Asset Management Plan* (2007). Detailed information on each can be found in the *San Antonio Missions Nomination to the World Heritage List by the United States of America.*

Section Two | Essential Health of Stone Buildings

A. CONDITION ASSESSMENT AS BASELINE DOCUMENTATION

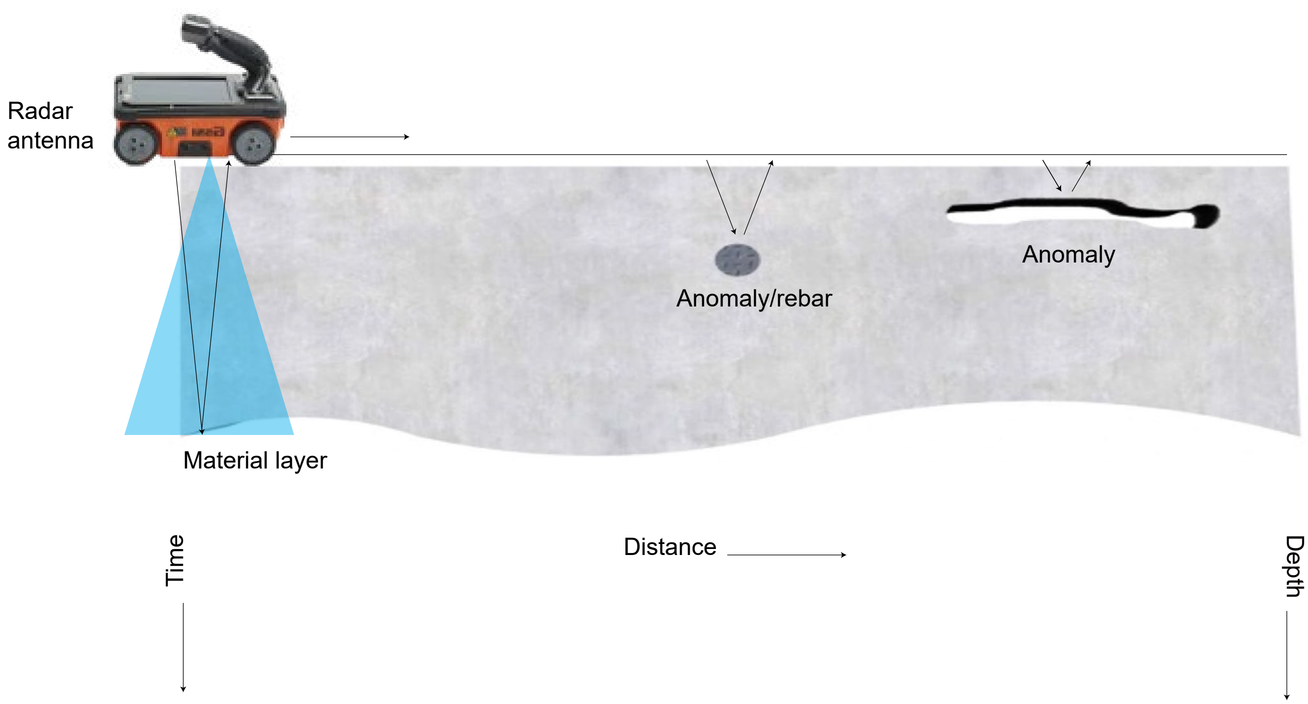
A condition assessment is a baseline document that details the current state of a building (or any cultural resource), identifies problems with building assemblies and material components and determines causes of the problems.

The key goals of a condition assessment are to identify preservation needs of historically significant materials and built features in order to make appropriate choices for maintenance, conservation and improvements or even new uses. **All condition assessments are based on field observations. Many also incorporate diagnostic testing or lab analyses of materials.** A thorough condition assessment contains the following elements:

1. A brief statement of historical significance and current preservation objectives or motivations;
2. Description of methods, equipment, personnel, weather, and other pertinent facts subsequent readers will need to evaluate the assessment decades in the future;
3. Relevant information about construction chronology and changes in the building(s) over time;
4. A summary of information from past condition assessments to use as comparisons for new observations;
5. Current description of materials and systems—exterior, interior, site drainage, structural, utilities, etc;
6. Assessment of identified problems with prioritized recommendations for treatment.

Condition assessments are an integral part of Historic Structure Reports (HSR), which are discussed in Section

Surface Penetrating Radar



Four.

Substantial conservation projects should always be informed by a recent condition assessment. In the context of rubble masonry walls at the SA Missions NHP, recent would mean within the past 6 to 8 years. Completion of a full Historic Structure Report is a routine expectation prior to undertaking any major conservation effort.

Analysis of conditions and diagnosis of problems requires thorough visual inspection. Site managers may need to provide access (or the funds for it) so topic experts can be close enough to touch the walls at all heights. Keep in mind:

- Drone use may not be as effective as up close, in-person inspection. Additionally, municipal codes may prohibit or restrict their use (Harvey, 2021).
- LiDAR is great for detailed documentation and has applications as a diagnostic tool but cannot alone be relied upon as a substitute for visual inspection. Also LiDAR data must be "read" by a knowledgeable assessor.
- Long-term diagnostic monitoring methods can be necessary to analyze and solve chronic conservation issues.

SAAN managers should understand diagnostic data collection without specific purpose is never cost effective. There should always be a targeted question or hypothesis to be solved or proven.

B. DIAGNOSTIC TECHNIQUES, INCLUDING MONITORING

See White Papers No. 1, 2, and 5

These topics are addressed in White Paper No. 1, "Diagnostics and Monitoring—Structural" by Donald Harvey of Atkinson-Noland & Associates Engineers. Harvey weighs the pros and cons of invasive and noninvasive techniques that include surface penetrating radar, infrared thermography, ultrasonic pulse echo, flatjack and shear testing, load testing, crack/tilt/vibration monitoring, LiDAR, and simple visual observation.

The historic structures of the San Antonio Missions are primarily heavy, rubble-stone walls. Many buildings exhibit differential settlement or structural movements with

Ultrasonic B-Scan

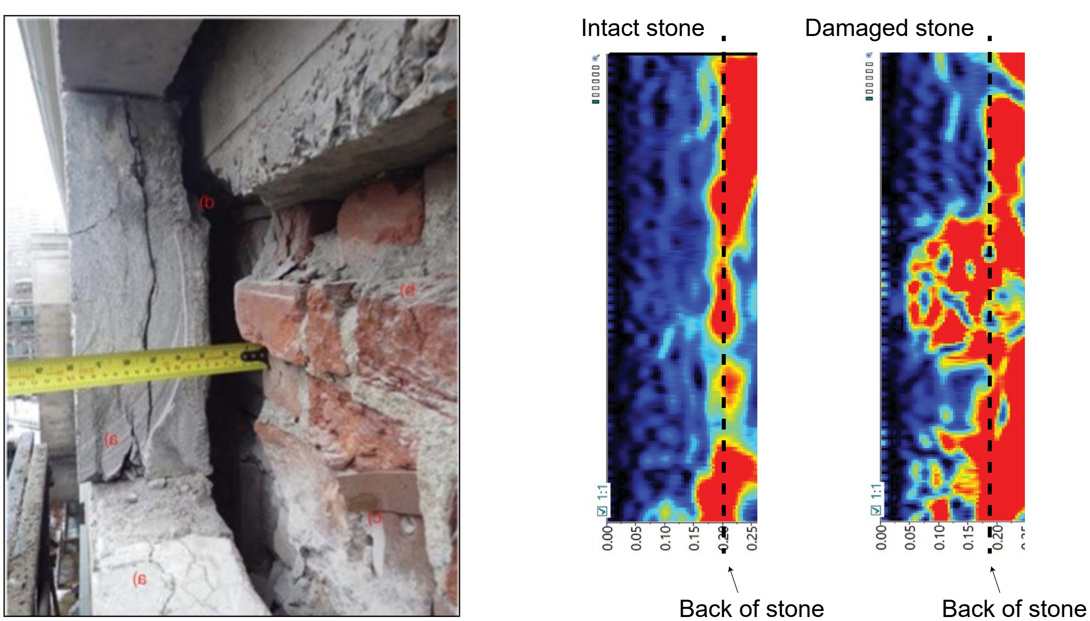


Figure 0.3 (This page and previous): Types of nondestructive evaluation methods, adapted from "Best Practices:Structural Diagnostics and Monitoring" PowerPoint presentation by D. Harvey, May 19, 2021. (GSSI Mini XT Image Source: Line Surveying)

corresponding cracks or wall rotations and deformations.

Assessment of foundation bearing conditions may require geotechnical investigations. When pursued, **geotechnical work always needs to take into consideration the presence of archaeological artifacts.** In the case of Mission Concepción, the compound sits on karstic limestone, with consequent groundwater movement and some erosion. This is a known trouble spot in need of further analysis.

A wide variety of diagnostic techniques are available to assess building health. Sometimes these will be part of a standard condition assessment. Other times a special diagnostic program may be needed. The white papers by Harvey and Henry appended to this manual provide more details on purposes and types of diagnostic monitoring. Identification of need for diagnostics will arise from recommendations of knowledgeable NPS staff or contractors/consultants with topical expertise.

Ongoing monitoring of various conditions is a necessity at areas of the Spanish Colonial walls exhibiting chronic problems of structural concern. The agent of multiple problems in masonry walls at the SA Missions is water. Water facilitates degradation of stones, bricks, mortars, and plasters by various mechanisms. The best practice regarding management of water (it can never be 100% controlled in rubble stone walls, but rather managed) is to first understand the patterns and cycles in the system. As Michael C. Henry of Watson & Henry Associates notes in his white paper appended to this manual, "Understanding masonry damage as the result of a system of moisture sources, movements, and sinks is an essential step in planning for a diagnostic program and testing. **Failure to understand moisture as a system can result in inappropriate interventions and unintended consequential damage** to historic building fabric" (Henry, 2021, p. 46).

The history of building analysis includes examples of expensive studies leading to inconclusive results. This problem can be avoided. Predicate diagnostic methods on hypotheses based in solid knowledge of how water damages the masonry assemblies at SAAN. The white paper by Henry provides the foundational knowledge needed by SAAN's site managers.

Engage topic experts in diagnostic monitoring of water problems only when there is a well-defined hypothesis or question to be answered and a reasonable certainty of findings which will prove or disprove.

At SAAN, some amount of structural movement is apparent in almost all the historic walls. Not all of it is a problem. Historic stone masonry assemblies are built and behave differently from modern walls. **Cracks alone are generally not a concern, but they can be evidence of potentially larger troubles.** The methods and techniques to diagnose movement of walls (evidenced by cracks and displacement) is detailed in the paper by Harvey, also supported by Nancy Hudson and Derek Trelstad in White Paper No. 5, "Stone Masonry Preservation—Mechanical," which is appended to this manual. In their paper, Hudson and Trelstad begin with an overview of wall assemblies at the San Antonio Missions, then outline the types of distress these walls experience, then conclude by weighing the pros and cons of interventions that include deep repointing, grout injection, pinning, and reconstruction.

Walls display patterns of deterioration; "these patterns involve clues such as the location and direction of cracking, the location and extent of spalling, visible bulging or leaning of walls, and indications of previous repairs" (Harvey, 2021).

Documentation of the structures in three dimensions using photogrammetry or LiDAR is a great tool with multiple purposes. Foremost among the benefits is the ability to read patterns of imperfections. Today, "the speed of data collection has increased with advancing technology, so complete LiDAR scans of structures of the type found in the SAAN can usually be completed in a few hours for a relatively reasonable price" (Harvey, 2021). LiDAR point clouds of data are extremely large digital files. Processing, analyzing, and manipulating the data requires commensurate computing power and skilled operators.

C. SITE WATER MANAGEMENT

See White Papers No. 2, 3, and 4

In White Paper No. 2, "Understanding Moisture Problems in Mission Masonry," Michael C. Henry of Watson & Henry Associates details how water—in both liquid and vapor form—enters, travels through, and exits the walls of the San Antonio Missions structures. A better understanding of masonry/water interaction and resulting deterioration, Henry asserts, will result in better long-term care of mission structures.

Water in all its phases is a catalyst for stone degradation because it facilitates the movement of minerals. Good building health depends on reasonable dryness of walls. Managing the water is key to reducing long-term problems. A primary strategy is to block or divert water away from the walls in the first place. "Site water management refers to techniques of managing liquid water occurring naturally on the site, whether from rain or in the ground. The limestone of the region is a permeable rock capable of transmitting and storing water" (Henry, 2021).

In White Paper No. 3, "Site Water Management and Roofing," Kenneth Itle and Erik Murray of Wiss, Janney, Elstner Associates provide an overview of intervention missteps that have occurred in the past and offer suggestions for preventing water infiltration. "The local geology, soils, and groundwater conditions also vary among the different missions, partly depending upon adjacency to the San Antonio River, which affects both the performance of foundations and the site drainage" (Itle and Murray, 2021).

The cycle of repeated wetting and drying, carefully described in Henry's paper, is problematic. Regrettably, this problem cannot be fixed, avoided, or 100% controlled because the stone walls sit out in the open, exposed to the elements. Though control is not possible, the situation can be well managed with high probability for successful outcomes.

Careful management of the problem through periodic maintenance is the only path to long-term care. Maintenance will be interspersed by larger, cyclical projects to address roofing and drainage.

D. ROOFS, ROOFING, PARAPETS, COPING, AND WATER DRAINAGE

See White Papers No. 3 and 4

Maintaining functional roofs with effective systems of water evacuation is a top concern for any historic building, and stone buildings are no exception. The evacuation needs to consider full drainage out and away from the buildings so the water is not splashed back or absorbed into walls through the ground. Best practices will include regular inspections by knowledgeable staff looking for roof leaks or flaws in the drainage systems.

Inspections tend to be most productive during and immediately after rain events. Also, the use of infrared cameras can be helpful in finding areas retaining moisture.

The missions include roofless, free-standing walls, in some cases two-stories high. Water readily enters walls through the top surfaces which are 2 to 3 feet wide. The builders did not intend to leave roofless rooms and structures. That is how they evolved to exist now in their romantic-ruin appearance. From a technical standpoint, it would improve longevity to have roofs, but new roofs would run counter to overall treatment objectives for preservation of resources as they exist.

There are numerous examples globally of archaeological sites covered by modern roofs for protection. The roofs can be small and localized to solve a specific problem, or large enough to span over an entire building such as at Casa Grande Ruins National Monument in Arizona. Modern roofs are a viable design choice for future consideration. A major change like this would be preceded by reevalaution of treatment objectives as discussed in the section above.

At the rooms and spaces with roofs intact, walls often extend past the roofline in a parapet condition. The tops of the very wide walls are an easy access point for water entry directly into the walls. There are reasonable solutions to protection of free-standing walls. As Itle and Murray note in their white paper appended to this manual, "Ideally, site water management and roofing strategies first rely on diverting water from the vulnerable structure or features using passive measures." However, they continue, "Given the architectural geometry and historic exterior appearance of the missions, a liquid-applied membrane may be an appropriate choice."

An area of great concern is the vast amount of exposed tops of walls. Recent approaches in capping the exposed tops have focused on application of appropriate water repellent coatings, often similar to a mortar and called a mortar wash, cement wash (when cement is used), and sometimes hard caps to describe any impermeable surface atop a parapet wall.

The mortar washes are historical appropriate and align with preservation principles, but this approach requires ongoing, routine maintenance attention in places very hard to reach with special equipment. In White Paper No. 4, "Going Green in Ruins Conservation and Management: Soft Vegetative Capping," author Alex B.

Lim of the National Park Service describes an alternate approach used in some other parts of the world but rarely employed in the U.S. In discussing the pros and cons Lim observes:

- "Hard caps may be easy to install but they are not sustainable. Once cracked and spalled, they do not meet the goals…"
- "When hard caps fail prematurely, the adverse impact on the original fabric continues."
- "Soft caps can be installed without harm to the historic walls. Once established, they acclimatize and do not need as much maintenance as hard caps."

E. PRESERVATION TREATMENT OF STONE MASONRY

See White Papers No. 5 and 6

The masonry assemblies (walls and vaulted roofs) at SAAN are a primary concern for conservation treatments. Presently, the structures have a backlog of needs. The masonry assemblies are different from roof surfaces described in sections above because they are not replaced on a 25-year cycle, are readily visible to visitors, and they embody the essential authenticity of the structures.

The masonry walls are generally porous as described in Henry's White Paper No. 2. During rain events, liquid water is absorbed into the walls, splashed onto the walls, or reabsorbed into the walls from the ground. None of this is good for the walls, so **best practices always include diverting the water as much as possible before it can enter the walls.**

Various past conservation methods have included disassembly/reconstruction, injections of strengthening/bonding formulations, and mechanical pinning. These methods are further described in the paper by Hudson & Trelstad, including the range of potential problems afflicting masonry assemblies of the type found at SAAN. The authors offer excellent advice, including:

- "Repair materials must be compatible with the original. Incompatible materials can accelerate deterioration."
- Instabilities of the wall must be addressed. "Different repair methods may be required for static conditions and dynamic conditions."

Damage caused by soluble salts is a primary concern. Moisture enables soluble salts to move, and then the masonry suffers mechanical deterioration and damage. The salts cannot realistically be removed, so care must focus on managing the moisture.

Surface cleaning of masonry is addressed in White Paper No. 6, "Stone Masonry Preservation—Chemical" by architectural conservator Frances Gale. **This is a controversial topic because professionals do not agree on the pros and cons of cleaning.** As Gale notes, removal of biofilm, "can increase porosity and surface area of stonework, encouraging the recurrence of the biofilm." She continues, "We recommend an in-depth investigation of the biofilms and whether they are damaging the stonework before removing them."

Gale also recommends avoiding cleaning products that are acidic, as the San Antonio Missions "are constructed of acid-sensitive materials such as limestone." Conversely, highly alkaline products are harmful as well. Detergent cleaners are preferred for "light to moderate soiling and those with near-neutral pH values (5.5 to 9.5)" (Gale, 2021).

Previous chemical conservation works have shown over time that deterioration of treated parts continues. During previous workshops at SAAN (Vanishing Treasures, 2016–2018), the question of stone surface treatments with chemical consolidants was discussed. Conservators postulated that the deterioration of stones was exponentially activated by previous chemical conservation treatments.

Gale notes in her paper, "In recent years, alternative conservation treatments have been developed for limestone and other calcareous stones. One is a tartrate treatment that converts calcium carbonate to a more stable mineral and has been effective as a pre-treatment for alkoxysilane consolidants (Doehne and Clifford, 2010). Another is nano-lime, an improved version of lime-based consolidants (Otero et al., 2017). Both treatments are said to strengthen deteriorated limestone."

Additionally, Gale recommends chemical consolidants be reserved only for severe stonework deterioration.

Table 0.2: Types of Stone at San Antonio Missions NHP

Name(s)			Characteristics	Dressing Types
		Pisolitic Limestone or Pisolitic Conglomerate (among which is included the so-called “caliche” stone)	Permeable Acid-sensitive Calcareous Grain diameter: 2 mm to 2 cm	Rubble Ashlar Special elements such as voussoirs
		Austin Limestone White Limestone	Permeable Micro-porous Acid-sensitive Calcareous Compact microcrystalline	Ashlar Rubble
		Concepción Tufa or Carbonite Tufa	Macro-porous Lightweight Friable Coarse and/or even textured Pore dimensions vary from 5 mm to 4 cm	Rubble Ashlar
		Wilcox Sandstone	Highly Permeable Micro-porous	Rubble Ashlar Flagstone

Special note regarding tufa stone

The wide variety of stone types used to construct buildings of the four mission compounds and their ancillary structures is shown in this table. One particular stone, tufa, has notably different performance due to large macropores. Water runs through the large voids of the tufa very easily, pulled downward by gravity. This physical condition of tufa impacts capping of rubble stone walls without roofs. A weather-tight surface on the tops of exposed tufa walls can be difficult to achieve with a fluid-applied membrane, and a mortar cap will be even higher maintenance than usual. Furthermore, use of tufa in the historic assemblies may complicate technical diagnosis of problems. Non-destructive investigations relying upon feedback from signals bounced through the stone can be more difficult because voids in the tufa can interrupt the signals. See Harvey’s White Paper for more detailed descriptions of non-destructive testing equipment.

Decision-Making Matrix: Can SAAN Do an In-House Repointing Project?

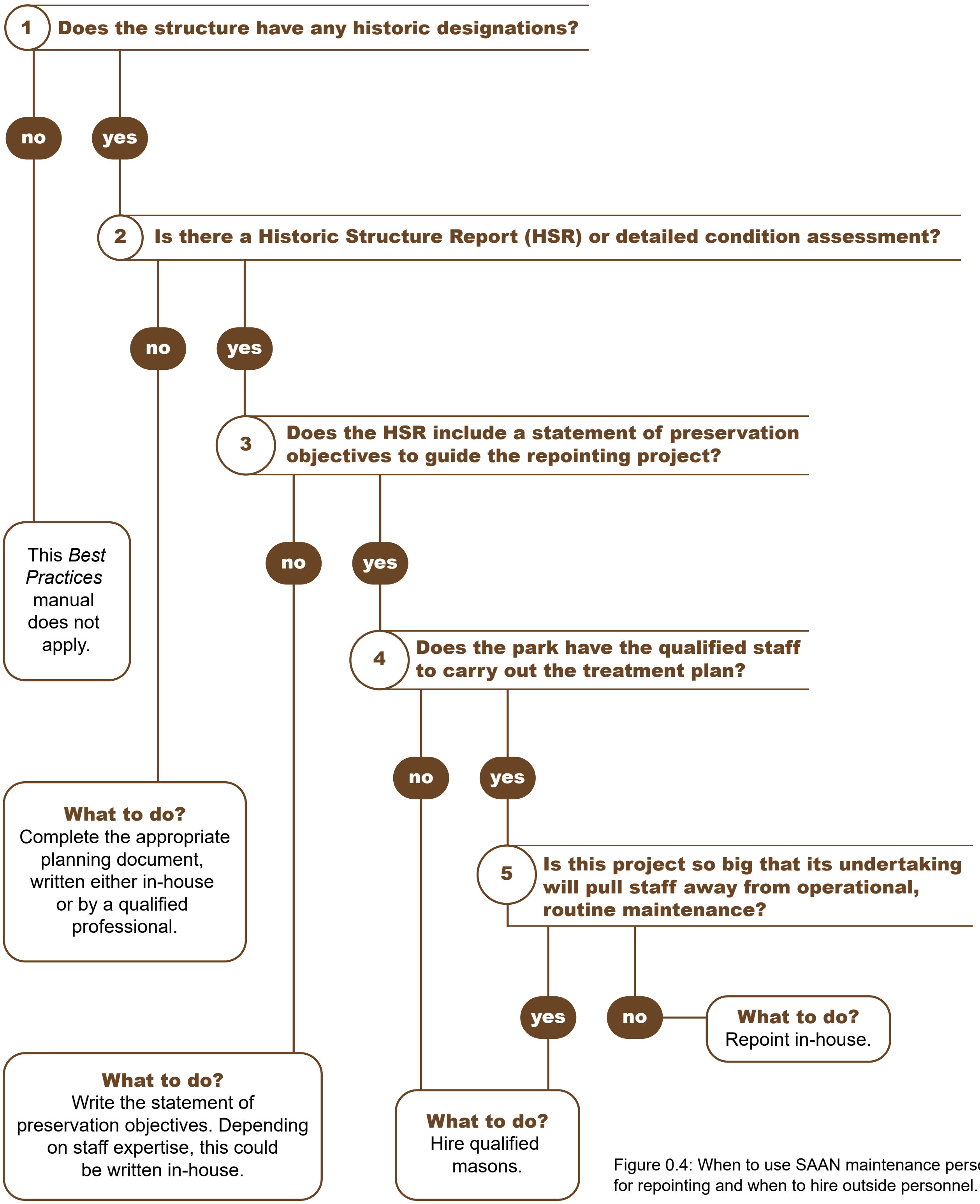


Figure 0.4: When to use SAAN maintenance personnel for repointing and when to hire outside personnel.

F. MORTAR REPOINTING

See White Paper No. 7

Appropriate mortar repointing techniques are grounded in the historic mortars' composition and color as well as application methods. This simple advice is difficult in practice on rubble stone walls worn by centuries of service, past maintenance, and natural weathering. Also, no two buildings or sites at SAAN are exactly the same.

Best practices for a cultural resource of this magnitude dictate that all work must be preceded by laboratory mortar analysis, product submittals, and mock-up demonstrations of repointing techniques. Mortar repointing methods and mix must be guided by lab analysis and approved in advance. Mortar repointing (properly executed) is good practice for long-term conservation of the walls, but **excessive frequency of repointing causes unnecessary loss of historic material** as each episode of repointing takes away a little more stone and historic mortar. A balance must be achieved wherein repointing is done only as needed, rather than on a routine cycle. Gentle cleaning will be necessary where repointing occurs. If water alone does not suffice, then gentle spray pump application of an appropriate cleaner, possibly followed by light scrubbing with a soft natural-fiber bristle brush. The principle of "gentlest means possible" must be followed to determine cleaning methods. Topical expertise and skilled labor is essential. See Figure 0.4 for guidance regarding when to use SAAN in-house maintenance personnel for repointing and when to hire outside personnel.

The finished appearance of new mortars at SAAN has been debated among professionals for many years. Unfortunately, that lack of consensus is occasionally visible on the facades of buildings at SAAN. The issue concerns whether to recess/depress the mortar, make it flush with surrounding surfaces, or feather the new mortar over the edges of historic stones. The matter is complicated by the natural erosion of stone edges which has happened over time, making the mortar joints wider at the surface than they would have been when first built, often necessitating additional chinking stones in the wide joints.

The treatment approach for mortar repointing is made

The Lime Cycle

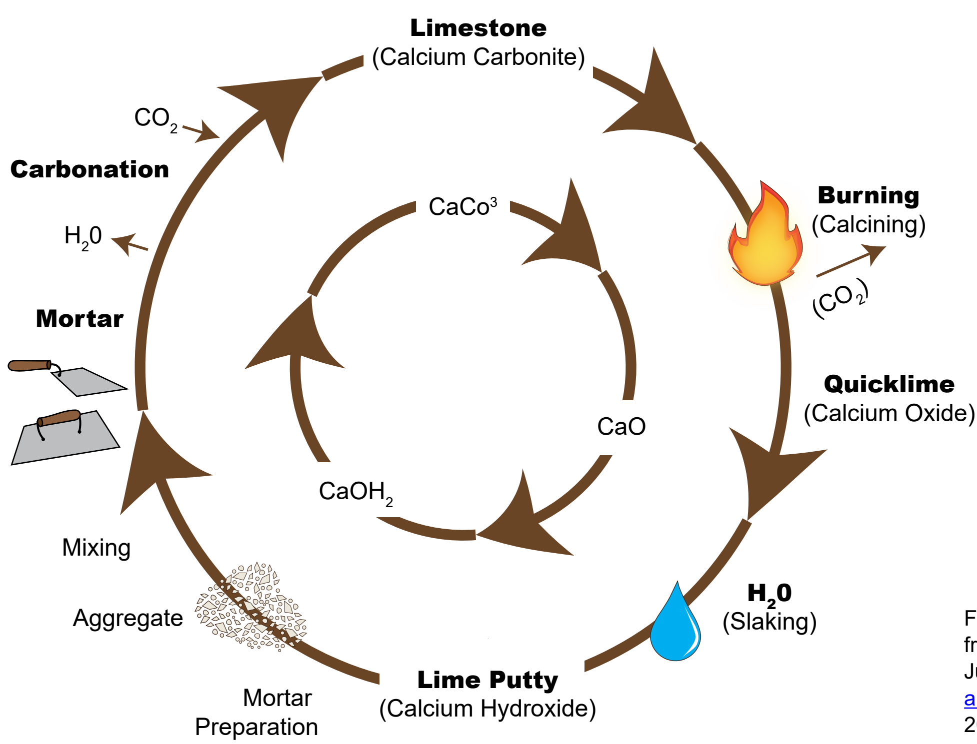


Figure 0.5: The lime cycle, adapted from "Hot Mixed Mortars" by A. Brown, July 12, 2018, https://cornishlime.co.uk/articles/hotmixed-mortars/. Copyright 2018 by Cornish Lime.

even more difficult by the loss of historic plaster over the centuries. Though not always applied to every building, the surface plaster coating was the weathering surface of Spanish Colonial stone buildings when first built. The plaster protected the stone wall assembly from water intrusion, plus it provided a wonderful 'canvas' for elaborate decoration of principle facades.

Most of the stones and mortar so prominent today would not have been visible during the height of Spanish missionary activity. Per the SOI's *Standards,* following the "Preservation" treatment, the historic plaster is not restored. The structures are held in perpetual state of romantic ruin.

Thus, all mortar repointing is retaining an appearance that is generally in alignment with the appearance of the walls from the time the missions became a managed public park in the 1930s, including changes made into the 1950s.

There are pros and cons to each approach and no correct answer applicable to all structures at SAAN. Deviations in approach to the finished appearance of mortar repointing may be appropriate, necessary, or at least tolerated, from location to location, say from San José to Espada, because they are separated some distance apart from each other. However, individual buildings/complexes deserve a consistent treatment approach to mortar application. **SAAN site managers should strive to attain consistency by first setting the treatment objectives for each resource** as described in Section One of this manual.

Appropriate mortar applications for the historic masonry walls are addressed in White Paper No. 7, "Considerations for Mortar Repair and Replacement at San Antonio Missions National Historical Park," by Rachel Adler of the National Park Service's Vanishing Treasures Program. Among Adler's key points:

- When examining mortars, don't underestimate the power of "simple visual analysis with low-level magnification."
- Ensure lead masons hired by the park to do a repointing project boast five or more years of experience.
- Replacement mortar, "should be softer and should have higher water vapor permeability than surrounding masonry and historic mortar."

G. SPANISH COLONIAL PLASTERS

See White Paper No. 8

Existing conditions exhibit numerous fragments of interior and exterior plaster, often featuring painted architectural decoration, surviving from the Spanish Colonial period. Delamination of plaster is a common problem in need of periodic assessment and corrective treatment by a plaster specialist.

The **best practice is to retain as much of the plaster as long as possible.** No period restoration has been practiced at SAAN since the time it has been under NPS management, so no new plaster has been added. Earlier 20th-century treatments did not add new plaster, either, even when engaged in restoration activity or restorative reconstructions. The only new plaster (a thin, lime-based mixture) was added by the Catholic Archdiocese to the facade of Mission San Juan, as part of a 2017 foundation stabilization project.

Advice arising from recent workshops and reports concern the necessity to identify conservation best practices for painted plaster, much of it exposed to the weather or in unconditioned spaces. Notably, the worst or most extensive losses suffered in recent decades have been to plaster inside air-conditioned spaces.

Long-term adherence of historic plaster to the walls is an essential preservation goal. Hairline cracks are best repaired by means of injection of grouting, a consolidating mixture made of hydrated lime and ventilated pozzolana, anti-bleeding agent and water reducer. The injection of the grouting mixture is usually preceded by the injection of a liquid meant to "clean" the internal voids by removing dust and fine debris. Dusts and fine debris hinder adhesion. In the case of hydraulic grouting, the injected liquid is just water. The preliminary injections are also useful to determine the points from which the grout might escape from the cracks and flow on the surface. The surfaces are treated with an appropriate plaster finish mortar. Color and texture matching are required. The entire process requires the experienced hand of a highly qualified specialist.

In the case of interior plaster, the presence of large lacunae sometimes interrupts the continuity of the painting's

Figure 0.6: Angelyn Bass and Douglas Porter at Mission Concepción reattaching and stabilizing delaminated plaster by grout injection.

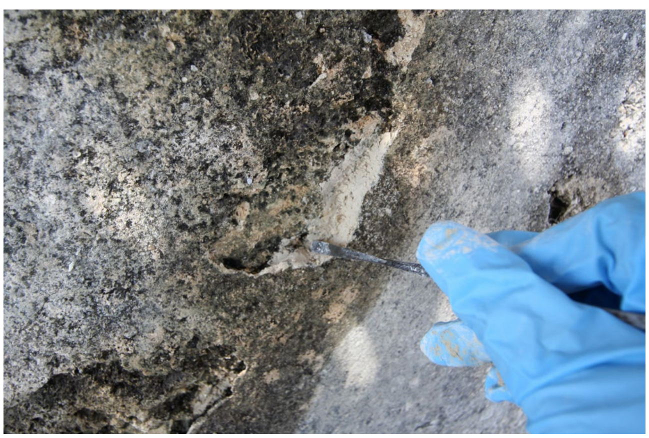


Figure 0.7: Detail of edging mortar applied to the border of fragile plaster remnant as a remedial conservation treatment.

figurative fabric.

Should integration of missing painted parts be allowed in certain areas to blend an integrated, whole appearance? A decision on this is only resolved by following a consistent approach set forth in a written statement of treatment objectives for the resource. Infill painting has been pursued occasionally as a preservation treatment, but only to reestablish 20th-century losses. No restoration beyond the ca. 1940s appearance would be appropriate under the guiding philosophy for treatment currently in play.

White Paper No. 8, "Conservation of Historic Decorated Lime Plaster: Preventive and Remedial Treatments," by authors Angelyn Bass and Douglas Porter, provides guidance on viable interventions known to be effective at the San Antonio Missions.

Bass and Porter describe two categories for plaster conservation treatment, "preventive, which are indirect

Figure 0.8 (right): Spanish Colonial plaster fragments remaining at Mission Concepción's south tower.

Figure 0.9 (below): Loss compensation and application of edging mortar at plaster fragments is done to support the edges and fill voids for the benefit of surviving plaster and its masonry substrate (see Bass & Porter White Paper No. 8).

measures (not performed directly on the plaster and substrate) to manage the deterioration risks and inhibit further loss; and remedial, where technical interventions are carried out to stabilize the plasters and the damage that has already occurred." Additionally, they stress the importance of intervening, "just enough to anchor the plaster to the substrate by grouting key locations."

Some plaster is on original interior walls of rooms now roofless. The artisans who installed it never anticipated their works would be exposed to exterior weather and sunlight. Efforts to conserve these plaster surfaces are necessary and appropriate.

A plaster conservation treatment will follow a sequence of phases: a) Pre-treatment protection/pre-consolidation b) Removal of previous repair c) Cleaning d) Reattachment to the substrate e) Reattachment of edges f) Protection, Aesthetic presentation/Integration. Previous, inappropriate repairs, such as those done with Portland cement, typically need to be removed to mitigate future damage. The surviving Spanish Colonial plasters must be protected before and during all masonry preservation work. Unpainted plaster receives slightly different pre-treatment protection/pre-consolidation than painted plaster. Chemical consolidates may be necessary in cases of disintegration, crumbling, and powdering. **Final, protective coatings are typically not recommended because they will do more harm than good.**

In many cases only fragments of what was once the underlying scratch coat (or brown coat) are still in place. Conservation of these fragile coatings is extremely difficult. Generally, the default and safe option is to stabilize fragile surfaces.

Decisions need to be consistent with overall conservation treatment objectives for the resource established per the best practices described in a section above. Some conservators will advocate for use of small ceramic or stainless steel pins at areas of extreme delamination.

H. CONSERVATION METHODS/TECHNIQUES FOR RELATED MATERIALS—METALS, WOOD, GLASS, ETC.

The topic of this manual is focused on stone building preservation. Non-masonry building materials are integrated into the stone wall assemblies which form (or once were intended to form) the exterior, weathering envelope of the building. Within the body or fenestration of the historic stone walls one finds, in addition to masonry units, plasters, and mortars, things such as:

- Wood posts, beams, and lintels;
- Wood doors and windows;
- Elements of wood floors and stairs bearing on walls;
- Metal fasteners (e.g. nails);
- Metal hardware for the doors and windows;
- Glass and associated materials (glazing points and putty) fixing the glass in position; plus
- Coatings (e.g. paint) on the wood materials.

The same *Standards* and principles of preservation treatment apply to these materials as to the masonry, yet each type of material has differing needs, naturally. A very common agent of deterioration for all building assemblies is water or moisture. Keeping water out of the walls and managing the moisture content is always a top priority for longevity and overall preservation. NPS has an array of Preservation Briefs and Preservation Tech Notes describing specific methodologies for care and maintenance of building assemblies relevant to SAAN. See the list of online publications available from NPS Technical Preservation Services here: https://www.nps.gov/tps/education/online-pubs.htm

Section Three | Risk Assessment and Disaster Management Planning (also see Section Five)

A. CLIMATE CHANGE AND THE SAN ANTONIO MISSIONS

The impact of climate change on the care of the stone walls must be considered. The prediction is for more frequent episodes of extreme weather. Thus, NPS managers must anticipate the San Antonio Missions may be subjected to greater highs and lows of temperature, more powerful wind (tornadoes, derechos, and hurricane-force), lightening, drought as well as more intense or lingering precipitation, including hailstorms. The likelihood of harm will be even greater where stone walls are exposed to weather without roofs, a common condition in the park.

What is the best response? NPS managers should focus on resilience against probable threats. The one controllable factor in reduction of vulnerability and better management of risks is resilience. This must be done with respect for historic significance, of course, so really it is a "heritage resilience." Heritage resilience means respecting the cultural resource while enhancing its capacity to survive and recover from disasters. Unlike resilience improvements to a non-historic building, enhancements at the SA Missions must still adhere to federal historic preservation laws and related NPS policies.

Why focus on resilience? Many disaster-precipitating factors are beyond the control of NPS managers. Extreme weather threats in coastal Texas are regional phenomena. These natural threats cannot be predicted,

Table 0.3: Natural Hazards Impacting Stone Walls

Climate Threat	Inherent Vulnerability	Primary Risk	Heritage Resilience Action
Extreme temperatures	Absorptive stone; sedimentary layers	Spalling in freeze/ thaw cycle	Keep walls dry
	Cellular nature of wood elements	Desiccation and UV degradation of wood	Maintain painted finishes or add protective coatings.
Rainfall, intense or prolonged	Absorptive stone/ brick; Bio-growth predilection	Degradation of assembly, masonry units, & finishes	Maintain drainage & roofs; keep walls dry
	Wood elements in wall are hygroscopic	Reduced structural strength; biodeterioration	Keep wood dry; maintain finishes; add borate
High wind, tornado, derecho	Lateral stability to withstand force	Partial wall collapse	Condition assessment and remedial work, if needed
Projectiles carried by wind	Fragility of materials, assemblies, or finishes	Material damage; breech in weather envelope	Remove or secure potential projectiles; maintain trees
Drought or rainfall moves water table	Expansive soils; lack of sub-grade waterproofing	Diminished bearing capacity at foundation	Maintain drainage systems; keep soil moisture consistent
Lightning	Flammable materials in wall assemblies	Fire	Electrical grounding
Hailstorms	Fragility of materials, assemblies, of finishes	Material damage	Add appropriate protections where feasible
Flood (regional)	Proximity to rivers, creeks, acequia routes	Erosion, destructive impacts, degradation	Disaster planning with City and County agencies
Pollution: acid rain	Porous masonry units & walls. Lime in mortar	Deleterious agents cause material loss, dissolution	Add appropriate protections where feasible; keep walls dry

yet they are certain to occur. Risk to a cultural resource like a stone wall is defined as the wall's vulnerability to damage from threats. Vulnerability is the wall's inherent weaknesses to threats, offset by the resilience of the assembly to survive and recover. Resilience is the factor people can control. Higher resilience equates to lower vulnerability to threats. Risk is lowered by enhancing resilience.

How will ongoing maintenance and preservation treatments of the walls be different in the future? Climate change and the greater threats it brings upon the walls of the SA Missions will necessitate more effort in disaster planning, less tolerance for deferred maintenance, and more attention to identification of risks from inherent vulnerabilities. Table 0.03 provides a list of the basic threats to be anticipated, related vulnerabilities found at the SA Missions, the primary risk to the resources, and actions to mitigate the potential damage. NPS managers will need to find an appropriate balance between increased resilience and retention of existing appearances. For example, a roof structure spanning over ruined walls would increase resilience, but would be an unacceptable intrusion into the aesthetic, recreational, and educational attributes valued by visitors.

B. PERIODIC AND CYCLICAL MAINTENANCE PLANNING

Exemplary principles of maintenance planning are well established in NPS policy and management documents, including the use of maintenance plans. Establishing and perpetuating a maintenance plan helps foster a routine of planned and predictable care. With good prediction, action can precede system failure, material loss, or unnecessary decay and damage to landscape features. **Preventive maintenance increases hazard resilience.**

A maintenance plan will have a list and schedule for cyclical work items, allowing both staff time and financial needs to be budgeted in advance of the need. **Unpredicted maintenance, especially in response to a crisis or emergency, almost always corresponds with loss of historic fabric,** decreasing both the integrity and cultural value of the historic site.

Regarding historic masonry walls at SAAN, a crucial element of maintenance concerns protecting the walls from moisture. This means inspection and care of roofs, flashing, and rainwater evacuation systems, as well as mortar pointing and the coping on top of the walls.

The maintenance plan may need sub-plans to accommodate the special needs of varying resources. The individual resources do not all have the same chronology of construction, so each may have slightly different treatment objectives.

Also, special features such as surviving Spanish Colonial plaster need to be called out for careful attention.

An ongoing record of maintenance and repairs is essential for long-term effectiveness of treatments. After treatment, staff need to monitor and review affected areas to assess performance of the treatment over time. **Documentation is key, as cyclical documentation can show how well a treatment is working or how fast an area is degrading.** The documentation will also help future professionals and consultants to understand problems and make good choices for future treatments to the masonry.

C. RISK ASSESSMENT

See White Paper No. 9

A conscious and deliberate approach to risk management will help limit deterioration and loss of the historic masonry at the SAAN sites. Day-to-day care indicates the loss of surviving historic material—plaster, mortar and masonry assemblies—is due primarily to degradation caused by excess moisture/water coming from the sky or ground, but this is not the only risk which threatens stone and fired clay masonry.

The attached white paper by Meyer and Semien broadly identifies risks and describes the threats posed by them. The value of planning and preparation for disasters is thoughtfully enumerated, charting a process for completion of essential tasks by NPS SAAN staff. Catastrophic risks include earthquakes, floods, fire, terrorism, vandalism, and theft. Identifying the parts of the SAAN sites that are susceptible and exposed to risk will give managers the tools to address affected areas within the time span and budgetary conditions that comprise the sites' total context.

Previous workshops and recent reports identified the need for assessment tools to address additional risk factors such as wind, drought, and hazard trees. Environmental factors include the local climate and pollution. Other risk factors are human activities such as vandalism and terrorism. Also, visitors can threaten the integrity of the resources.

The risk context of the sites includes the financial, cultural, legal, and operational aspects in which SAAN is situated. Failures or changes in any of these aspects of SAAN's context may elevate risks or expose new ones.

Deterioration and loss can occur due to unfavorable Rh, temperature fluctuations, light and UV damage, pollution, pests, water damage. "Pest and fungal changes, for example, that may affect historic properties as temperatures and consequently biological species diversity change should be added as a future risk to historic properties" (Meyer and Semien, 2021).

Flooding appears to be a primary risk at SAAN. According to Meyer and Semian, "a large minority (up to 50% in some areas) of flood damages [is] occurring outside the 1% floodplains." (Meyer and Semien, 2021).

Overall, there are three types of risk occurrence: rare events (such as large fires or floods); common events (such as water leaks and accidents); and, most importantly for historic masonry, cumulative processes (such as erosion and alveolarization of stone, as well as corrosion of metals). After the risks are assessed, the Site Manager must assign a level of priority to risks in order to address or treat them in a carefully planned manner.

D. DISASTER PLANNING FOR ASSESSED RISKS

Although NPS staff cannot prevent disasters such as hurricanes or lightning strikes, they can limit negative effects. Preparedness is a serious responsibility that falls within the mandate of staff who preserve the SAAN sites. **A complete disaster preparedness and response plan outlines what the priorities for action should be and where to turn to for help during an emergency.** The benefit of a thorough disaster preparedness plan will limit harm to human lives and property, not just the cultural value of the historic site. To best ensure protection, staff must work as a coordinated team to limit or avert damage. The disaster plan, which must be written by SAAN staff and updated periodically, will cover four sequential areas of responsibility:

- Preparedness
- Response
- Recovery
- Mitigation

Best practice for writing or updating disaster plans would include consultation from professionals who specialize in disaster planning. Alternatively, SAAN staff might receive specialized training from other NPS staff who have requisite expertise. The authors of the SAAN disaster plan will need to understand Bexar County emergency response plans. SAAN managers should coordinate with Bexar County on the county's Hazard Mitigation Plan. Overall, a balanced collection of topical experts and stakeholders is necessary to have readiness for a coordinated response. **Research indicates "public participation in hazard planning results in more efficient and effective (and accepted) plans than those conducted only by technical experts."** (Meyer and Semien, 2021)

E. ADDITIONAL

For more about assessing risk, please refer to *A Guide to Risk Management of Cultural Heritage,* published by ICCROM (2016).

Section V below deals with management of risks during construction projects when historic buildings are extremely vulnerable to rapid, irreparable damage.

Section Four | Long-term Management, Documentation and Interpretation

The National Park Service has established guidelines for cultural resource management including documentation, and interpretation. Part of comprehensive best practices for care SAAN includes the research, documentation, and eventual public interpretation (or reinterpretation) of the historic, archaeological, ethnographic, and cultural elements present. Ongoing documentation creates a baseline record of data serving many purposes, from shaping the interpretive programs to help with the treatment, monitoring, and protecting of the sites' cultural resources.

Expected baseline documents commissioned or executed by SAAN Site Mangers include reports about historic, archaeological, ethnographic, and other cultural elements of the sites, which are detailed in DO-28 and NPS-28.

Cultural Resource Management Guidelines. https://www.nps.gov/parkhistory/online_books/nps28/28contents.htm

Director's Orders, Handbooks and Reference Manuals: https://www.nps.gov/applications/npspolicy/DOrders.cfm

Commissioning all the applied reports prescribed by DO-28 and NPS-28 would certainly be considered a best practice. Highly relevant, specific reports detailed below are essential for the preservation and maintenance of stone masonry on site.

A. HERITAGE DOCUMENTATION

A record set of drawings and photographs should exist for all primary historic resources. **Conditions must always be documented prior to physical change** that will cause information to be lost either temporarily or permanently. Documentation of as-built conditions following a construction project is also necessary.

Good documentation and records of physical conditions are essential to effective and successful long-term care of the SAAN sites. Before making any changes to the fabric of a site, it is important to carefully document the existing structure so that information about it is easily accessible for future reference. The Historic American Buildings Survey/Historic American Engineering Record (HABS/HAER), in addition to the Historic American Landscape Survey (HALS), forms a component of the federal government's involvement in historic preservation. The published guidelines of HABS/HAER and HALS programs are useful references for preservations projects. A complete set of HABS/HAER or HALS documentation provides information about the structure or landscape at the time of documentation, before any preservation work, construction, or demolition.

All SAAN structures warrant thorough documentation. While full and complete sets of drawings and photographs are not always necessary for every feature, **generally more documentation is a better strategy than less.**

B. PROJECT COMPLETION REPORTS AND AS-BUILT REPORTS

Project completion reports and as-built reports are crucial documents to help with maintenance long-term care of a site. Project completion reports **should be formally completed and filed upon the conclusion of any capital improvement that modifies the historic Spanish Colonial masonry at the SAAN sites.** Project completion reports are heritage preservation documents that contain a complete account of the administrative details of a project, as well as a narrative statement that includes a description of the work performed, any plans and specifications developed for the project, as-built drawings, project activities, limits of the project, and project photographs. They also detail challenges staff and contractors encounter in the process of the completing work projects. They are vital for planning future projects.

As-built reports are an official record of a project at the time construction is completed. Accurate, as-built drawings must be included because they are crucial for future maintenance. **Drawings will inform future modifications to a site, particularly for non-visible features like buried or concealed utilities.**

Information about the preparation of as-built drawings is available for staff and contractors from the NPS document *Guideline for the Preparation of Design and Construction Drawings: Reference Manual 10A* (2001).

C. HISTORIC STRUCTURE REPORTS AND CULTURAL LANDSCAPE REPORTS

Historic Structure Reports and Cultural Landscape Reports assess tangible and intangible features of a site. Like project completion reports and as-built drawings, they help detail a site's features while also providing staff a "snapshot in time" of the condition of a site upon the report's completion.

Historic Structure Reports:

Historic Structure Reports (HSR's) are key to developing a comprehensive maintenance plan for a site's historic buildings. Although HSR's can vary in scope according to the needs of site managers, most combine primary source evidence with field investigations to describe the developmental history of the structure, its treatment and use, and a record of its treatment, or condition assessment.

Information about past treatments and outcomes is particularly important for developing a smart maintenance plan. HSR's also provide guidance on future treatment recommendations, which can then be incorporated into SAAN Site Management planning discussions, work plans, and annual budgets.

Cultural Landscape Reports:

Whereas the goal of an HSR is to minimize the loss of materials in a historic structure, cultural landscape reports (CLR's) aim to minimize the loss of or irrevocable change to historic landscapes and sites.

It is a baseline document that details the history, significance, and treatment of a landscape and can be used as justification to protect a landscape when changes are proposed. It is thus an important part of a preservation maintenance plan. The report comprises documentation of existing conditions, chronological development, historic plant inventories, and an analysis of the site's integrity and significance.

D. INTERPRETATION OF THE SITES TO VISITORS

Interpretation of the sites to visitors requires integration of public history programs and architectural conservation. Construction projects and large-scale maintenance efforts at historic sites entail design choices for technical treatment of historic materials. Such projects often involve larger questions about what gets saved or emphasized and what is changed or removed. The priorities are determined in planning, design, or scoping phases. Choices are made. At these decision junctures the SAAN site management team should pause to evaluate the objectives in concert with public history education goals, which is interpretation of the site. If an HSR was written for the subject resource, look to see if it addresses the coordination of interpretation and preservation treatments. Ensure there is no inadvertent loss of important evidence nor physical erasure of people's stories through omission or miscalculation. Best practice requires deliberate forethought.

Site managers should be mindful that interpretive programs are easily adjusted from year to year. Historic materials and assemblies, once removed, can never be brought back.

E. LIBRARY ARCHIVES MANAGEMENT

Good archives of past actions, accessible and well-maintained, with duplicates offsite in event of emergency, are a tremendous resource for staff, consultants, and researchers. Archives are a key element to long-term care of historic resources. This is well understood, yet the effort required to make a retrievable record of activities through archived documents is frequently deferred. When the action is deferred, knowledge diminishes as time passes. Sadly, an archive at a historic site may contain a nicely detailed project description lacking subsequent record of information about what was discovered during the process, if it was executed exactly as designed, or even if the project was pursued at all.

The best practices for archival techniques are beyond the scope of this manual. NPS has standard policies and procedures, of course, and these should be followed. The necessary elements include organizational format, retention guidelines, use policies, and long-term security of holdings. Ideally, the site will have sufficient personnel assigned to the task. Even with a dedicated staff person, all staff need to work in a coordinated manner to maintain and augment the site's archives over time.

Also, proper archival practices are necessary for artifacts uncovered or encountered by people working at SAAN, especially archaeological artifacts. Management of archaeological resources is a large topic deserving its own manual of practice, and is only tangentially addressed in this manual. NPS has numerous publications on the topic, and SAAN has staff dedicated to care and protection of archaeological resources.

F. BUILDINGS AND GROUNDS MANAGERS

Duties and responsibilities of buildings and grounds managers include diverse tasks ranging from building arts to writing reports. NPS has well-established protocols and procedures to set the job duties and qualifications for all their staff, including those who manage buildings and grounds. Of relevance to best practices for care of masonry buildings at SAAN, duties of this position will include:

- Visitor and staff safety,
- Construction project management,
- Ongoing care (routine, cyclical, and periodic) of buildings and grounds,
- Maintenance of records and documents regarding all completed work,
- Preparation and perpetuation of maintenance plans and disaster preparedness plans, plus
- roles in disaster response and recovery.

In this manual, the term Buildings and Grounds Manager (or Manager) refers to any combination of staff, interns, or professional consultants who perform these duties.

The Building and Grounds Manager needs appropriate training and experience in the preservation skills necessary to care for, or manage the care of, the SAAN sites. Consistent with the sites' maintenance plan (described below), the Manager monitors the condition of the buildings and grounds, and reports on preservation needs. The Manager must look after the general upkeep of the facilities, ensuring that utility systems such as plumbing, electric, fire alarm, fire suppression (if any), and site security are all properly functioning.

The Manager provides copies of work plans and budgets for site maintenance and capital improvements needs, including a periodic listing of critical priorities, if any, with cost estimates and other pertinent information to the site superintendent.

Section Five | Best Practices for Preservation During Construction Projects

See White Paper No. 10

Coordination note: baseline documents, particularly project completion reports and as-built reports, provide crucial information for future construction projects involving historic resources. See previous sections for information on baseline documents.

A. HIRING DESIGN PROFESSIONALS AND OTHER CONSULTANTS

All significant conservation, preservation, and new construction work must be designed and specified by qualified professional practitioners. Typically, these will be outside professional consultants working in close collaboration with SAAN Site Managers.

Design professionals and other consultants are often selected through a competitive process that includes consideration of professional qualifications, prior experience on comparable projects, and sometimes cost. Qualifications and experience are far more important than cost. The variance in consultants' billing rates is usually small, and a good consultant will save time, money, and historic building fabric.

Minimum qualifications for consulting professionals are established and described in the federal register. For more information, see: https://www.govinfo.gov/content/pkg/FR-1997-06-20/pdf/97-16168.pdf

All significant preservation and new construction work must have an Agreement or Contract commensurate with the anticipated complexity of the work.

B. TEMPORARY PROTECTION OF HISTORIC STRUCTURES DURING CONSTRUCTION AND REPAIR

Part of any thorough preservation program is careful construction project management, which should take into account the effects construction will have on the historic structures at the SAAN sites. Please refer to the checklists in the chart below for Site Manager and Contractor protocols.

Fire is typically the most common disaster resulting from construction operations. Fire safety for construction is part of temporary protection and must be addressed in contract specifications.

The NPS has three Preservation Tech Notes on temporary protection, all with useful for guidance for construction and repair projects. Effective planning and protective measures can help prevent damage. Pre-planning, project-specific specifications, vigilance on the part of SAAN staff, contract enforcement, and contractor diligence will all help limit risks posed by construction or preservation treatments.

A Tech Note by Charles Fisher includes details about protecting stairways, including the walls, in historic structures. Notable is the importance of not using anchoring devices that might damage historic material (Fisher, 1985, p. 2). This advice is applicable to all situations where a protective cover or cushion will be installed—the temporary work must never threaten, mar, or destroy the surviving historic materials/ assemblies or buried resources.

Protection of historic interiors is covered by Dale Frens (1993) in Temporary Protection #2. Advance consideration of construction project means, methods, and sequence can protect fragile historic materials such as Spanish Colonial plaster.

Chad Randl's Tech Note (2001) provides guidance on protecting a historic structure during adjacent construction. Some of the most common risks include vibration from demolition and temporary (or even permanent) problems regarding site water management. Other dangers include fire and increased levels of airborne debris infiltrating the historic structure.

Any new construction, either in or near the historic structure, should be presaged by thorough documentation and routine visual inspections by the SAAN site manager to mitigate damage.

C. FIELD QUALITY CONTROL DURING CONSTRUCTION AND LARGE MAINTENANCE PROJECTS

See White Paper No. 10

This section of the *Best Practices* Manual concerns the topic of "field quality control" for specialized, complex, or large projects. Management might be a more accurate word in this context, because the quality is managed by a variety of players working in concert, but quality control is the term of the construction industry.

Highly specialized project work, or complex undertakings of multidisciplinary nature or very large size, need to be described and approved (by SAAN or other NPS staff) in advance of the work. This is standard practice for construction projects, and the resulting products are called "construction specification documents," or simply "contract documents." The contract documents are typically drawings and written specifications packaged together. The drawings show quantity and location of work; the specifications describe quality.

Responsibilities for field quality control may be assigned or shared among the owner, contractor(s), and owner's representative(s) possibly including a construction project manager and/or a team of consultants usually led by a licensed professional architect or engineer. This manual focuses on field quality control anticipated for SAAN's stone buildings and does not presume which party will be accountable. The SAAN Site Managers are responsible for field quality control. Field quality control permeates the organizational hierarchy of the construction site, but ultimate success rests in the hands of on-site supervisors and skilled workers engaged in the construction activities. The team of managers/supervisors and hands-on workers together need one playbook of rules—the construction specifications. Content will vary depending on the project. There are six basic elements of quality control:

- Mandatory prior skills/successful experience;
- Written plans (e.g., fire safety, public access);
- Product literature submissions;
- Product material samples;
- Mock-up assembly samples; and
- Demonstration of skills, often with certification credentials.

All of the above need on-site briefings or discussion to review purpose and gain concurrence from all parties on what will be done. **Best practice for a site like SAAN will include periodic review of historic significance and the site's treatment objectives.** Everyone should be given the opportunity to reflect upon the immediate goals of the construction project in the context of SAAN's educational and recreational values to humanity.

The construction specifications describe all elements of the field quality control for the project. These are typically written by a preservation specialist such as an architect experienced in historic preservation. Table X.xx inlcudes items to be addressed or considered for stone building preservation at SAAN.

During construction, there is further need for a preservation specialist to review and monitor construction activities and contractor performance, consistent with field quality control in the specifications, and in close collaboration with site managers. When project complexity warrants, the preservation specialist or contractor (or both) will need to document the progress of work through photographs and field reports, maintaining a construction diary. Depending on specified field quality control, there is the need to review/ approve submittals and mock-ups, respond to requests for clarification, and to track completed work. Ultimately, best practice demands a project completion report filed in the SAAN archives as a record of exactly what happened, also including information on what was learned in the process.

In White Paper No. 10, "Construction Project Risk Management/Field Quality Control During Construction," Ron Staley of Southeast Michigan Operations and the Historic Preservation Group at Christman explains preservation-specific risk management strategies and effective quality control in construction and masonry conservation projects. Staley emphasizes the importance of effective policies and procedures to achieve long-term preservation goals. Among the author's best practices, he writes that:

- "Hidden conditions including unknown foundations or multiple prior-era structural modifications over time suggest more in-depth investigation to minimize or eliminate risks to associated work. This level of investigation, while commonly resisted as an expense early in the project planning, can be demonstrated to save a project considerable costs in project delay or design modification during the construction phase."

- "Using past experience of practitioners in the field, detailed design phase investigation and pre-production mock-ups are all part of defining the best process."
- "Other best practice tools used to help a project's success include a process to instill the risk plan to the individual workers. Consider a Historic Preservation Trades Orientation Program."

D. ARCHAEOLOGY

Construction can uncover unforeseen archaeological artifacts, and contractors are responsible to report and protect the archaeological resources. Work must stop to assure resources are appropriately protected, preserved, and managed. Standards for handling archaeological resources can be found in Chapter 5 of *NPS-28: Cultural Resources Management Guideline.*

As noted above, archaeological resource management is beyond the scope of this *Best Practices* manual.

E. MANAGEMENT OF COLLECTIONS AND ARTIFACTS

Collections are beyond the purview of this *Best Practices* manual. Rather, a separate *Scope of Collections Statement* is a baseline document detailing the curatorial plan for SAAN's accession and preservation of museum objects or any other material objects the NPS is legally mandated to preserve. This document defines the extent, purpose, and significance of the collections and defines subject matter, location, and time period for additions to the collection. A statement about the interpretive use of the collections should be periodically updated within this document.

Many artifacts collected from past archaeological excavations at SAAN are now housed at UTSA's Center for Archaeological Research. Ongoing coordination between SAAN and CAR is necessary for good stewardship of the collections.

CHECKLISTS FOR ENSURING TEMPORARY PROTECTION OF HISTORIC STRUCTURE DURING CONSTRUCTION AND REPAIR

Table 0.4: Best Practices "Checklist" for SAAN Site Managers

- ☐ Review (or establish) the overall preservation treatment objective for the subject historic site, and then assure the proposed work is in accord with the treatment objectives. Note the four mission sites, rancho, aqueduct, and features on the cultural landscape may have separate or unique treatment objectives due to their differing periods of significance, histories of chronological development, and existing conditions of integrity.
- ☐ Predicate all contracted conservation and construction work on recommendations of approved baseline planning reports including condition assessments, historic structure reports, and cultural landscape reports.
- ☐ Hire a design professional (architect, engineer, or landscape architect) to specify all work in a set of contract document necessary for describing and pricing the work. Engage the same consulting professional to provide quality assurance services during construction.
- ☐ Determine degree, type, and location(s) of public access to be required/maintained during project work. Include this in the scope of work described to the contractors. Take all appropriate steps for public safety.
- ☐ Set and enforce appropriate qualification standards for the specific individuals who will execute work. Minimum qualification levels will vary based on trade or type of work.
- ☐ Mandate a pre-construction meeting with contractors and other parties to determine extent of work; identify necessary protective measures; and consider all aspects of the best practices checklist for contractors.
- ☐ Conduct or commission a documentation of existing conditions, including photographs, crack inventory, and other description of damage.
- ☐ Update the site emergency preparedness plan in consideration of proposed construction activity and establish expectations for the contractor's fire safety plan.
- ☐ Secure any areas of the site or buildings off-limits to construction workers, such as windows and rooftop doors, that will be made accessible by the construction operations.
- ☐ Protect, remove and/or safely store all artifacts, cultural objects and equipment or furnishings threatened by proposed construction activities.
- ☐ Install temporary protections and supports as needed for features that cannot be moved.
- ☐ Erect or require construction of plywood protections, lockable doors and dust-proof seals at openings to construction areas not needed for emergency egress.
- ☐ Budget increased staff effort to remove dust from adjacent structures and interior surfaces on an accelerated schedule
- ☐ Clean all HVAC system and filters on an accelerated schedule.
- ☐ Perform additional monitoring of gutters and drainage systems at the structures adjacent to construction activity to keep systems operating without obstructions.
- ☐ For highly significant or very sensitive areas, consider establishment of an owner's monitoring program, including:
    - ☐ Seismographs to ensure that effects of disassembly, demolition or other construction work remain at acceptable levels
    - ☐ Crack monitors and optical survey methods to detect structural movement
    - ☐ Moisture montioring and other diagnostic monitoring methods appropriate to the scope of work.

Table 0.4: Best Practices "Checklist" to be provided to Contractors, Conservators, and Consulting Professionals

[Note: this checklist is focused on practices for conservation of cultural resources. **Safety and protections of people (workers/staff/public), which are the highest priority, are not specifically addressed in this checklist.**]

- ◻ Consult with SAAN Site Manager for guidance on all policies and contractual obligations.
- ◻ Document pre-construction conditions, or review and sign off on a pre-construction condition survey of subject and adjacent properties potentially impacted by construction operations.
- ◻ Become familiar with the SAAN disaster response plan; discuss the plan at a pre-construction meeting and then inform all workers on relevant elements of the plan.
- ◻ Establish and implement a fire safety plan. Coordinate fire safety with the SAAN disaster plan. Include adjacent historic structures in the fire safety plan.
- ◻ The fire safety plan must specify the procedures for hot-work operations (if any are allowed), plus restricted times for such activities, often not permissible after 2:00p and never the day before the weekend or holidays.
- ◻ Do not store any flammable or explosive items of any type within or anywhere near historic structures.
- ◻ Rags and brushes soiled by flammable liquids require special disposal procedures and must never be allowed to accumulate within or adjacent to any historic structure.
- ◻ If hazardous material remediation is involved, ensure compliance with all applicable laws and regulations. Additionally, protect cultural resources from contact with chips, dust or particles resulting from activity.
- ◻ Erect specified (or necessary) protective and temporary stabilization measures.
- ◻ Implement policies to protect the subject of construction activity and adjacent properties potentially impacted by construction operations.
- ◻ Arrange a secure marshalling yard and delivery locations to limit disruption and possible damage to neighboring historic structures and other cultural resources including archaeological sites.
- ◻ Anticipate construction activity that might cause harm or damage to any cultural resources at SAAN; provide advance notice to SAAN staff regarding potential problems; and propose solutions to avoid or mitigate negative consequences.
- ◻ Mitigate vibration from required excavation, disassembly or demolition methods that might harm or damage any cultural resources at SAAN.
- ◻ When there is any chance of structural movement due to construction operations, establish and maintain a monitoring program at the historic site to ensure that vibration levels or indications of movement are within established thresholds, and not causing any harm or damage.
- ◻ Be aware that sub-surface conditions and historic walls at SAAN may be fragile. Protect against movement of structures or adjacent buildings with appropriate stabilization methods approved in advance by SAAN staff.
- ◻ Avoid any changes to site ground water level and moisture levels in load-bearing soils that might be caused by any construction operations.
- ◻ Ensure water runoff from construction activity is not directed toward any structures, foundations, or buried cultural resources.
- ◻ Install appropriate debris nets or protective covers to prevent damage from any dropped material impacting historic structures.
- ◻ Direct debris chutes (if used) away from cultural resources.
- ◻ Install and maintain fabric enclosure system to reduce spread of construction dust.
- ◻ Install and maintain temporary protections for floor or ground surfaces across all areas of construction activity.
- ◻ Establish and maintain pest control program(s) consistent with specifications or NPS policy; include adjacent historic structures; seek NPS guidance to seal openings in walls or foundations.

Clean the work site daily, and remove all trash from the premises promptly and in accord with any SAAN policies.

White Papers

White Paper No. 1

Diagnostics and Monitoring—Structural.

Donald W. Harvey, Jr., P.E.of Atkinson-Noland & Associates Engineers, provides a methodology to investigate the structural health of the San Antonio Missions through a variety of non-destructive diagnostics and discusses the benefits and limitations of each technique.

White Paper No. 2

Understanding Moisture Problems in Mission Masonry.

Michael C. Henry, PE, AIA, Principal at Watson & Henry Associates and Michael C. Henry, LLC. and Adjunct Professor of Architecture from the Weitzman School of Design at the University of Pennsylvania, provides a methodology and diagnostic techniques for historic masonry deterioration caused by moisture damage.

White Paper No. 3

Site Water Management and Roofing.

Kenneth Itle and Erik Murray, of Wiss, Janney, Elstner Associates, Inc., provide techniques to assess and maintain site water management issues and propose intervention strategies to mitigate the long-term impacts of site water in the historic context of the San Antonio Missions.

White Paper No. 4

Going Green in Ruins Conservation and Management: Soft Vegetative Capping.

Alex B. Lim, of Tumacácori National Historical Park in Arizona, reviews the processes and benefits of soft vegetative capping as a strategy for sustainable maintenance of masonry walls and cultural landscape conservation.

White Paper No. 5

Stone Masonry Preservation—Mechanical.

Nancy Hudson, Principal at Silman, and Derek Trelstad, Associate at Silman, establish criteria for the structural repair of historic masonry walls by providing information on masonry wall assemblies and their deterioration.

White Paper No. 6

Stone Masonry Preservation—Chemical.

Frances Gale, an Architectural Conservator based in Austin, Texas, discusses the effective use of chemical applications of cleaners and treatments in the conservation of historic stone masonry and provides information to assist in planning conservation efforts for this building type.

White Paper No. 7

Considerations for Mortar Repair and Replacement at San Antonio Missions National Historical Park.

Rachel Adler, of the Vanishing Treasures Program within the National Park Service, reviews the importance of mortar in historic masonry building systems and provides technical information on the proper management of mortar in a historic building context and site-specific pointing techniques.

White Paper No. 8

Conservation of Historic Decorated Lime Plaster: Preventive and Remedial Treatments.

Angelyn Bass, of the Department of Anthropology at the University of New Mexico, Department of Anthropology, and Douglas Porter, of the School of Engineering at the University of Vermont, provide clarity on the most appropriate techniques to extend the life of Spanish Colonial plaster by providing context for this building material, detailing the missions' finishes and deterioration, and providing a methodology for plaster conservation.

White Paper No. 9

Understanding Risks and Disaster Planning Processes for the San Antonio Area Missions.

Michelle Annette Meyer and Joy Semien, of the Hazard Reduction & Recovery Center within the College of Architecture at Texas A&M University, provide best practices for site-specific hazard planning and emergency management within historic preservation through the four phase emergency management cycle with emphasis on long-term strategies.

White Paper No. 10

Construction Project Risk Management/Field Quality Control During Construction.

Ronald D. Staley, FAPT, of The Christman Company, explains risk management strategies and field quality control best practices for construction projects in historic masonry preservation, particularly for sites that remain open to the public during construction such as the San Antonio Missions.

White Paper No. 1

Diagnostics and Monitoring—Structural

By Donald W. Harvey, Jr., P.E.

Atkinson-Noland & Associates Engineers

ABSTRACT: Much of the important structural fabric of the San Antonio Missions National Historical Park consists of historic masonry walls. Performing investigation or monitoring of structural conditions of these often massive assemblies can be daunting, especially if the goal is to minimize damage and disruption. This paper endeavors to provide an overview of the state-of-the-art methods and tools available to aid structural investigation of these mission structures. Additionally, the limitations and benefits of these techniques specific to the mission structures is presented, along with some indication of relative costs.

KEYWORDS: Structural, Diagnostic, Monitoring, Masonry, Nondestructive

1.0 INTRODUCTION

In historic masonry structures such as those found in the San Antonio Missions National Historical Park (SAAN), it is not uncommon to observe cracking or spalling that suggests structural distress. However, in these generally thick-walled assemblies, the causes of distress and the overall structural function and stability of structures are not necessarily obvious or intuitive. Often, an understanding of structural behavior in historic missions and associated features begins with structural investigation and/or monitoring.

1.1. Structural Investigation and Monitoring

This paper describes various types of structural investigation and monitoring techniques that are the most likely to be appropriate for use in the SAAN. The focus is on methods appropriate for evaluation of stone mass masonry walls, but these techniques are also generally well-suited for use at masonry vaults, domes, and plaster. This paper does not address evaluation of moisture conditions since that is the topic of a separate paper.

1.2. Common Objectives

The purpose of structural investigation and monitoring is generally to understand structural distress conditions and/or to provide information useful in a structural analysis. The performance of this analysis, including the use of finite element software and other analytical meth-

Figures 1.1a and b: Examples of borescope imagery from a historic stone masonry wall showing void areas. (Author 2019)

ods, is the subject of a separate white paper and is not discussed here. However, the types of information that are generally relevant to structural evaluation include data on cracking, voids, connection between layers of masonry, thicknesses of units and elements, strength of assemblies, leaning or bulging, and vibration. In this paper, the types of structural investigation are divided into the categories of "Structural Diagnostics" and "Structural Monitoring." In general, the diagnostic methods involve single readings or measurements, and the monitoring section describes measurements over time in order to establish patterns or trends.

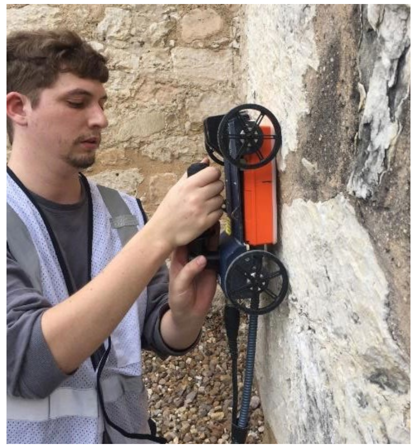


Figure 1.2a and b) Radar scanning on the interior of a historic stone masonry wall using a GSSI SIR-3000 radar unit with 1600 MHz antenna. Laser levels were used to guide the movement of the antenna on an accurate path and provide a consistent starting elevation for the vertical scans. (Author 2019)

2.0 STRUCTURAL DIAGNOSTICS

At SAAN, most of the structures of interest are historic and protected. Therefore, **the use of invasive or destructive investigation techniques is often undesirable or even prohibited.** While it may be possible in some areas to perform localized deconstruction and reconstruction to allow for probe openings to examine subsurface conditions, this is generally not the preferred approach. Therefore, this section of the paper will focus on diagnostic methods that are nondestructive or minimally destructive in nature. This includes subsections discussing visual observation, surface penetrating radar, infrared thermography, ultrasonic pulse echo, flatjack and shear testing, and load testing.

One of the challenges for those seeking structural diagnostic services is that there are numerous types of testing available, and each type has both advantages and limitations. Often companies with only one or two test-

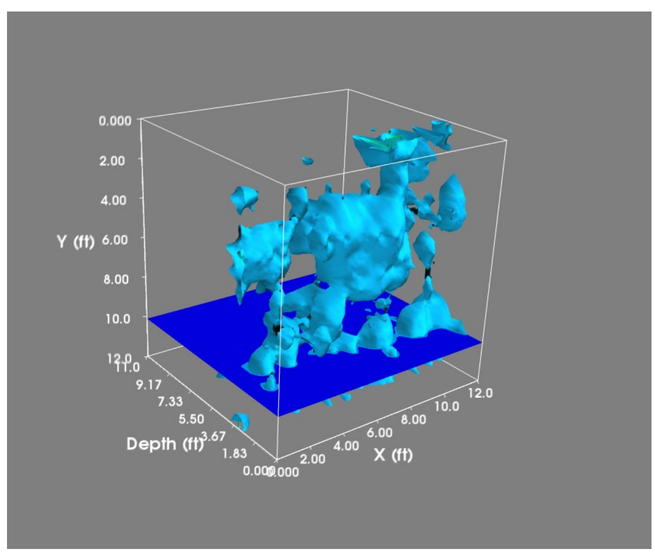


Figure 1.3: View of void information collected using SPR displayed in a 3-dimensional graph. (Author 2019)

Figure 1.4: View of engineer measuring an individual stone thickness using the Proceq GPR Live unit. (Author 2019)

ing technologies available will advocate strongly for the use of these tools, even if they are not the best or most appropriate.

If all you have is a hammer, everything looks like a nail. The situation is further complicated in a low-bid procurement process by entities that can provide inexpensive testing (for example, GPR scanning) but do not provide any interpretation of the results, or even determine if the results are meaningful. Due to these circumstances, it is recommended that, whenever practical, procurement of structural diagnostic services should focus on answering questions, rather than using a specific tool or technology.

Knowledgeable investigators should be capable of determining which tools (usually more than one tool is needed) will work best to answer your questions about the structure.

This should include interpretation of the test results and the ability to try other techniques if the first one tried is unsuccessful. If possible, **schedule interviews as part of the procurement process for structural diagnostic services, and ask a lot of "why" questions.** For example, "Why are you recommending these tools to answer our questions? Why might these tools fail? Why would we see various different results of this type of testing?" Wherever possible, **focus on determining underlying causes of observed distress or anomalous conditions, rather than the distress itself.** Sometimes this approach will require multiple phases of investigation in order to determine the best approaches at small scale prior to site-wide implementation.

2.1. Visual Observation

Although it often does not involve advanced tools and technology, **visual observation can still be one of the most powerful and effective nondestructive diagnostic methods for historic masonry structures.** If the observer has experience with the types of construction used and the common patterns of distress, a quick walk around a structure can provide a wealth of information. Just as an experienced doctor can often obtain a preliminary prognosis from visible symptoms of a patient before ever picking up an instrument, an experienced investigator can often begin to evaluate patterns of distress in a historic structure prior to performing any type of testing. Generally, these patterns involve clues such as the location and direction of cracking, the location and extent of spalling, visible bulging or leaning of walls, and indications of previous repairs.

There are several modern tools that can significantly assist in the visual observation of structures. One extremely helpful tool for evaluation of historic masonry structures is the borescope (also known as the videoscope).

Borescopes are fiber-optic cameras that can be threaded through small holes in the surface, often drilled into mortar joints, in order to view subsurface conditions such as voids and bond stones (Figure 1.1). The primary advantages of borescope investigation for historic masonry structures include the minimally destructive nature of the opening (generally a small hole in a mortar joint), relatively low cost, and the ability to visually confirm subsurface conditions.

Borescope investigation is often used in conjunction with other techniques as a confirmation method. Borescope observations are limited in nature since the field of view is limited to the immediate surroundings of the hole. Additionally, the light source on borescopes is generally only capable of illuminating surfaces within a few inches of the borescope's tip. Therefore, borescope observation is not well-suited for evaluating large, dark subsurface areas.

Another tool that is becoming increasingly common to assist with visual observation is the use of unmanned drones. Drone aircraft have the advantage of relatively rapid and close-up access to conditions that can be difficult to see without special equipment.

However, the use of drones is often restricted in urban settings, and these devices do not provide the opportunity to feel or sound (see explanation below) the surfaces being observed. The cost of drone observations and video recording is moderate. It is generally best suited for medium- or high-rise construction where access is very limited to the building exterior.

Sounding of surfaces by tapping and listening for a hollow resonance is often used in conjunction with visual observation to probe for shallow cracks and delaminated conditions. This is a very inexpensive, nondestructive, and rapid method to obtain initial indications regarding the nature of observed cracks and spalls where hands-on access is available.

Figure 1.5: Elevation photo with stone thicknesses indicated by different intensities of red. (Author 2019)

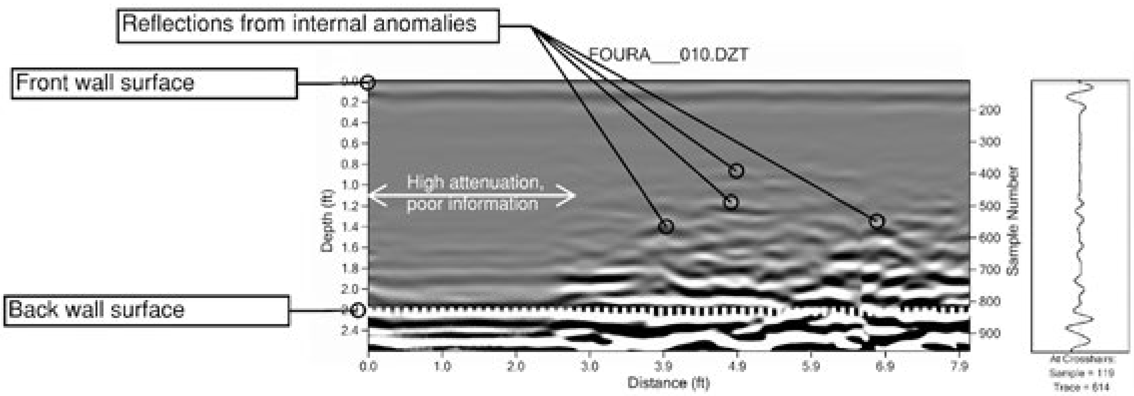


Figure 1.6: Example of vertical radar trace from bottom of wall to top, showing moisture- and salt-related attenuation and the presence of radar "noise" evident in first 3 feet. (Author 2019)

2.2. Surface Penetrating Radar

Surface penetrating radar (SPR) is also often referred to as ground penetrating radar (GPR). The SPR testing technique uses reflections of electromagnetic wave energy to identify internal anomalies (Figure 1.2). This method is often used to provide information on subsurface condition of walls, including as-built configuration, detecting voids or rubble fill, and identifying if internal collar joints are mortar-filled or void (Schuller, 2019). Results of SPR scans can provide critical information for determining typical wall sections and locating internal anomalies that may affect structural response. Additionally, SPR is an effective method for locating embedded metals in historic masonry. These metals could include original accessories and attachments or more modern reinforcing.

If a series of SPR scans are conducted adjacent to one another, the information gathered can often be post-processed to provide more intuitive graphical information about the location and extent of voids. Since the SPR data includes the depth of the observed anomalies, the information can be displayed in three dimensions (Figure 1.3) and even incorporated into a BIM model of the subject structure. BIM models are three dimensional representations of a structure that include embedded information about individual components. This type of modeling is becoming common practice as a supplement to conventional 2D drawings.

SPR is often used along lines or in grids to evaluate areas of masonry. However, the method can also be used on individual stone units in order to evaluate stone thickness (Figure 1.4). This information can then be compiled into drawings that provide an indication of stone thicknesses based on location and visible size (Figure 1.5).

Like all nondestructive evaluation methods, SPR has both advantages and limitations. The method is almost completely nondestructive (although it typically requires the wheels of the antenna to make contact with stone surfaces), and it provides valuable subsurface information that can be assembled into intuitive graphics. It also does not require evacuation of a site or hazardous radioactive sources like X-ray imaging. However, **SPR only gathers information along a single line at a time, so collection of information on large areas can be time-consuming and rather expensive.** The electromagnetic waves used by SPR devices can also be attenuated by certain conditions in the substrate. At the mission structures, the primary concerns related to SPR attenuation are moisture and salts that can be deposited in the walls by rising damp (see Figure 1.6). Moisture, salts, and clay particles have dielectric properties that disperse SPR waves and can make readings impossible (Conyers, 2004). **Limestone masonry is particularly prone to rising damp, so this can be limiting to the efficacy of SPR near ground-level at SAAN structures.**

2.3. Infrared Thermography

Infrared Thermography (IRT) is a nondestructive evaluation method that involves very precise temperature measurement of surfaces that are compiled into an image or thermogram to show patterns of heat transfer (see Figure 1.7).

IRT images are captured using infrared cameras that tend to have somewhat lower resolution and narrower angle lenses than modern digital (optical light) cameras (see Figure 1.8). Often, the primary use of IRT in historic masonry structures is related to moisture patterns, which is beyond the scope of this paper. However, IRT can also be used to detect certain structural features or distress such as near-surface delaminations or variations in wall

Figure 1.7: Infrared thermogram of a historic stone masonry wall that is generally cooler near the bottom and warmer near the top. (Author 2019

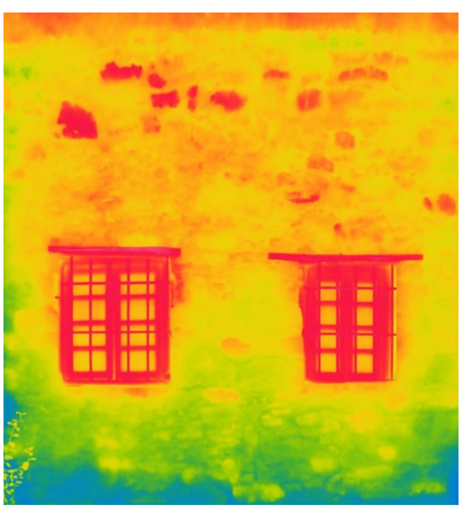


Figure 1.8 Recording a thermogram with an infrared camera. (Author 2019)

thickness. IRT has unique advantages among nondestructive evaluation methods in that the images can be used to rather quickly and inexpensively evaluate large areas at a glance, and the images are relatively intuitive since they resemble photographs.

However, structural applications in mass masonry walls are limited due to the thermal mass of these systems and IRT behavior can be dominated by near-surface phenomenon such as discoloration of units or shadowing.

2.4. Ultrasonic Pulse Echo

A relatively new nondestructive evaluation method that has application in historic masonry walls is ultrasonic pulse echo (UPE) testing. Previously, ultrasonic testing in stone masonry was primarily performed using ultrasonic pulse velocity (UPV) methods that require simultaneous access to both sides of an element and measure along only a single path per reading. UPE technology allows for collection of information from an array of transducers using a hand-held device (see Figure 1.9).

The device emits pulses of ultrasonic energy from a single row of transducers while the other transducers in the array "listen" for the reflection of this energy from a crack or back surface (see Figure 1.10). The timing of these echoes is instantaneously post-processed to produce images of subsurface conditions such as cracks and delamination (see Figure 1.11).

UPE is well-suited for detecting cracks and discontinuities in solid substrates such as stone, and it is relatively quick to perform spot measurements. However, **the method has limited application for SAAN structures because it requires relatively smooth surfaces** for coupling of the ultrasonic transducers.

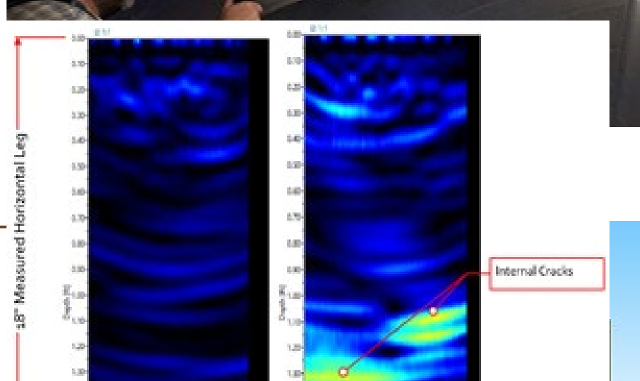
Additionally, unless mortar joints are completely solid and of similar stiffness to the masonry units, these joints create reflections that can interfere with measurements of subsurface conditions.

Therefore, it is likely only practical for cut stone surfaces of relatively large (more than 1-foot wide) units in most historic masonry buildings.

2.4. Flatjack and Shear Testing

If there is a need to evaluate the mechanical properties of a historic masonry wall assembly, limited test options are available. Even if it is permissible to extract samples of masonry for destructive testing, these samples are extremely difficult to obtain as intact assemblies that remain undamaged during transportation to a test laboratory. Testing of masonry units alone is not representative of the assembly properties, and there is no practical means of extracting mortar samples for physical testing at a lab. Therefore, the only available method to evaluate masonry mechanical properties of structures of the type found in the SAAN is to bring the laboratory to the site and test mechanical properties in situ.

Masonry compressive strength and modulus of elasticity can be evaluated using flatjack testing in accordance with ASTM C1197, In Situ Measurement of Masonry Deformability Properties Using the Flatjack Method (see Figure 1.12). The deformability test method involves cutting horizontal slots for insertion of two parallel hydraulic bladders (flatjacks), one located above the other. As the flatjacks are pressurized, the corresponding deformations of the masonry between the jacks are measured using a set of surface-mounted linear variable differential transformers (LVDTs). Test results are in the form of stress-strain response, with the compression modulus calculated and masonry compressive strength, f'm, either directly measured or estimated from the test data based on the compression modulus (see Figure 1.13).



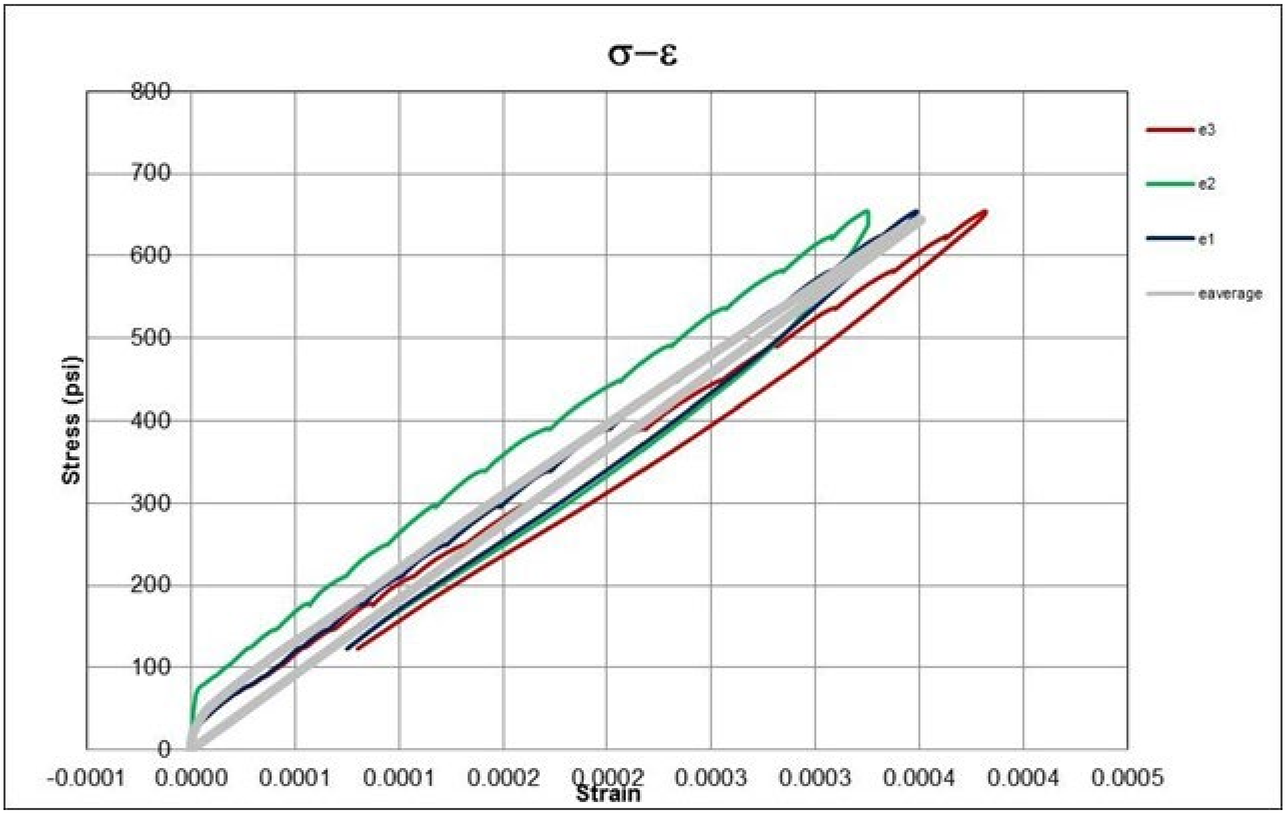


Figure 1.13: Graph of compressive stress versus strain in a masonry assembly produced by flatjack testing. (Author 2018)

Figure 1.12: In situ compression testing of stone masonry using flatjacks in accordance with ASTM C1197. (Author 2007)

Figure 1.14: In situ shear index testing at a clay brick masonry wall in accordance with ASTM C1531. (Author 2018)

Similarly, if the masonry includes rectangular units, in situ testing to determine mortar joint shear strength can be conducted in accordance with ASTM C1531, Standard Test Methods for in Situ Measurement of Masonry Mortar Joint Shear Strength Index (see Figure 1.14). The shear test requires empty mortar head joints on both sides of the unit being tested. The test unit is displaced horizontally by pressurizing a small flatjack inserted into the opening on one side of the unit. A dial gauge mounted across the other opening measures the lateral movement. Horizontal pressure is recorded after the first visible movement has occurred and is used to calculate

Figure 1.15: Structural monitoring system installation at stone arch bridge prior to load testing. (Author 2008)

the masonry shear strength.

Both in situ compressive and shear testing of masonry are best suited for rectangular masonry units with continuous bed (horizontal) mortar joints. In these conditions, flatjack testing can be conducted in a minimally destructive manner with removal of several feet of mortar. For ashlar or rubble stone masonry, cuts generally need to be made through the stone itself. Additionally, there is always some risk of damage to the masonry being tested, even though the intent is generally to stop testing when the masonry response becomes nonlinear prior to failure. **In situ mechanical testing is fairly involved and relatively expensive per test.**

2.5. Load Testing

Another means of evaluating historic masonry structures is to perform load testing on the structure. Since the exact construction and material properties of historic masonry assemblies are often uncertain, this type of evaluation can be very risky.

There is always a possibility that an unforeseen defect or anomaly could lead to a partial or total collapse under load. Therefore, **this technique is rarely used for sensitive historic structures.**

However, it is possible to gain valuable structural response information even under relatively light loading. Additionally, advances in digital video image correlation technology can often allow for real-time monitoring of deflections and movements under load with minimal attachment of gauges and monitoring sensors. Due to the risk of damage, **load testing should be used only with extreme caution but can occasionally be a useful structural diagnostic tool.**

3.0 STRUCTURAL MONITORING

While testing of structural properties provides a snapshot of conditions, the nature of structural distress in mass masonry walls often involves a gradual progression. The pace and nature of these gradual movements can often be observed more effectively using a structural monitoring system. These types of systems have significant advantages in determining whether or not structural distress is active and ongoing and can be set up to have alarms that are triggered by excessive movement. However, **structural health monitoring systems are generally fairly expensive to install and monitor.**

Additionally, **they require someone with knowledge of the system to pay attention to the results for months or years, and it can be tedious to weed out false alarms.** The first three sections below (Crack Monitoring, Tilt Monitoring, and Vibration Monitoring) describe some common types of sensors used for historic masonry structures as part of a structural monitoring system (Figure 1.15). The fourth

Figure 1.16: View of a stone arch bridge instrumented with a vibrating wire strain gage (indicated with an arrow) to measure strains during a load test. (Author 2018)

section (LiDAR) describes a stand-alone documentation method that can also be used for structural health monitoring.

3.1. Crack Monitoring

One of the most common types of structural health monitoring for historic masonry walls is crack monitoring. Crack monitoring can be performed using simple techniques such as measurement with a crack comparator on a regular schedule or using a plaster patch as a tell-tale indicator of movement. Crack monitoring can also be part of a more comprehensive digital structural health monitoring system with continuous measurement. Strain gauges and vibrating wire gauges are typically used to detect even extremely small movements across a crack (Figure 1.16).

These systems generally must be calibrated to compensate for the effects of temperature changes on the gauges themselves. Due to their sensitivity, crack gauges generally need to be protected from incidental contact and, whenever possible, should not be installed in areas subject to minor movements from slamming doors, windows, or other minor impacts.

The primary benefit of crack monitoring is to establish whether observed cracks are actively moving/growing over time. If they are moving, this monitoring can give some indication of the rate of growth. Unfortunately, crack movement can also be cyclical over time.

This includes daily solar cycles that heat portions of the structure at different times, seasonal cycles of temperature and moisture, and even longer cycles of drought or heavy annual rainfall. Therefore, drawing conclusions from limited crack monitoring data can be problematic. One of the disadvantages of crack monitoring is that collecting meaningful data can take quite a long time and can be labor intensive.

3.2. Tilt Monitoring

A fairly common structural concern with mass masonry walls is the appearance of bulging or leaning in a wall element. This displacement may be an indication of local structural instability, but it could also be related to movement that took place many decades previous. It is even possible in some structures that the wall was constructed with this type of imperfection.

One structural health monitoring approach to address this type of condition is tilt monitoring. Similar to crack monitoring, the installed gauge can detect whether or not a wall is leaning or bulging further out of plumb over time, suggesting an active distress mechanism. Also like crack monitoring, this approach generally requires at least weeks or months of measurement in order to establish a pattern, must be installed by a subject matter expert, and can be fairly expensive to monitor by professional consultants.

It is also generally necessary to perform monitoring on a roughly hourly basis at least initially in order to determine if there are daily patterns associated with sunrise and sunset or other daily occurrences. Once patterns are determined or daily "noise" is accounted for, it may be possible to monitor conditions daily or even weekly, depending on the monitoring objective.

3.3. Vibration Monitoring

The use of vibration monitoring in a structure of the type at the SAAN is generally related to concerns regarding adjacent construction or other outside impacts (since these structures are not typically subject to dynamic loads). Vibration monitoring has become more common adjacent to construction sites in urban settings such as New York City, and guidelines for acceptable levels of vibration for various types of structures are beginning to become better established.

This type of monitoring can be set up with alarms to indicate excessive vibrations to alert individuals when there is a concern. **Historic masonry structures can be damaged by excessive shaking, and vibration monitoring should be considered for the subject structures if there are concerns about heavy construction nearby,** especially if the construction involves vibratory soil consolidation, pile driving, or drilling of caissons. This type of monitoring can be heavily influenced by the placement of the sensors, and should be designed by qualified experts who are familiar with the specific structures being monitored and any existing structural distress.

3.4 LiDAR

LiDAR (Light Detection and Ranging) systems also known as **3-D laser scanning systems have become more accessible and affordable for use in evaluation of historic structures.** These devices use laser distance measurements to create a point cloud that can be compiled into a three-dimensional model of an existing structure (Figure 1.17). This model can be used to provide structural information such as the size and shape of structural elements. It **can also be used to detect and monitor some types of structural distress.**

For example, LiDAR imaging may detect sagging, bulging, or leaning of a structural element. If there is concern about ongoing movement of this condition, other types of monitoring can be used or subsequent LiDAR imaging can be used as a sort of time-lapse imagery to evaluate changes to the shape of the structure.

LiDAR imaging generally requires multiple setup locations in order to gather complete interior and exterior data. However, the speed of data collection has increased with advancing technology, so **complete LiDAR scans of structures of the type found in the SAAN can usually be completed in a few hours of site work for a relatively reasonable price (often under $5,000 for a structure).** In fact, close-range LiDAR scanning of a wall or feature can now even be conducted with an iPhone (e.g. the 12 Pro model). The analysis, comparison, and reduction of LiDAR data can be more labor intensive, especially if comparing different scan results.

4.0. SUMMARY

It is apparent from the extensive list of technologies described in this paper that there are numerous tools available to assist with the assessment and monitoring of structures of the type found in the SAAN. Unfortunately, most of these tools have limited applicability. They are generally very effective for detecting certain structural conditions, but **a single technique is rarely appro-**

Figure 1.17: Three-dimensional point cloud of a historic masonry structure generated using LiDAR. (Foley Associates 2016)

priate for many different types of investigation.

While it is hoped that this paper provides some initial insight into the appropriate uses for various technologies, it is generally beneficial to discuss an assessment or monitoring plan with professionals familiar with the strengths and limitations of multiple techniques prior to investing in this type of work.

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White Paper No. 2

Understanding Moisture Problems in Mission Masonry

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ABSTRACT/TOPIC SENTENCE: Moisture damage to masonry and applied finishes in San Antonio Missions is often readily observable. However, the damage is usually symptomatic of a more complex and largely concealed system of moisture sources and paths that include transport of salts. Understanding moisture problems as the result of a system of sources, inflows, storage, outflows, and sinks allows us to develop hypotheses as to the probable causal factors that drive the deterioration. Systems thinking also informs the design of moisture monitoring programs to validate our hypotheses and informs where appropriate interventions might be most effective in reducing the rate of deterioration of the historic masonry and finishes.

KEYWORDS: Moisture, Salts, Efflorescence, Rising Damp, Soil, Groundwater

1.0 INTRODUCTION

1.1 Purpose and Scope

This brief provides a basis for understanding of moisture sources and movement at the San Antonio Missions so that the potential causal factors of masonry damage may be identified as an initial step in diagnosis. Understanding masonry damage as the result of a system of moisture sources, movements, and sinks is an essential step in planning for a diagnostic program and testing. Failure to understand moisture as a system can result in inappropriate interventions and unintended consequential damage to historic building fabric.

This brief provides the basis for diagnostic thinking about the causes and enabling factors in moisture damage so that credible hypotheses may be developed for observed deterioration.

This brief does not address selection of diagnostic techniques and monitoring methods to validate/invalidate since these are highly dependent on site-specific factors and the complexity of the specific building and moisture problem.

1.2 Moisture and Salt Damage in Mission Masonry

Moisture and soluble salts are the complementary enabling factors of most biological and mechanical deterioration and damage to Mission masonry. Mission masonry typically includes one or more regionally available stone types such as tufa limestone with fine to very coarse pore sizes, limestone with clay inclusions, and dense chalk that is often carved. Each stone type has specific vulnerabilities to moisture-driven deterioration. Porous limestone is susceptible to biological growth, limestone with clay inclusions is susceptible to disaggregation from sub-florescence and from shrink/swell of the expansive clay, and chalk is susceptible to sub-florescence and surface loss to erosion.

Masonry mortars can be highly varied in composition and properties and are susceptible to sub-florescence and biological activity. Sub-florescence and biological deterioration may also occur in historic plaster finishes and paints applied to the masonry.

Efflorescence may occur on surfaces of all of the above materials. The coincidence of saturated materials and freeze-thaw cycling appears to be rare at the Missions but is possible during unusually cold winters.

Moisture and salt damage in Mission masonry typically occurs at or near the surface. While the damaged surface appears to be "where the action is," the moisture and salt sources and their points of entry into the masonry may be concealed and remote from the damage location. This is why it is important to understand moisture in masonry as a system.

2.0 MOISTURE AS A SYSTEM

2.1 Water and Its Properties

Straube (2002) provides an excellent review of the interaction between water and porous materials. Straube notes that the small size and spatially-unbalanced bipolar character of the water molecule allows vapor molecules to be attracted to the interior surfaces of porous materials at low relative humidity and transition to liquid water at higher relative humidity.

The bonding of molecules in liquid water results in tensile forces at the liquid/vapor surface that pull the liquid through interconnected pores by capillary suction; the presence of soluble salts increases the surface tension. Surface tension must be overcome for drying by evaporation to take place.

2.2 The Moisture System

Straube (2002) presents a systemic approach to understanding the interaction between moisture and building materials and assemblies. Figure 2.1 illustrates that approach graphically, beginning with moisture sources along the top and moisture sinks along the bottom with stored moisture in the building at the center.

Of particular note in Figure 2.1 is that while there are multiple paths for liquid water and vapor to enter a building material, most building materials must dry by evaporation or desorption rather than by gravity drainage. **Moisture removal by drying is typically slower than moisture uptake of liquid.**

The application of Figure 2.1 to the San Antonio Missions is discussed below.

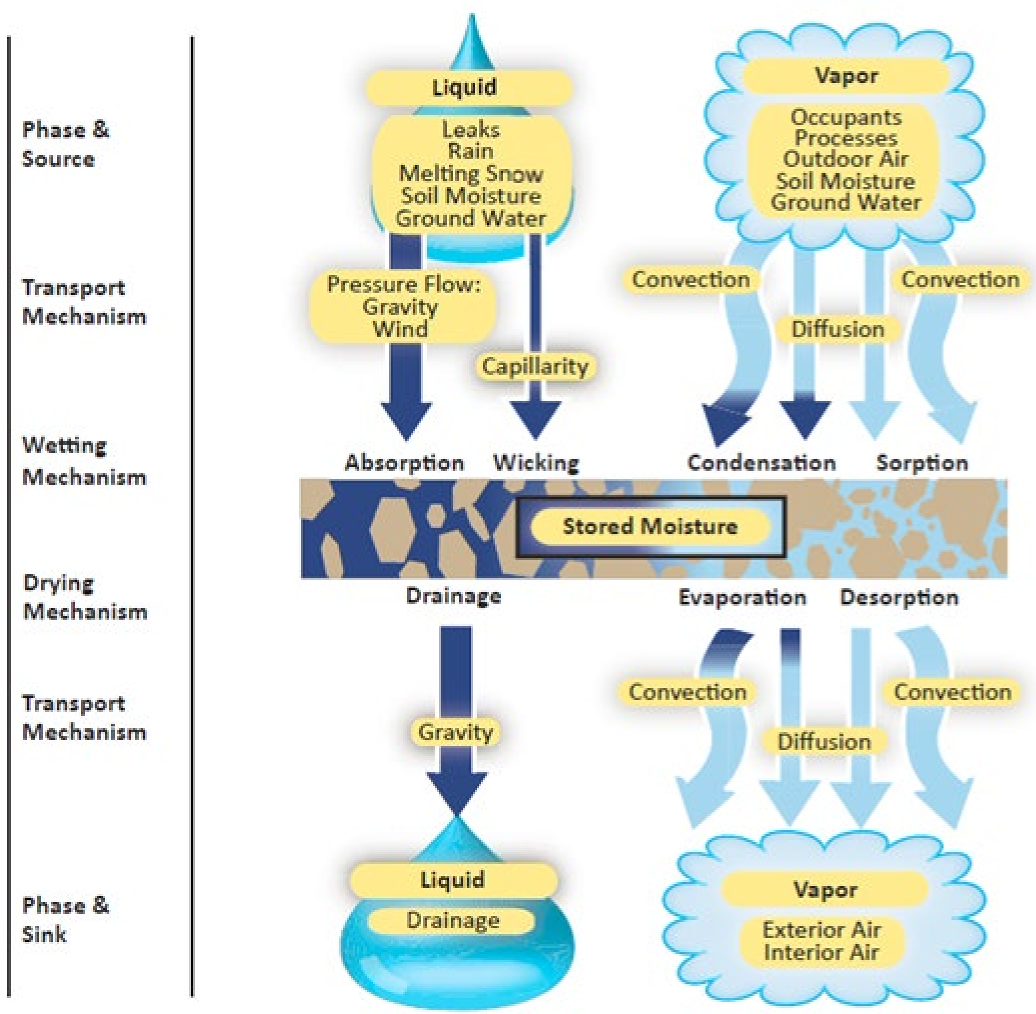

Figure 2.1: Moisture as a system in buildings.Credit: Reformat of (Straube 2002) by Christine Beckman and Michael C. Henry (Maekawa 2015)

3.0 MOISTURE SOURCES AT THE MISSIONS

3.1 The Climate of the San Antonio Missions

The San Antonio Missions are located in Hot-Humid Climate Zone 2A where annual precipitation has ranged between 16.4 and 52.3 inches and the annual average is 31.8 inches.

Atmospheric moisture ranges from 9.9 to 134.8 grains moisture per pound of dry air (ASHRAE 2020). **The available rainfall and the seasonally high moisture content of the air act to retard drying, and both factors peak in summer.**

The San Antonio region can experience more than fourteen atmospheric freeze-thaw cycles annually, but the actual number experienced by a south-facing wall may be greater when diurnal air temperatures remain below freezing. The low ambient temperatures may be offset by the thermal mass of the wall, lowering the risk of freeze-thaw damage.

Hail is a particular concern, because of impact damage to weathered stone. At the onset of a strong rainstorm, hailstones can block roof and surface drainage until they melt. NOAA reports 252 hail events in Bexar between May 2001 and May 2020 with hail diameters ranging from 0.75 inches to 4.5 inches (NOAA 2021).

At each Mission, the regional climate may be attenuated or exacerbated by site-specific factors, such as building orientation, adjacent structures, openness, vegetation, shade, and urban versus rural development. **Projections for climate change for the region include rainstorms of greater intensity and frequency, which will increase the amount of moisture available to the building** (Hayhoe 2015).

3.2 Soils and Hydrology

Soils and hydrology are site-specific and are important factors in the moisture system of any building. Soil consists of soil particles and surrounding voids. The voids may be as high as 30% of the total soil volume and these voids are available for moisture in the liquid or vapor phases. Sandy soils may drain surface moisture quickly. Water and clay soils can have a special affinity, resulting in bound water on the clay surface. Clays and silts can retain significant amounts of moisture, slowly releasing it into adjacent building foundations.

Hydrology addresses the lateral and vertical movement of water in the various soil strata around and under a building. In the Mission region, natural formations of caliche may be encountered within the soil strata near or below the building foundation. Caliche formations typically extend laterally and vary in thickness, depth and hardness. Caliche is typically less permeable than the adjacent soils. Elsewhere in the Mission region, karstic limestone formations can be highly efficient in the movement of groundwater due to their large, interconnected voids.

The natural stratification of soils and hydrology surrounding and under a Mission is likely to have been disturbed by human activity.

The builders' trenches for foundations and utilities, excavations for burials and planting, and surface alterations such as pavements or grade changes can greatly alter soil types and arrangement. These will result in anomalies in site hydrology, impacting the movement of moisture at or near the building foundations.

3.2 Moisture Sources—Liquid

Rain is a significant source of liquid moisture and may enter the building masonry by several paths. Wind-driven rain can penetrate porous stone, fissures, and joints between materials. Rain runoff from roofs is concentrated at *canales,* locally saturating the soil at the base of a wall. Ground surface features such as poor slope and slightly elevated impervious pavements can retard surface drainage of rain and increase soil moisture near the building.

Although infrequent, snow perched on roofs and projections in the masonry can slowly release water directly into the masonry.

Historic landscape features such as *acequias,* and their modern reconstructions, can be a significant source of soil moisture if located near the building.

Modern interventions and landscape/hardscape features at Mission sites can unintentionally result in increased soil moisture. These can include landscape irrigation, fountains and ponds, leaks in water supply and drainage piping, and improper collection and discharge of condensate from air-conditioning equipment.

Groundwater in aquifers deep below a Mission can result in increased soil moisture at the building foundation due to artesian pressure in the aquifer or due to the capillary fringe in soils above the aquifer.

Wet mopping of interior floors and pavements can be also a source of direct liquid moisture in a Mission.

3.3 Moisture Sources—Vapor

In the San Antonio Missions, sources of moisture vapor include atmospheric moisture due to weather, evaporation of soil moisture around the building and evaporation of soil moisture through the floor and walls.

The contribution of humans to interior moisture vapor can be significant, depending on patterns of visitation and use.

Occupants contribute to environmental moisture vapor by respiration, evaporation of perspiration, and drying of rain-soaked clothing. Liturgical events may result in large numbers of occupants as well as moisture vapor as a combustion product of large numbers of candles.

The exchange of interior and exterior moisture vapor will depend on the moisture vapor difference between the two environments and the permeability of the building envelope, especially at openings for doors and windows.

3.4 Sources of Soluble Salts

Liquid moisture is the vehicle by which soluble salts are transported through building materials. Soluble salts may be found in the atmosphere as pollutants, in building materials such as stones or mortars, in groundwater, and in soil as a result of past agricultural activity and human or livestock waste.

4.0 STORED MOISTURE AT THE MISSIONS

4.1 Porous Building Materials

In Figure 2.1, stored moisture refers to liquid and vapor moisture that is contained within porous building materials such as stone, mortar plaster, and wood.

4.2 Uptake of Liquid Moisture by Porous Building Materials

As shown in Figure 2.1, liquid moisture enters large pores in materials by absorption and small pores by capillary wicking.

Absorption may occur with porous limestone or large cracks in masonry, but capillary wicking is most likely at the masonry/liquid interface in chalks and limestone with clay inclusions.

Capillary wicking in soil can be rapid in fine-grained soils and some clays. In masonry walls, the rate of moisture uptake will depend on the types of stone and mortar and the fill material of the wall core.

Soluble salts may be introduced into a porous material with liquid uptake. Dehydrated soluble salts in a porous material are mobilized upon contact with entering water.

Liquid water uptake is generally apparent on exposed masonry surfaces.

4.3 Uptake of Moisture Vapor by Porous Building Materials

Water vapor uptake by porous materials depends on the porosity and permeability of the material and the surrounding atmospheric temperature and relative humidity. There are several regimes or stages of vapor uptake by adsorption until the equilibrium moisture content is achieved. At equilibrium moisture content, there is no exchange of moisture vapor between the material and the surrounding air.

Figure 2.2 illustrates the relationship between ambient relative humidity and the moisture content of a hypothetical porous building material at constant temperature. Note that dehydrated soluble salts within the material pores will be mobilized when free capillary water is available.

Vapor uptake in porous materials with efflorescence is complex as the water vapor molecules are more likely to be adsorbed by the salt crystals than by the material pores, in which case a saturated salt solution is wicked into the material.

Vapor uptake is generally not observable unless vapor condensation or saturation occurs at the surface.

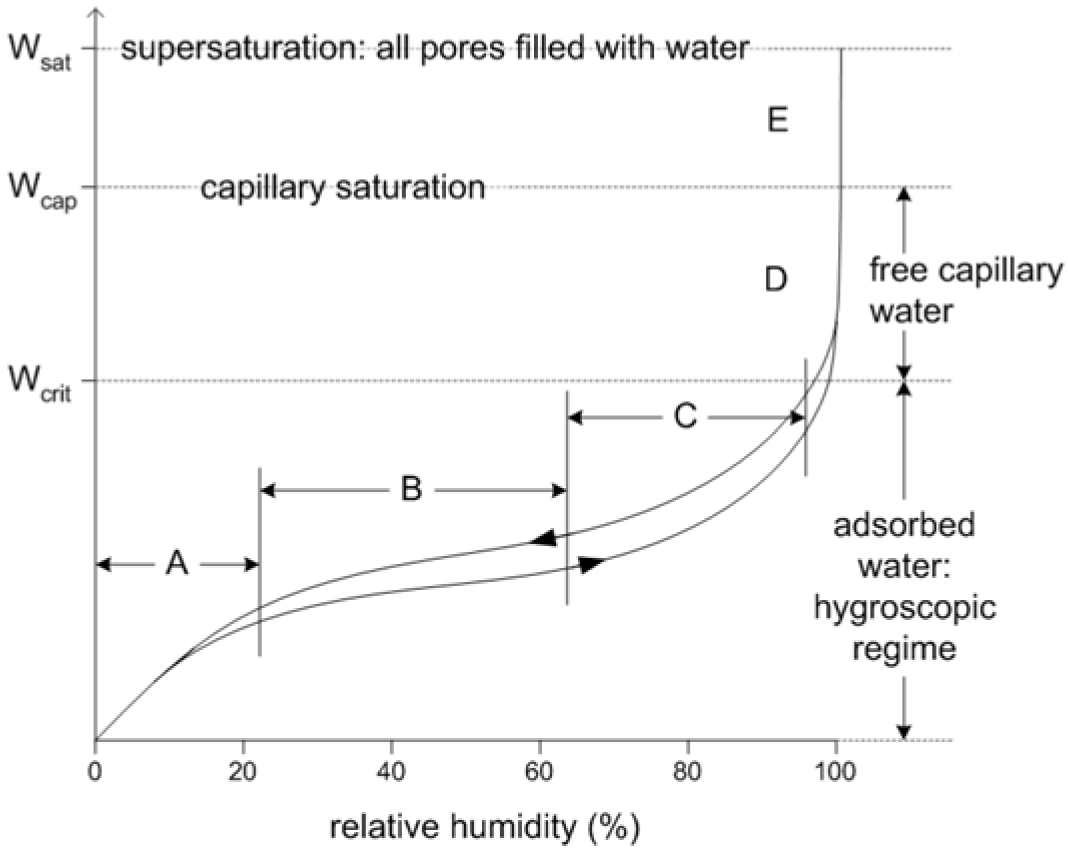

Figure 2.2: Moisture storage regimes of a hypothetical porous material showing relationship of material moisture content W to relative humidity (Straube 2006).

A: Single layer of adsorbed water vapor molecules line the pore surfaces

B: Multiple layers of adsorbed water vapor molecules line the pore surfaces

C: Multiple layers of adsorbed water vapor molecules connect across the pore opening

D: Pore is saturated with liqiud water, capillary movement occurs in the connected pores

E: Material is supersatured with liquid water due to pressure (±)

Note that for the same moisture content, desorption (downward arrow) occurs at a lower relative humidity than adsorption (upward arrow)

5.0 MOISTURE SINKS AT THE MISSIONS

5.1 Available Drying Mechanisms in Mission Masonry

Unlike modern cavity walls, the mass masonry walls of the San Antonio Missions lack provisions for removal of free-draining moisture by gravity. As a result, liquid moisture is removed from mass masonry by evaporation of liquid or desorption of adsorbed vapor. Either mechanism results in deposition of dehydrated salts below or on the masonry surface. Both mechanisms are accelerated by thermal energy, low ambient relative humidity, and convection with the latter increasing the rate of air change at the masonry surface. However, in some instances, thermal energy from solar radiation may simultaneously drive moisture vapor into, and out of, a wall.

In situations with moisture saturation and high salt concentrations, supersaturated salts at the surface of the masonry may retard evaporation due to high surface tension.

An exterior wall is exposed to two environments, interior and exterior. Differences in the environmental conditions will result in different rates of drying. In the case of rising damp, moisture uptake from large sources of groundwater and soil moisture may keep pace with higher rates of drying. The result of increased drying rate will be increased deposition of salts in the form or efflorescence or sub-florescence, the latter accompanied by an increased rate of masonry damage.

5.2 Exterior Environment as a Moisture Sink

The exterior environment is a result of climatic patterns, weather events, and site factors. Drying rates, and therefore damage rates, will vary diurnally and seasonally dependent on variations in solar radiation, atmospheric relative humidity, and wind.

5.3 Interior Environment as a Moisture Sink

The interior environment of a Mission will be influenced by patterns of occupancy, moisture sources affecting the interior, and the exchange of moisture vapor and air with the exterior. **Mechanical heating or air-conditioning of the interior environment will tend to lower interior relative humidity and result in faster drying rates on interior walls than on exterior walls**, especially where soil moisture sources result in rising damp. The increased drying rate of masonry due to sustained operation of air-conditioning and the resultant dehumidification **will increase the rate of damage to interior finishes and masonry** due to efflorescence and sub-florescence.

6.0 DIAGNOSTICS

6.1 Simple Moisture Problems

Some moisture issues can be readily mitigated through identification and management of moisture sources. For example, rising damp on an interior surface of a masonry wall, opposite a roof *canale* on the exterior, strongly suggests that water discharge by the *canale* should be intercepted and diverted away from the building without water penetrating the soil. Verdant growth of plants and grasses next to the building is an easily observable indication of abundant soil moisture, and the source should be identified.

As a preventive approach to reducing moisture damage in the Missions, **building stewards should routinely observe the building and site for moisture sources that can affect the building.** Important observations include performance of roof and surface drainage systems during storms, irrigation systems, and disposal of condensate for seasonal operation of air-conditioners.

Strategies for source moisture control can be found in *NPS Preservation Brief 39 (*Park, 1996).

The effects of air-conditioning on the rate of interior damage, such as efflorescence or sub-florescence should also be noted. By lowering the moisture content of the interior air through dehumidification, air-conditioning can accelerate drying of moisture from walls, floors, and ceilings, resulting in efflorescence, sub-florescence, and associated damage. These effects may be reduced by minimizing duration of operation, by carefully directing supply air away from historic surfaces. **Air-conditioning thermostats should be set as high as reasonable for human thermal comfort (76°F to 78°F)** to avoid excessive dehumidification.

6.2 Complex Moisture Problems

Concealed moisture sources and paths present complex moisture systems that will require diagnostic investigation prior to introduction of interventions.

Diagnosis of complex moisture problems begins with assembly of factual information and quantitative data for the relevant history of the building, wall construction, stone characteristics, mortar properties, salts in soils and in masonry, soils and soil properties, aquifers, subsurface water systems, subsurface drainage systems, and climate.

Archaeological investigation and exposure of foundations and subgrade conditions will likely be necessary where rising damp is an issue. In this respect, any archaeological excavation is an opportunity to observe, measure, and record valuable geotechnical and hydrological information about soil typologies and stratigraphy, moisture conditions, and potential moisture sources for future diagnostics.

With complex moisture problems, professional expertise in building moisture, building materials conservation, soils, geology, and hydrology should be consulted.

With the necessary information and data and with multidisciplinary expertise, preliminary hypotheses can be formulated as to the moisture sources and paths of moisture flow into the building that could result in the observed deterioration. Figure 2.1 provides a graphical basis for exploring these possibilities. It is important to develop multiple credible hypotheses to allow for validation and invalidation when designing a monitoring program.

A monitoring program should be designed to determine the response of building moisture to variations in known and hypothesized moisture sources and the interior and exterior environments. In essence, the monitoring program collects data at critical points on the moisture system diagram so that the comparative importance of all moisture sources and sinks on stored moisture can be assessed.

Monitoring programs require a full year of data for assessment of seasonal influences.

Diagnostic devices such as infrared thermal imaging and handheld moisture meters can be useful when used by an experienced professional. However, these devices do not measure moisture directly and can be influenced by a variety of unrelated factors, resulting in incorrect interpretation of images or data by novices.

7.0 INTERVENTIONS

7.1 A Cautionary Note

Every building presents a unique combination of materials, construction quality, history of use, and site-specific context of climate, soils, hydrology, and site orientation. There is no toolbox of standard interventions for moisture problems. **A trial-and-error approach to interventions should be avoided.** Moisture systems, especially when concealed, tend to be slow-moving, making it difficult to assess the efficacy or the beneficial impact of an intervention. Unintended consequences of inappropriate interventions may be too small to observe initially and take years to appear.

Interventions should be based on careful diagnostic study of all of the factors that may affect the transport of moisture and salts in Mission masonry.

8.0 GLOSSARY

Absorption: Uptake of liquid moisture by a material

Adsorption: Uptake of moisture vapor by a material

Desorption: Release of moisture vapor by a material

Drainage: Release of liquid moisture by a material

Drying Mechanism: One of three mechanisms by which moisture leaves a material—desorption (vapor), evaporation (liquid to vapor), or drainage (liquid)

Efflorescence: The formation of crystalline salt structures or powders when water containing soluble salts evaporates on the surface of a porous material, leaving the salts behind

Phase: State of the moisture as solid, liquid, or vapor

Sink: Destination of moisture after leaving a building material

Sorption: See adsorption

Source: Original of moisture before entering a building material

Sub-florescence: The formation of crystalline salt structures or powders within the pores of a building material when water containing soluble salts evaporates below the material surface, leaving the salts behind. The pressures exerted by the solid phase salts within the pores can cause cleaving, spalling, or disaggregation of the building material

Transport Mechanism: How moisture moves from one point to another in the environment—diffusion (due to differences in concentration), convection (due to differences in temperature or pressure), gravity (due to differences in height)

Wetting Mechanism: One of four mechanisms by which moisture enters a material—absorption (liquid), wicking (liquid, due to capillary action), condensation (vapor to liquid), or adsorption (vapor)

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White Paper No. 3

Site Water Management and Roofing

By Kenneth Itle and Erik Murray
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ABSTRACT/TOPIC SENTENCE: The historic San Antonio Missions suffer from the effects of uncontrolled water infiltration, which is related to poor site drainage, rising damp, deteriorated roofing and masonry materials, and past use of inappropriate repair materials. This paper reviews water management issues and suggests appropriate interventions to mitigate the effects of moisture on the historic structures.

KEYWORDS: Moisture Infiltration; Rising Damp; Roofing; Waterproofing; Site Drainage

1.0 INTRODUCTION

Throughout their history, the structures of the San Antonio Missions have suffered material deterioration from the effects of uncontrolled water infiltration. At these sites, sources of moisture often relate to poor site drainage, rising damp, or deteriorated roofing and masonry materials. **In some cases, interventions in the 20th century used inappropriate repair materials that failed to solve or exacerbated moisture management issues.** Before repair work can be defined and implemented, the sources of distress must be understood.

2.0 FINDINGS FROM PREVIOUS ASSESSMENTS

Previous assessment and preservation activities since the late 1980s that are relevant to current strategies and efforts to manage site water and roofing issues include, but are not limited to, the following:

- Roof membranes have been replaced
- Roof slopes and drainage have been modified, including lining of the *canales* (scuppers)
- Waterproofing has been installed on the exterior below-grade portions of walls
- New foundation underpinning piers have been installed to address unstable soils
- Exterior masonry walls have been repointed
- New stucco and plaster have been applied to the exterior walls

3.0 MOISTURE INFILTRATION SOURCES AND IMPACTS ON THE HISTORIC FABRIC

The following sources of moisture relate to site water management and roofing, presenting threats to the durability and preservation of the stone buildings at the San Antonio Missions.

- Poor site drainage, resulting in ponding water near the walls. At some sites, the slope of the ground directs water toward the historic structures, or changes in grade over time result in the present-day exterior ground level being above the level of the interior floor. Note that saturation of the soil near the structures can result in heaving and displacement related to the wetting of expansive clay soils.
- Landscape irrigation close to the walls, resulting in frequent saturation of the masonry materials.
- Rising damp, in which subgrade moisture rises via capillary action through the porous masonry walls. Rising damp results in deterioration, staining, biological growth, and efflorescence on the walls. Rising damp is especially likely to affect stone units

Figure 3.1: Poor site drainage, resulting in ponding water near the walls. At some sites, the slope of the ground directs water toward the historic structures, or changes in grade over time result in the present-day exterior ground level being above the level of the interior floor.

installed with the bedding planes oriented vertically.

- Deteriorated or inappropriately detailed roofing, resulting in water infiltration.
- Roof drainage that discharges close to the building and/or directly onto the masonry walls.
- Deteriorated mortar joints or cracks in the masonry wall, allowing water infiltration.
- Lack of appropriate coping or other protection on upward-facing surfaces of walls that are preserved as ruins.
- Plumbing or mechanical systems, particularly condensate drainage for air-conditioning systems. Additionally, moisture accumulation within walls due to condensation can occur in spaces that have been retrofit with air-conditioning, although this appears to occur only at localized areas related to the locations of supply registers or mechanical equipment.

Given the local climate, in which periods of cold temperatures lasting more than a few days at a time are uncommon, condensation does not appear to be a significant issue, except in cases where inappropriate non-historic finishes are present. Some SAAN structures are air-conditioned, resulting in lower indoor humidity than the exterior ambient conditions in summer. Vapor migration through the walls of conditioned structures needs to be considered. Potential vapor migration may occur in some special cases where the interior temperature is persistently well below the dew point in localized areas, such as directly adjacent to air supply registers. Similarly, heat from condensing units can affect the vapor drive dynamics of localized areas of walls if the units are placed too close to the wall.

Where water is allowed to collect on or around the building, and in particular close to the building walls, it can seep into the soils or directly into the masonry and mortar, increasing the local moisture content. As the moisture level cycles and moves through the materials it can damage their integrity, especially the lime plaster commonly used at the interiors of the missions. Higher moisture content in the masonry also promotes biological growth, which causes deterioration of the stone and mortars.

Efflorescence is commonly observed where water infiltration or rising damp occurs. This phenomenon is caused by salts within the masonry and plaster materials being transported by water to the surface, where they are deposited as the water evaporates. **The salt deposits themselves are not necessarily harmful to the materials but are indicators of moisture infiltration that is harmful in other ways.**

The locations and patterns of moisture-related distress can point investigators and preservationists to the likely sources of water infiltration where, ideally, targeted repair and remediation efforts can be performed. **Poor**

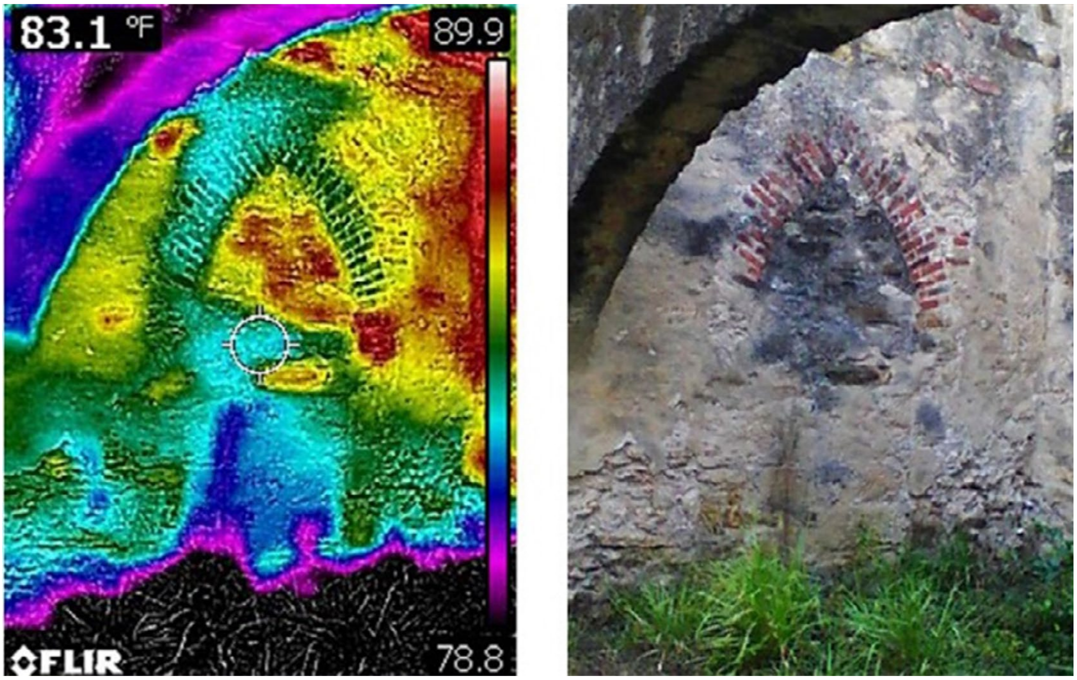

Figure 3.2: Rising damp, in which subgrade moisture rises via capillary action through the porous masonry walls. Rising damp results in deterioration, staining, biological growth, and efflorescence on the walls. Rising damp is especially likely to affect stone units installed with the bedding planes oriented vertically.

site drainage and groundwater tend to manifest as rising damp, flaking of limestone surfaces within a few feet of the ground, and deterioration of interior plaster low on the wall;[1] leaks in subsurface plumbing and mechanical system lines can manifest in a similar way. **Roofing and roof drainage problems tend to manifest as interior plaster distress and water staining/efflorescence high on walls,** around fenestration, and proximate to external features such as *canales,* buttresses, and ornamental elements.

One of the challenges in managing long-term water infiltration and deterioration is the choice of materials to use for waterproofing and roofing repair/remediation. Traditionally, the copings and vaulted roofs of the missions were protected with lime-based “mortar wash” materials, which are susceptible to cracking and have relatively short service lives; they require annual maintenance to remain reasonably watertight. More recently developed materials can provide better and more reliable waterproofing for a longer service life, but may also not be reasonably reversible or removable without damaging the original construction, and thus may be less desirable from a preservation perspective. A balance must be struck between the effectiveness and durability of the currently available roofing and waterproofing materials and the appropriateness of their use on these historic structures. For example, the Mission Concepción convento was reroofed in the past using rolled membrane roofing, which the 2019 *Historic Structure Report* recommended be removed and replaced with a more traditional mortar wash.

Although the San Antonio Missions share many of the same construction techniques and moisture infiltration challenges, there is some variation in performance among the various structures, and interventions need to be adapted to these variations. For example, the original quality of the stone masonry is somewhat variable. At Mission Concepción convento, the stonework has survived mostly intact with little structural distress, while many of the other missions have suffered significant structural distress, foundation movement, or previous partial collapses. The local geology, soils, and groundwater conditions also vary among the different missions, partly depending upon adjacency to the San Antonio River, which affects both the performance of foundations and the site drainage.

[1] The Historic Structure Reports performed for the Mission Concepción and Mission San José Conventos include excellent diagrams documenting the patterns and character of interior plaster distress.

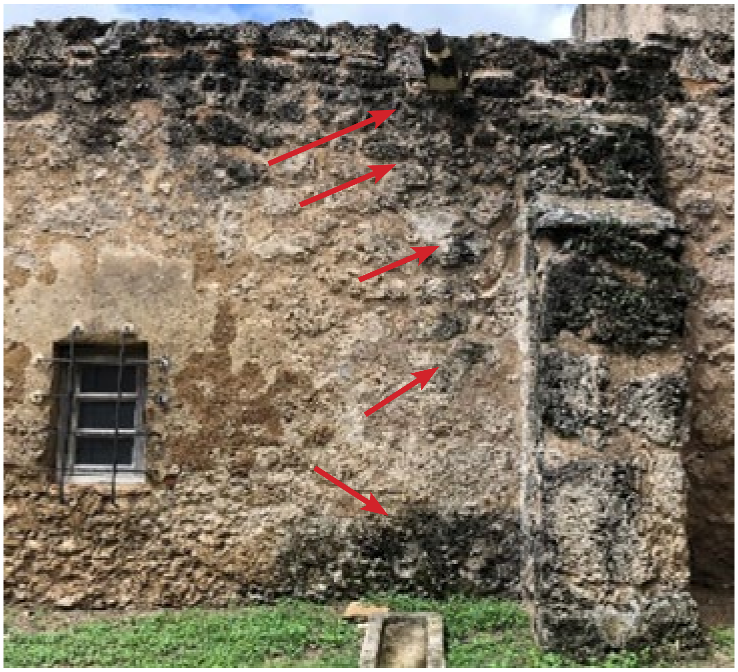

Figure 3.3: Evidence of roof drainage discharging close to the building and/or directly onto the masonry walls.

4.0 TECHNIQUES TO MITIGATE MOISTURE INFILTRATION

The above-noted sources of moisture infiltration at the stone buildings at the San Antonio Missions cannot be completely eliminated; however, there are techniques that can mitigate the negative effects of water infiltration and extend the life of the stone, mortar, and plaster materials. In some cases, materials with relatively low durability are the most appropriate choice for roofing, coping caps, and stone repointing mortar due to aesthetic or historical authenticity considerations; however, that choice also has the consequence of requiring frequent maintenance to prevent harmful water infiltration.

Ideally, site water management and roofing strategies first rely on diverting water from the vulnerable structure or feature using passive measures. An example of diversion is grading the topography to provide positive slope away from the structure or using *canales* (or scuppers) that extend well away from the exterior walls, so that storm water does not wash over the stone when draining from the roof.

For water that cannot be diverted away, management techniques include providing a means of capturing and directing water off and away from the structure. Examples of management techniques include **ensuring that roofs with significant slope direct water to canales and trench drains at grade to capture water at areas that cannot surface drain away from the building, so that water can be routed to a more distant discharge point.** Also, for some structures, it may be beneficial to excavate at the perimeter and install subsurface perforated drainage piping and free-draining soils against the foundations, to ensure that soils adjacent to the structure are not saturated. Depending upon site topography, subsurface drainage would be sloped by gravity to an above-ground discharge point, but sump pumps could be used if necessary for sites without adequate slope.

For water that will inevitably be present near building walls or drain over building elements, a barrier to water infiltration must be provided. More historically appropriate barriers to water infiltration in stone walls, such as lime mortar for pointing and mortar washes for roofing surfaces and copings, tend to require frequent maintenance to preserve reasonable watertightness. **Unlike other types of construction, mass stone masonry has the capacity to store and manage some amount of water without damage, so the materials used do not need to be completely impervious to water.** Instead, for this type of building material, the goal should be to manage moisture in the masonry and maximize breathability and drying, without damaging the interior plaster or promoting excessive biological growth. More modern waterproofing materials may provide a better barrier to water but may also make permanent changes to the stone they are protecting, trapping water within and damaging its integrity. Traditional materials tend to have higher breathability to promote drying of the mass masonry.

At roof levels, the traditional approach was to provide a lime-based wash over the masonry construction. This installation required frequent (annual) renewal to maintain even a limited degree of watertightness. For walls and other structures that are preserved as ruins, a mortar wash may provide an acceptable degree of waterproofing to upward-facing surfaces. For enclosed and occupied structures, it is likely necessary to use some type of contemporary roofing material. Given the architectural geometry and historic exterior appearance of the missions, a liquid-applied membrane may be an appropriate choice. A wide variety of products are currently available, and can be selected considering the resulting surface texture, color, gloss, durability, and future reversibility of the material.

With all these considerations in mind, the recommended best practices for the San Antonio Missions with respect to site water management and roofing include the following:

- **Provide positive drainage away from buildings and structures** by adjusting site drainage as necessary. Do not allow water to pond or dwell around or near structures.
    - Where positive drainage cannot be achieved, capture and route water away from buildings with trench drains or subterranean storm drainage systems. Consider historic resources below grade and always coordinate in advance with NPS archaeologists.
- **Limit irrigation around buildings to only what is necessary.**
    - Use primarily native plants that do not require regular irrigation adjacent to the buildings.
    - Where irrigation is needed, use low flow systems.
- **Provide positive drainage for all roofs. Do not allow water to pond on roofs for extended periods of time.**
    - Route drainage to *canales* (scuppers) or other drainage elements so that roof drainage does not wash over walls or ornamental building features.
    - Protect discharge points from roof drainage at the ground to prevent erosion and splash-back onto the walls.
- **Protect roofs and copings with waterproofing materials.**
    - Maintain a mortar wash at the top of walls and other structures preserved as ruins.
    - For occupied structures where traditional techniques do not provide effective or reliable protection to the historic fabric, consider the installation of contemporary liquid-applied roofing materials. Material selections need to be balanced for effectiveness, appearance, appropriateness (preference for historically-used or easily reversible materials), and consequences for poor performance (e.g. periodic roof leaks at poor flashing conditions may result in irreversible damage to interior plaster; therefore, a less traditional but more reliable repair at the roof flashing would be appropriate).
- **Provide improved ventilation for attics, vaults, basements, and other unconditioned interior spaces, to the extent feasible without altering historic assemblies.**
- **Provide appropriately designed air-conditioning systems where necessary for occupied spaces.**
    - Condensate drainage should be piped well away from historic structures.
    - Interior setpoints and locations of air supply grilles should be controlled to prevent condensation, which could occur on windows or areas of thin or hollow wall construction.
    - Condensing units should be placed well away from the exterior of walls so that operation of the equipment does not affect the performance of the wall, for example, by locally heating the wall from the discharge of vented air.
    - Appropriately manage the operation of systems, considering the times of day when the structure is occupied, the need to protect fragile historic artwork or furnishing from rapid swings in temperature and humidity, and the need to avoid creating excess moisture evaporation at the interior surface of the walls.
- **Protect walls by using appropriate repair materials.**
    - Repair cracks and deteriorated mortar joints using traditional lime-based mortars.
    - Use only highly breathable interior and exterior stucco, plaster, and coatings. Traditional lime-based materials are appropriate. Where surfaces were historically painted, consideration could be given to the use of highly breathable mineral-based coatings. Assessment of appropriate treatments should be accomplished by experienced conservators. Refer also to other related topics in this collection from subject matter experts on painted plaster treatments.
    - Where rising damp is not resolved by improved drainage and/or roofing, consider the use of

subgrade waterproofing, extending from the bottom of the footing up to the level of grade. Although liquid-applied or fully adhered sheet waterproofing materials typically provide more reliable performance, it may be preferable to use loose-laid sheet waterproofing to provide for reversibility of the treatment, with careful attention to detailing to ensure water cannot migrate between the sheet waterproofing and the masonry foundation.

- **Frequent Inspection**
    - Inspect grading, roofing, and roof drainage at least twice per year, and after major storms or floods, to assess damage to the roofing/waterproofing materials, erosion of the site grading, or other adverse conditions.
    - Identifying and mitigating emerging distress conditions with these inspections will provide an opportunity to address the conditions before serious damage is suffered by the buildings.

5.0 CONCLUSIONS

The historic San Antonio Missions experience ongoing challenges related to the management of moisture infiltration. The mitigation of moisture in these structures should consider both passive means to direct water away from the historic fabric as well as interventions that prevent water ingress while allowing for breathability and evaporation of moisture contained with the mass masonry construction. Given the high historic significance of these structures, **traditional repair materials such as lime-based mortars and plasters should be used whenever possible**, even if more frequent maintenance will be required.

Passive measures to drain water away from the structures, or management decisions such as limiting the installation of contemporary air-conditioning systems, are preferred over interventions that affect the historic fabric. Interventions that are not visible, such as subgrade drainage, are generally preferred to modifications to the above-grade portions of the structure, as long as there will not be a negative impact to significant archaeological features. The use of contemporary materials should be considered only when essential to provide protection for the historic structure. Although a holistic view of all potential sources of moisture and the overall movement of moisture through the structure is required, it may be reasonable to implement further repairs in a phased approach, so that the efficacy of less intrusive work can be assessed before more intrusive repairs are considered.

White Paper No. 4

Going Green in Ruins Conservation and Management: Soft Vegetative Capping

By Alex B. Lim
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ABSTRACT/TOPIC SENTENCE: Soft capping ruin masonry walls can help to enhance cultural landscape conservation and to bring about sustainable maintenance.

KEYWORDS: Ruin, Cultural Landscape, Wall Capping, Cyclic Maintenance, Sustainability

1.0 INTRODUCTION

Hard capping is a common repair on masonry ruin walls. It is often done with Portland cement, lime, hydraulic lime or even soil mortar (see Figure 4.1). Contrary to the appearance of durability, however, it cracks and spalls, allowing water to enter into the wall core, rendering the cap ineffective.

Hard capping is not sustainable. Its appearance—especially once it fails—intrudes on the ruin-scape and is distractive.

Wall capping is more than a technical prescription, and its application should be part of a broader strategy in conserving and presenting a ruin site. An alternative to hard capping exists within the frames of cultural landscape conservation and sustainable maintenance.

Figure 4.1: Typical hard capped masonry ruin walls in the American West. (Photo by Author)

2.0 RUINS PRESERVATION AS CULTURAL LANDSCAPE CONSERVATION

When ruin walls are viewed solely as subjects of archaeological and scientific study to extract information, it is easy to consider wall capping as a simple patchwork against further deterioration and for a temporary peace of mind. However, masonry ruin walls are not just skeletal remains in the landscape, laid bare separately as isolated exhibits. They are an integral part of the ruin landscape and define visitors' movement in the cultural landscape, therefore their whole experience and understanding (Tilley, 1994).

There is nothing more fundamental to ruins conservation than wall caps. Where roofs have collapsed, leaving wall remains, wall tops are usually capped, as a Band-Aid. They take on the brunt of weathering. Unfortunately, they are underappreciated.

Outlines of traceable and visible wall tops, combined with subsurface wall remains, are spatial guides in the ruin landscape. They help to understand the whole site from its conception and through its lifetime of use, disuse, reuse, and even misuse. Ruins are special spaces to relate and to relax, with an emphasis on how it is experienced. Ruins generate meaning through experience, and that experience is dictated by how we interact in the landscape where the ruins are located. Ruins are places and demand treatment as such, not as exhibit monuments (Matero, 2015).

Soft wall capping can enhance the place-making. By bringing nature to wall tops, we show clearly and harmoniously how we can welcome nature once again into the ruin creation process, and this time as a preservation technique as opposed to an element of ruin formation. When wall cap highlights nature, we emphasize ecological harmony, not disruption (see Figure 4.2). To borrow what Julian Smith said about cultural landscape in urban heritage, it is the relationship between objects that gives meaning in cultural landscape (2017, p. 182). In ruin landscape, the relationship between the ruined walls and the surrounding can certainly be highlighted, and wall tops make for obvious and attractive media.

It is easy to think that where a cap ends is where the ruin preservation stops. It is just the opposite: Where a cap ends is where the landscape connects to the standing ruin walls. A ubiquitous hard capping fails to bring about the full potential of a wall as an organic unit of the whole ruin landscape. There is an alternative.

3.0 TOWARD SUSTAINABLE MAINTENANCE

Sustainability describes an ability to continue an act for a certain period of time at a particular level. An intervention, including capping, requires a set of goals to gauge its sustainability. Wall caps should:

- Minimize water absorption into a wall.
- Hold the wall top together.
- Lower thermal stress on walls.
- Give cohesion to wall presentation.
- Be distinguishable from the original fabric but presented harmoniously.
- Be easily replaceable without harming the original fabric.
- Be maintained using local materials and personnel.

Cyclic maintenance and sustainability are often confused. The goal of cyclic maintenance is not setting the service life arbitrarily and meeting that goal of cyclic repair as a self-prophesy. The ultimate goal of any maintenance is prevention. Prevention is more economical, less burdensome, and more importantly can avoid sudden, irreversible, and catastrophic loss of the original. It means when we defer maintenance, we should and can do it because the condition is sound, not because the condition

Figure 4.2: Soft capped ruin in Gordion, Turkey, blends well with its landscape of royal tumuli and open field. (Photo by Author)

is poor nor because the significance is low nor because the work is overwhelming. Frequent cyclic maintenance that does not allow time and resources for other areas is not a cyclic maintenance. It is a poor maintenance and it is not sustainable. A cyclic maintenance forcing stewards to give up a wall top to treat other walls will continue to compound problems. This is not sustainable nor wise.

Hard caps may be easy to install but they are not sustainable. Once cracked and spalled, they do not meet the goals outlined above. To replace a cap with poor service life, significant amount of labor, time, and budgeting is repeated. This is wasteful.

When hard caps fail prematurely, the adverse impact on the original fabric continues. The illusion of hard cap is that even when it fails, it is left alone for a considerable amount of time, because it takes so much effort to remove it and redo it. In hard capping we find all the incompatibilities, including the look, the differential volumetric expansion, the oddity of smearing on or crowning a wall top with cement regardless of wall construction, materials, design and maintenance needs. To make it worse, hard caps are used regardless of the environmental context of the ruins. We treat hard caps as if they are a cure for all. They are not.

4.0 SOFT CAPPING AS ALTERNATIVE

Soft capping was born out of a simple desire to present a ruin and its context as a place of harmony between man-made and nature, where each does its part in creating and preserving a ruin site. Soft caps are reminders for the visitors that the green they see is covering the area of loss that walls suffered over time. Just like the greens on the ground around the walls, the scars on the ground and on the walls can heal over time, until the equilibrium is reached between man-made and nature. Soft capping is an encouragement toward that equilibrium.

Soft capping consists of soil, vegetation and geofabric. The soil and vegetation passively manages water and inhibits water on wall top from penetrating into a wall core. Soft capped wall tops blend with the ruin landscape. Unlike hard caps that crack, soft caps do not. Soft capping can be done relatively easily and without harm to the original fabric. Most importantly, they do not require much maintenance input since they do not need to be redone. Instead, they get better through acclimatization. Several studies have quantified the effectiveness of soft capping (Lee et al., 2009; Lim et al., 2013, Matero et al., 2011). Its benefits over hard capping include buffering of thermal stress and dampening concentrated water damage through evapo-transpiration.

5.0 TESTING SOFT CAP

Before going full scale, try pilot wall(s) first. They should be:

- Easily accessible for monitoring.
- Fairly flat on wall top (Grade change is O.K.).
- Structurally stable.
- Wide enough (at least a foot).
- Representative of the masonry walls at the site.

Use wireless sensors to record temperature change of the cap surface and core, volumetric change of the wall, and absolute moisture content change inside the wall, among other environmental parameters.

Compare the data to the site data including precipitation, relative humidity and temperature and evaluate the cap performance.

Design guidelines are as follows:

- **Wall Preparation:** Decide whether to build the cap up above the hard cap or to replace the hard cap. Before intervention, document the wall integrity and conditions. Existing hard cap can be kept as a separation layer.

Figure 4.3: In Mesa Verde National Park, the Park botanist and natural resource specialists advised on the selection and harvest of locally available grass. (Photo by Julie Bell)

- **Minimal Soil Volume:** Soil is the key component of moisture management. The cap will not work if there is not enough soil.
- **Vegetation:** Candidate plants should survive the extreme conditions of wall tops. Go for perennials instead of annuals for the ease of maintenance. Encourage a colony of plants instead of a single plant type to discourage weeds. Sods minimize plant death and seed balls are useful in introducing desired vegetation after cap establishment. Consult botanists for information on regional vegetation types, harvest locations, root depth and type, drought resistance, dormancy, among others. (see Figure 4.3)
- **Soil, Again:** Not all soils are the same. The amount and ratio of clay, sand and gravel varies from soil to soil. It is easier to choose soil that works for the selected vegetation than vice versa. Layer soils for desired water permeation and/or water uptake. Clay absorbs moisture but once fully saturated will impede water permeation. Sand and gravels are good for water permeation. Use ASTM tests as needed.
- **Cap Edging:** Soil cap needs protection against erosion. Dig into the reconstructed part of the masonry wall tops or build up above the original to create a compatibly designed parapet—extra masonry courses done in similar construction/design methods—before filling in with soil. (see Figure 4.4)
- **Geofabrics:** A variety of geofabrics—geotextile,

Figure 4.4: In Gordion, Turkey, adobes edged the soil cap which became part of the soil cover. (Photo by Author)

geomembrane, geogrid, etc.—are used for trench backfilling, landfilling, green roofing, soil engineering and even gardening (Koerner 2012). Combine different types for an optimized function. For example, one type of geofabric can retard or prohibit root penetration. Another can hold certain amount of moisture in its pockets.

- **Static Load:** The maximum soil load means full water saturation of the soil. Calculate the void space based on the porosity of the soil per applicable ASTM standard.

6.0 SUMMARY

Soft capping is a versatile alternative to traditional hard capping. It represents a philosophy to present a ruin site as a landscape and as a place, not just as an artifact nor an afterthought in cyclic maintenance. Its success depends on a holistic understanding of a ruin site including wall construction, design, material, environment, local ecosystem, soil and the site's operational needs. Designing and installing soft caps naturally require bringing together an interdisciplinary team and can help build a spirit of stewardship among all participants for the whole site beyond just one treated wall.

In a ruin landscape, all parts play an integral role in constituting a wholesome ruin. Sustainability is realized when this wholesomeness is maintained, just as a healthy ecosystem sustains itself when all its parts are balanced in their roles. Healthy ecology cannot be established when a select part receives an extreme attention or the lack thereof. Ruins conservation works the same way as ecology. Soft capped walls are only one part of the ruin ecology. Successfully done, they will lead the visitors to see nature as part of a ruin-scape, not a separate space. Hopefully, the soft wall cap can reinforce the idea of a ruin as part of our environment that leads to an emotional bond to a place, perhaps the most important ingredient for a place to be sustained.

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White Paper No. 5

Stone Masonry Preservation—Mechanical

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Silman

ABSTRACT/TOPIC SENTENCE: Understanding masonry wall assemblies and deterioration phenomena are critical for identifying appropriate interventions for structural repair.

KEYWORDS: Masonry Walls, Structural Assembly, Deep Repointing, Grouting, Pinning, Reconstruction

1.0 STRUCTURAL INTERVENTIONS

Stone masonry walls are generally the vertical gravity and lateral load-resisting systems of the San Antonio Missions. The structural performance of stone walls is dependent on how they are assembled.

1.1. Stone Masonry Walls Assembly

A multi-leaf wall is a typical method of construction used in Spanish Colonial Architecture, including the San Antonio Missions. The most common assembly is a three-leaf wall where; the two face leafs have exposed tooled surfaces. Between them is an internal leaf or core of coursed stone masonry, integrated with the inner and outer leafs, or small uncoursed stones set in mortar. Mortar is used to transfer loads and minimize point contact between stones, as well as to create a solid barrier between the interior and exterior faces of the wall.

Connections among the multiple leafs of masonry are critical to the structural performance of the wall. Connections between the core and the exterior leafs are mechanical; by friction where little mortar is present and by physical and chemical bond between mortar and stones. Tie stones that extend through the wall create the most effective connections; tie stones are infrequent in the masonry walls of the missions.

1.2. Structural Distress in Stone Masonry Walls

Structural distress in stone masonry walls may include systemic cracking from settlement or overloading; local cracking from deterioration of the assembly or local overstress; bulging or local displacement as the result of failure of the connection between face leafs and the core; bowing from large lateral loads; and loss of section from material deterioration, erosion, and/or mechanical alteration; etc. To appropriately treat the structural conditions, it is important to identify the cause of the distress and to determine if the condition is static or dynamic.

Static conditions may include the existing geometry of the wall like changes in thickness or plumbness; changes in the soil such as permanently lowered water table or undermining; and/or previous modifications to the building.

Dynamic conditions may be caused by environmental factors like daily and seasonal thermal stresses; cyclic changes in ground water levels that affect soils; capillary movement of water into the masonry; precipitation; wind; vibration from traffic; etc. Different repair methods may be required for static conditions and dynamic conditions.

The conditions that typically require structural treatment and/or repair are:

- Instabilities and defects that affect the whole wall, such as:
  - Bows (both surfaces of the wall moving in concert)
  - Large bulges (large areas of one or both face leafs moving away from the core)
  - Cracks through mortar and/or stone that extend vertically, horizontally, and/or transversely
  - Discontinuities such as construction or cold

joints between sections of wall

- Instabilities in the leafs, such as:
    - Missing mortar
    - Displaced stones
    - Deteriorated or cracked stones
    - Small bulges (small areas where one face leaf is moving away from the core)
- Instabilities or defects at the core, such as:
    - Voids
    - Loose rubble and/or deteriorated mortar

1.3. Structural Repair Techniques

For all repairs **it is critical that the repair materials are compatible with the original materials** and components of the wall. Incompatible materials can result in stress concentrations, changes in permeability, and other conditions that can accelerate deterioration. Several different approaches can be used to make structural repairs to masonry walls. They include deep repointing, grout injection, pinning, and reconstruction.

Deep Repointing—Repointing is the process of removing and replacing the mortar between stones. The outermost portion of the mortar at the surface of the wall is called pointing mortar; this is fully removed in pointing and deep pointing. When deep repointing a portion of the bedding mortar in the horizontal (bed) and vertical (head) joints between stones is also removed. If mortar deterioration extends past the surface, deep repointing can improve the structural performance by increasing the connectivity between the stones.

Issues to consider when using deep repointing:

- Improvement is at the face of the wall; it does not address deeper defects, such as voids.
- Deep repointing may not improve structural performance for dynamic loads.
- Extensive removal of historic materials decreases authenticity.

Grout Injection—Injection of grout, through ports or holes drilled into the wall, fills internal voids and creates a more cohesive assembly from the existing components of the masonry wall. Grouts need to be custom formulated to be compatible with existing materials and to achieve an optimal bond with all basic wall components.

Complete and sound pointing is required to confine the grout. Non-destructive evaluation of the wall assembly is recommended before and after grout injection to help locate voids (before) and confirm that they have been filled (after).

Issues to consider when using injection grout:

- The existing masonry remains in place and the wall remains a three-leaf assembly.
- The grout consistency should allow for the filling of bed joints, head joints, and core voids at the same time.
- The leafs of masonry are connected by the cohesion and adhesion of the grout.
- Local bulging may not be effectively stabilized with only grout.
- Finishes on the surface of the wall may be affected by pointing, ports, and bleeding grout.
- Water is used to flush the voids and wet the core; it may harm adjacent wall plaster finishes and wash out loosely cohesive mortars.
- May require temporary bracing to resist the pressures from injection of the grout.
- Voids may act as a capillary break, limiting movement of moisture and salts in the wall. Filling voids may allow future moisture movement, leading to other forms of deterioration.
- While the structural performance is improved, the grouted wall responds to dynamic environmental factors, at best, in the same manner as the original wall assembly.

Pinning—Pins are set in holes drilled through the face of one leaf into the leaf on the opposite face of the wall; ends of the pins can be recessed. Stainless-steel, titanium, and glass-fiber reinforced polymer threaded rod can be used for pins. Pins need to be fixed with chemical adhesives, such as epoxy or cementitious grout; a pin in a grout-filled sock can also be used.

Issues to consider when pinning:

- This is a standard practice in the masonry restoration industry.

- All three leafs of the wall are positively tied together improving the structural performance for static and dynamic loads.
- Pinning introduces a new material into the masonry wall that needs to be compatible and inert. Salts and moisture in the wall may have an adverse effect on the pins.
- Bed joint, head joints, and voids are not filled with grout.
- Deep repointing may be required to stabilize the masonry.
- Pins are the only tie. Pins may create local "hard points" in the masonry assembly that could have an adverse effect as the masonry responds to environmental factors.
- Grout-filled sock anchors are proprietary products that may have additional requirements by the manufacturers.
- Pinning may be combined with grouting to eliminate the need for shoring and bracing during the grouting process.

Reconstruction—Disassembly and reconstruction of a wall can be for the full height and depth of the wall or it can be local for a portion of the wall thickness or wall height. Reconstruction could include local removals to allow installation of through stones. Structurally it is important that the reconstructed assembly connect the leafs of masonry together. This can be accomplished by introducing new through stones or pins. It is important to consider the transition of the existing masonry to the new reconstructed masonry. Compatibility of all materials is crucial for structural performances of the wall.

Issues to consider when reconstructing masonry walls:

- Some of the existing masonry may need to be removed and replaced, not just re-set.
- Ties make the wall composite, but will introduce a new material into the wall.
- The masonry core may not be cohesive and local reconstruction may not be viable due to the potential for the core material to collapse.

1.4. Conclusion

Structural repairs to historic masonry walls may involve several of the repair methods noted. Example: pinning may be combined with grouting; deep repointing may be combined with pinning; the top of a wall may be reconstructed while the bottom is grouted. For any structural repair is it is important to understand the assembly, the source of the distress, and provide repair materials that are compatible with the original assembly.

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White Paper No. 6

Stone Masonry Preservation—Chemical

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ABSTRACT: Stone masonry begins to deteriorate when exposed to the weather and soiling, staining and graffiti vandalism detract from its appearance. Chemical cleaners that contain acids, alkalis, and organic solvents have been used to clean stone masonry and remove graffiti; water repellents and chemical consolidants are designed to protect stonework from future deterioration; and graffiti control treatments are used to facilitate the removal of graffiti. With a plethora of chemical treatments available, how do managers of historic sites such as the San Antonio Missions select treatments that will be effective without damaging stonework? Our discussion includes an overview of chemical treatments and a review of information that will help in planning conservation work on historic stone masonry.

KEYWORDS: Chemical Treatments, Cleaning, Consolidation, Graffiti Control

1.0 INTRODUCTION

Preservation professionals and site managers have a responsibility to preserve and maintain historic sites. As the structures on these sites weather, managers are faced with decisions about treating the soiling and staining that detract from their appearance and may be damaging to historic building materials. In addition, if deterioration of the materials is ongoing, managers sometimes have to decide whether a protective treatment is needed. These difficult decisions are complicated by the number of cleaning materials and protective treatments that are available. What information is needed before making treatment decisions? This paper discusses the types of chemical treatments that have been used to clean and protect historic structures and provides information to inform decisions about their use at the San Antonio Missions. A final section on best practices suggests guidelines for selecting appropriate chemical cleaning materials and protective treatments that will address soiling and deterioration without adversely affecting historic masonry.

2.0 CLEANING

2.1. Review of Methods

Cleaning is undertaken for a variety of reasons including removing dark-colored soiling and staining for aesthetic reasons. Although improving the appearance of historic structures is sometimes desirable, our focus in developing best practices for the San Antonio Missions is on cleaning to eliminate harmful substances such as pollutants, salts, and bird droppings. Regarding salts, it is important to remember that **efflorescent salts are symptoms of ongoing deterioration processes, and removing them from the surface of the stonework doesn't eliminate the problem.** In most cases, soluble salts are also present below the surface and cyclical wetting and drying creates crystallization pressures that can damage the stonework.

Cleaning is sometimes carried out to remove biological growth that masks underlying conditions or detracts from the appearance of historic masonry. Biofilms such as those that are seen on the stonework of San Antonio Missions are often complex microbial communities comprising algae, fungi, lichen, and other micro-organisms. There is an ongoing debate as to whether removing them is necessary or beneficial (Villa et al., 2016). In fact, many cleaning methods can increase porosity and surface area of stonework, encouraging the recurrence of the biofilm. **We recommend an in-depth investigation of the biofilms and whether they are damaging the stonework before removing them.**

There are several methods for cleaning stone substrates including water washing, mechanical and chemical cleaning, and there are pros and cons for each technique

(Mack and Grimmer, 2000). Water washing techniques include pressure rinsing, water soaking, and intermittent misting. Although water washing is thought to be the gentlest method, it is not effective in removing all types of soiling. Mechanical cleaning includes abrasive blasting with a variety of media such as fine sand, glass beads, baking soda, and micro-abrasive materials. If carefully controlled, this can be an efficient method for removing a buildup of surface soiling, but **mechanical cleaning requires an experienced technician and expensive equipment.** Also, both abrasive blasting and high-pressure rinsing can damage soft or fragile stone substrates. Our discussion considers chemical cleaning. This method is versatile but is not always effective and can create problems if an inappropriate material is selected.

2.2. Chemical Cleaning Treatments

Chemical cleaning compounds comprise a vast array of chemicals but the principal categories are acids, alkalis, organic solvents, and detergents. Acids that are commonly used include mineral acids such as hydrochloric and phosphoric, and organic acids such as acetic. Sodium, potassium, and ammonium hydroxides are commonly used in alkaline cleaners.

The pH scale, which ranges from 0–14, measures the acidity or alkalinity of these products. Acids have a low pH value and alkalis have a high value. Detergent cleaners contain surfactants and chelating agents and most are slightly alkaline. Chelating agents are chemical compounds that form bonds with metal ions and are effective in removing discolorations.

With chemical cleaning, the goal is to remove the surface soiling without damaging or adversely affecting the masonry substrate. In theory, the chemical cleaner reacts with the soiling, and rinsing removes the newly formed compounds from the surface. Damage may occur if the chemical cleaner also reacts with minerals in the stone. To decrease this risk, chemical cleaning products are used in dilute solutions or are buffered. Many historic structures, including the San Antonio Missions, are constructed of acid-sensitive materials such as limestone; because of this sensitivity, **acidic cleaning products are generally not recommended.**

There are also risks with alkaline cleaning products. With highly alkaline products, cleaning involves a two-step process—following application and rinsing of the alkaline cleaner, the surface must be neutralized with a dilute acidic solution to ensure that soluble salts are eliminated. For the limestone of the missions, there also is a risk that stains might be an unwanted result due to the reaction of the cleaning products with iron minerals that are present.

Solvent cleaners contain a wide variety of organic solvents and are useful in removing soiling that is not water-soluble. However, **determining which solvent or blend of solvents will be effective requires testing.** Although most organic solvents are safe to use on stone masonry surfaces, there are health and environmental concerns with many.

Detergent cleaners are effective in removing light to moderate soiling and those with near-neutral pH values (5.5 to 9.5) are generally safer for historic limestone and sandstone. In addition, detergent cleaners are less toxic to humans and to the environment.

Most commercially available products contain several chemical compounds, and manufacturers are required to provide Safety Data Sheets (SDS) with information about the product's composition and physical properties. The SDS also provides toxicological and ecological information and describes safe handling and storage of the product.

3.0 PROTECTIVE TREATMENTS

3.1. Overview

Chemical treatments are also used to arrest ongoing deterioration that has affected the integrity of historic stonework. Because water is a precursor to many deterioration processes, **water repellents** have been used to treat vulnerable stonework. However, these treatments **are generally not recommended for historic structures such as the missions** due to problems that have occurred with their use. Many restrict water vapor transmission through the treated surface, and some treatments result in an uneven appearance (Park, 1996). Our discussion of protective treatments for the missions focuses on chemical consolidants. These treatments are intended to strengthen friable stonework and protect it from future weathering. The goal is to replace the stone's binding materials or "cement" that has been lost to weathering; consolidation treatment may be appropriate if deterioration is severe.

3.2. Chemical Consolidation Treatments

Consolidation treatments containing organo-silicon compounds such as ethyl silicate and other alkoxysilanes (Doehne & Clifford, 2010) have been available in the U.S. since the mid-1980s.

These low viscosity treatments can penetrate into masonry pores and form chemical bonds if silicate minerals present. Alkoxysilanes are effective on most sandstones, but calcium carbonate minerals present in limestone are said to have an anti-catalytic effect, slowing the reaction and subsequent cure of alkoxysilane consolidants (Wheeler, 2005).

In recent years, alternative conservation treatments have been developed for limestone and other calcareous stones. One is a tartrate treatment that converts calcium carbonate to a more stable mineral and has been effective as a pre-treatment for alkoxysilane consolidants (Doehne & Clifford, 2010). Another is nano-lime, an improved version of lime-based consolidants (Otero et al., 2017). Both treatments are said to strengthen deteriorated limestone.

When considering chemical consolidants, it is important to understand the conditions that should not be treated. These include cracks, exfoliation, and surface crusts. Consolidation treatment is not recommended when soluble salts or other contaminants are present; accelerated deterioration can be an unintended result. Residues of previously applied treatments also present problems (Weiss, 1995).

In fact, reports of condition assessments suggest that water repellents and consolidation treatments were previously used to treat stonework of the missions (Dupont, Lombardi et al., 2019a), and a 2008 report documents tartrate pre-treatment of salt-contaminated limestone at Mission San José (Correia & Matero, 2008).

Some of these previous treatments may have damaged the stonework or accelerated its deterioration. In our view, **chemical consolidants should only be considered when deterioration of stonework is severe.** Before treating irreplaceable masonry of the San Antonio Missions with chemical consolidants, the results of laboratory testing should be carefully evaluated, and onsite testing of affected stonework should be monitored over an extended period of time.

4.0 GRAFFITI CONTROL

4.1. Introduction

Graffiti can negatively impact our appreciation of historic stonework, and recurring instances of graffiti sometimes encourages additional vandalism. Graffiti control products include materials to remove graffiti and treatments to protect vulnerable surfaces from graffiti vandalism. **Removing graffiti as soon as possible is recommended.** At historic sites such as the missions, graffiti removal is best accomplished by trained staff with a supply of materials and equipment stored onsite. Although mechanical removal and lasers have been used to remove certain types of graffiti, most historic sites do not have the equipment that is required for these methods. Our discussion focuses on chemical cleaners.

4.2. Graffiti Removal

Before selecting a graffiti removal product, it is important to identify the materials used to produce the graffiti. Spray paint is a common graffiti agent and its removal is often accomplished with organic solvents or alkaline cleaning products. With organic solvents, extended dwell periods improve results in removing tenacious graffiti. Poultices—which are made by combining the solvent with clay or another inert substance—provide extended contact time with the graffiti and facilitate removal of deep-seated graffiti (Weaver, 1995).

Although there are many commercially available graffiti removal products, no single product is effective on all types of graffiti. Avoid using the highly alkaline or acidic products that can result in adverse effects to historic masonry materials. Products that create health hazards or are harmful to the environment should also be avoided. As discussed above for chemical cleaning, Safety Data Sheets should be reviewed before graffiti removal is undertaken.

4.3. Graffiti Control Treatments

There are two types of graffiti control treatments: sacrificial graffiti control coatings that provide protection for only one graffiti episode and non-sacrificial coatings that are intended to provide long-lasting protection. Sacrificial coatings are generally composed of waxes or polysaccharide compounds. Following tagging, the graffiti and the sacrificial coating are removed with hot water pressure rinsing. Organic solvents or alkaline cleaners are sometimes required if residues or graffiti "shadows" remain. Following graffiti removal, the sacrificial graffiti control coating must be re-applied to the affected area.

Non-sacrificial graffiti control coatings contain a silicone elastomer, urethane or other polymeric resin, and most are solvent-borne. Non-sacrificial graffiti control coatings form films on the treated surface, often resulting in a glossy appearance or darkening. Manufacturers of commercially available graffiti control products generally recommend organic solvent or alkaline cleaners to remove graffiti from treated surfaces. Non-sacrificial graffiti control coatings are designed to protect treated surfaces for several graffiti episodes.

If graffiti is a persistent problem at the San Antonio Missions, application of a graffiti control treatment to vulnerable locations is recommended. **In the tests that we have conducted, polysaccharide sacrificial coatings have been effective.** It is worth restating that, with sacrificial coatings, graffiti removal is accomplished with hot water pressure rinsing which usually requires specialized equipment (Limbacher & Godfrey Architects, 2017).

5.0 BEST PRACTICES

How do we make decisions about the best materials and methods for maintaining and protecting historic stonework? Obviously, managers of historic sites need to select chemical treatments that will be effective in removing soiling and in providing protection again future deterioration without causing harm to the stone masonry. However, the wide variety of chemical cleaning products and protective treatments available can complicate decision making. Also, marketing claims about the product's superior performance can be confusing. Below is a discussion of issues to consider in developing a strategy for maintaining and protecting historic stonework.

5.1. Substrate Identification

A first step for managers of historic properties is obtaining information about the site's historic stone masonry. For some of the San Antonio Missions, Historic Structure Reports and other documents identify the masonry materials, including the quarries where they were obtained. If information is incomplete or unavailable, laboratory testing should be conducted to determine the stone's mineralogy and physical properties such as porosity. Regarding mineralogy, the clay minerals that are found in some building stones are sometimes problematic, particularly when the stonework is exposed to moisture. The cyclical wetting and drying of clay minerals and their associated swelling can result in deterioration. In addition to identifying possible sources of deterioration, laboratory test data help rule out adverse effects and determine effectiveness of the chemical treatment. For example, the limestones that were used to build the San Antonio Missions are sensitive to acids, are prone to iron staining from alkaline products and are not candidates for some consolidation treatments.

5.2. Existing Conditions

Documenting existing conditions is another essential step in the planning process, and existing reports of conditions may require updating. If masonry cleaning is considered, it is important to identify the nature and extent of soiling. With deterioration conditions, surface erosion, losses, cracks, and other weathering effects should be noted. Documenting soiling and deterioration conditions on elevation drawings will help determine patterns that can aid in identifying their sources. An illustrated report of existing conditions sets a baseline for future inspections (*Illustrated Glossary,* 2009).

5.3. Product Data

Information obtained from product manufacturers can assist in the selection of appropriate chemical treatments. As discussed above, the **Safety Data Sheets that are mandated by the Occupational and Safety Health Administration (OSHA) have valuable information** including product components, environmental and health hazards, storage, and disposal. Product data and technical data sheets have instructions for use and include the results of laboratory testing conducted by the manufacturer. **For many products, reference lists of projects with contact information for site managers are available upon request.**

5.4. Testing

Once a chemical cleaning product or conservation treatment has been selected, small scale on-site testing should be carried out to confirm its effectiveness and to monitor any adverse effects to the stone masonry. **Select a test area with representative conditions in an inconspicuous location.** Document the test with information about the application method, including dilution and dwell period. "Before" and "after" photographs are helpful in assessing effectiveness and adverse effects. On-site testing may also determine if the full-scale work can be accomplished with an in-house crew or is better carried out by a conservator or contractor.

6.0 NEXT STEPS

Managing historic structures is an important responsibility, and protecting stone masonry and other building materials from harmful soiling and future deterioration requires careful planning. We have outlined the types of chemical treatments designed to clean stone masonry, consolidate friable materials and control graffiti vandalism. However, **each historic site is unique with different issues to consider before treatments are undertaken.** When planning conservation work at the San Antonio Missions, it is important to research the history of each individual site, assess current conditions, and investigate the sources of deterioration before selecting chemical treatments for cleaning and protecting the stonework.

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White Paper No. 7

Considerations for Mortar Repair and Replacement at San Antonio Missions National Historical Park

By Rachel Adler

Vanishing Treasures Program, National Park Service

ABSTRACT: Mortar is an integral part of the masonry building system, providing support for individual masonry units as well as structural stability for the system as a whole. When dealing with historic buildings, it is of extreme importance that compatible mortar materials that are sensitive to historic fabric and appearance be developed and applied appropriately. This paper presents information that can guide informed management decisions regarding the repair and replacement of mortars at San Antonio Missions National Historical Park. It also explains the technical aspects of acceptable mortar materials and their use. Recommended actions include reviewing preservation guidance documents, thoroughly documenting both pre- and post-treatment conditions, analyzing and testing existing and proposed mortar formulations, and ensuring proper pointing techniques specific to the San Antonio Missions are implemented by trained professionals.

KEYWORDS: Mortar, Preservation, Repointing

1.0 INTRODUCTION

Mortar is by nature a sacrificial material, easier and less expensive to replace than more valuable system components such as stone. Inappropriate mortar materials are not only visually incompatible, but can be physically incompatible, causing irreparable damage to original materials.

The development of appropriate specifications for mortar and repointing at San Antonio Missions National Historical Park (SAAN) will necessarily **rely on the guidance of a subject matter expert.** However, a basic knowledge of the repointing process and the challenges it entails will allow park managers to ask appropriate questions and make informed decisions regarding the repair of SAAN's sensitive resources.

2.0 GUIDANCE DOCUMENTS

The following guidance documents should be referenced by park management when developing, soliciting or evaluating proposed methods and techniques for mortar replacement at SAAN.

2.1 *NPS-28: Cultural Resource Management Guideline*

NPS-28 provides guidance for cultural resources stewarded by the National Park Service (NPS). Chapter 8 provides recommendations that should be followed by SAAN management before undertaking mortar repair or replacement projects.

Relevant guidance includes ensuring research supports treatment interventions, requiring all contracted work be carried out by qualified individuals, and providing appropriate training for park personnel engaged in preservation activities *(NPS-28).*

2.2 *Secretary of the Interior's Standards for the Treatment of Historic Properties*

There are four standards of treatment of historic properties presented in this document: Preservation, Rehabilitation, Restoration, and Reconstruction. Projects involving mortar repair and replacement at SAAN should adhere to preservation treatment guidelines, which emphasize maintenance and repair to retain a structure's form and materials.[2]

The *Standards* recommend repointing mortar joints when necessary, removing deteriorated mortar without the use of power tools when possible, and duplicating historic mortars in terms of strength, composition, appearance and application (Grimmer, 2017).

2.3 *Preservation Brief 2: Repointing Mortar Joints in Historic Masonry Buildings*

This publication includes technical information about historic mortar analysis, formulation, mixing, and application. It provides guidance on selecting and working with masonry contractors, including minimum qualifications, suggested project specifications, and potential budget and schedule concerns.

3.0 RECOMMENDATIONS: APPROPRIATE MORTARS FOR San Antonio Missions NATIONAL HISTORICAL PARK

This section reviews general information for planning and implementing repointing projects. This information is not meant to provide a step-by-step guide to mortar development and application; rather, it should be used by park management to guide discussions and planning for repointing projects.

3.1 Sampling and Analysis

Sampling and analyzing historic mortar with the aim of understanding its composition and structure is an essential step in the repointing process. A well-planned sampling strategy can provide the desired information while causing as little damage as possible to historic fabric.

A sampling strategy should begin with a set of well-defined questions that analysis of the samples will answer (Henry and Stewart, 2011).

Sampling at SAAN in support of developing appropriate replacement mortars will be informed by the following questions:

- What areas of the building need repointing and how much area is to be covered?
- What is the cause of deterioration in the area to be repointed, and has that cause been addressed?
- What intact areas containing historic mortar best characterize the qualities of the desired replacement mortar?
- What types of analysis will be done on the collected samples?
- How will the park document and archive the samples and associated information?

Other questions may be appropriate as required by the project. **Park managers should work with a conservator to develop an appropriate sampling strategy.**

The types of analyses to pursue will also depend on pre-defined questions that resource managers should finalize before engaging a subject matter expert to perform testing (Schnabel, 2011). Because a suitable binder has already been specified for repointing work at SAAN (Myjer, 2015), testing should focus on the characterization of aggregate and structure. Some analyses that can yield this information are summarized in Table 4.1. A combination of analyses will give the most complete picture of a historic mortar's properties. However, **because petrographic and thin section analyses provide the most information from a single test, they are the recommended minimum procedures.**

Acid digestion of samples to isolate and identify aggregate can also provide useful information but should be used with caution in cases where aggregate may be acid soluble, as is the case at SAAN, where limestone sands were often used. **The utility of simple visual analysis with low-level magnification should not be discounted.** Because the testing process can be expensive, the park should prioritize the information it hopes to gain and limit the types of analyses it uses to focus on those goals (Davies, 2012). Sampling and analysis should be undertaken for each repointing project, and the **results of testing from one building or area should not necessarily inform work on another building or area.** It is likely that formulas for pointing mortar were different than formulas for bedding mortar, even within the same wall segment. Where possible, samples of both mortar types should be taken so that

[1] Page 28 of the *Secretary of the Interior's Standards* provides the most useful specific guidelines as they pertain to repointing work at SAAN.

Table 7.1: Mortar Analysis Suitability									
	General appearance	Aggregate colour	Aggregate shape	Aggregate grading range	Aggregate type/mineralogy	Binder type	Binder colour	Mix proportions	Presence of organic additive
Visual (low-level magnification/hand lens)	yes	yes	yes				yes		
Chemical disaggregation		yes	yes	yes		yes			
Sectioning/ petrographic analysis	yes	yes	yes	yes	yes	yes	yes	yes	
Scanning electron microscopy			yes	yes	yes	yes		yes	
X-ray microanalysis					yes	yes			
Thermal analysis					yes		yes		
Gas chromatography									yes

both types can be replicated where appropriate. Strategies for sampling can vary in scope depending on the size of the project, but should be developed with the guidance of a conservator, and if possible, a conservator should oversee the sampling work.

Knowledge from mortar analysis must be acquired prior to repointing work so that resulting information is available for specifying materials (Henry and Stewart, 2011). This work will include the analysis itself, as well as the interpretation of analysis results, which should be done by a preservation professional. With this expense in mind, projects submitted for funding through PMIS[3] should include a line item specifically for mortar sampling and analysis.

3.2 Mortar Development and Replication

Development of replacement mortar should be based on the results of testing and analysis as described above. **Mortar should be softer and should have higher water vapor permeability than surrounding masonry and historic mortar** (Mack and Speweik, 1998). When properly mixed and applied, mortar can last several decades; it is nonetheless a sacrificial material, meant to protect the masonry units it supports from deterioration.

In keeping with guidance developed by Myjer (2012 and 2015), **repair mortars used at SAAN should be a formulation of Natural Hydraulic Lime (NHL) and aggregate only**.[4] Only feebly hydraulic (NHL 2) or moderately hydraulic (NHL 3.5) lime should be used, with NHL 2 being an appropriate choice when adjacent mortar and masonry materials are very friable. NHL 3.5 may be used in areas that deteriorate more quickly due to exposure, such as wall copings or below-grade struc-

[3] The Project Management Information System (PMIS) is a budget formulation system used by the National Park System.

[4] NHL 2 has been previously recommended by Myjer as the binder most compatible with the soft stone that makes up most of the masonry construction at SAAN. NHL 3.5 may be used in areas subject to severe weathering and exposure.

tures.

Currently in the United States, NHL is more readily available and less expensive than other types of lime. Its strength and quality are carefully regulated, making it easier to work with consistently.

Because aggregate accounts for the bulk of mortar material, it influences both a mortar's visual appearance as well as its workability (Davies, 2012). **It is important that the selected aggregate match that of the historic material as closely as possible.** In cases where original mortar has failed due to poor materials, a more suitable aggregate should be found; while this aggregate may differ in physical characteristics, it should still visually match the historic as closely as possible. Most of the aggregate in a repair mortar will be sand, which should conform to ASTM C144 standards but may need to be modified to more closely match historic material (Mack and Speweik, 1998). If appropriate sand can be acquired locally, it is more likely to be visually compatible (Schnabel, 2008). **Managers may also choose to include in the aggregate an inert marker material, such as small glass beads or ceramic microspheres. Used in small amounts, these will have little effect on appearance and performance but will be identifiable if the replacement mortar is analyzed in the future.**

Although careful replication of existing mortars is ideal, it may in some cases be necessary to change the formulation of certain mortars, for example bedding or fill mortars, in service of creating a more stable wall. In such cases it is still imperative that replacement mortars be carefully developed and rigorously tested, especially when it comes to strength and water vapor permeability. Mortar appearance becomes less important when talking about materials that are not meant to be seen and do not affect the visual experience of a building, but should not be discounted completely.

It is likely that a single repointing project will require the development of multiple mortars. Sample coupons representing all possible mortar formulations should be produced and visually compared to historic material. These coupons can also be tested for hardness and strength to ensure they are physically compatible with stone. Any contract for masonry work should include the requirement that samples be produced and tested before new material is introduced to a wall. Upon project completion, the coupon of the mortar chosen for use should be accessioned to the park's collections, along with project documentation that includes the formulations of all other mortars not chosen. It is not necessary to retain the coupons of the unselected mortar formulations.

3.3 Application and Implementation

Proper application of mortar is as important to project success as correctly formulated mortar. **Lead masons should have at least five years of experience repointing historic buildings** (Mack and Speweik, 1998). Park staff who do not have equivalent experience should undergo both classroom and practical training in the proper use of lime mortars.

The scope of a repointing project should correctly identify the areas of a wall that are truly in need of repair. Joint erosion or loss may not require intervention if the mortar is still performing its primary task, which is to prevent water from entering a wall's interior (Henry and Stewart, 2011). Managers should work closely with an expert to develop project specifications, whether a contractor or park staff is doing the work.

Project plans should explicitly state the limits of what deteriorating mortar should be removed, as well as the shape and depth to which joints should be raked out in preparation for repointing (Henry and Stewart, 2011). Removal should be done with hand tools wherever possible; power tools should only be used as a last resort to avoid damaging masonry units (Mack and Speweik, 1998).

Managers should ensure that workers have the requisite experience to perform such work and are, at a minimum, familiar with and able to carry out the techniques described in *NPS Preservation Brief 2*. These competencies can be demonstrated through test panels completed by the workers. Panels should be 3' x 3' minimum in size (Mack and Speweik, 1998) and should include the full range of pointing situations the workers are likely to encounter during the project. Work should not proceed until panels meet expectations for acceptable work. Additionally, techniques and overall competency in removal of old mortar must be demonstrated and approved in advance. Irreparable damage can result from poor removal methods.

It is likely that, in the course of mortar repair and replacement, large voids will be discovered both at wall surfaces and within the walls behind masonry facing. In the case of voids at the wall surface, the same mortar mix used for repointing can be used to fill the void. Angular or sub-angular chinking stones should be pushed into the mortar towards the center of the void to control shrinkage and minimize cracking. Chinking stones should then be covered entirely by mortar so they are not visible when repointing is finished. For blind voids, a lime grout mixture can be developed and injected into the wall interior, filling the void and providing stabilization to loose inner material. Grout development and application should be performed by a qualified conservator, and sometimes a structural engineer as well.

Because the Mission buildings have undergone multiple repair campaigns and because the Spanish Colonial-era masonry was mostly covered by lime renders, it is difficult to understand the visual character of the historic mortar joints. They may have been flush with the masonry units or they may have been recessed. It is possible that the mortar in first-build construction of the 18th century was feathered over the stones in order to provide a stable surface on which to apply finishes.

They may have exhibited exposed chinking stones that would then have been hidden by those finishes. As a result of this uncertainty, in areas where the Spanish Colonial appearance is unknown, decisions made by management regarding mortar in the present must consider what will best preserve the masonry in its current condition. In areas where the historic appearance has been documented, pointing techniques should replicate it as closely as possible.

3.4 Documentation

Repointing projects should start with a review of existing documentation to reveal the chronology of mortars existing at a site, from Spanish Colonial-era materials through all later repair campaigns. A **pre-project condition assessment should be performed to collect photographs** and narrow the scope of the project. Photographic and written documentation in the form of **daily and weekly work reports must be a requirement of the project,** whether it is undertaken by park staff or a contractor. This will provide accountability and create a record of work for future researchers and stewards. Photographic documentation and **a final report describing the work done, as well as any unexpected issues and their resolutions, must also be a requirement** of any repointing project.

4.0 CONCLUSION

It is important to remember that **mortar is just one component of a masonry wall system. Decisions about mortar repair and replacement cannot be made in a vacuum,** but must take into account how they will affect neighboring masonry units, existing mortars and the structure as a whole. In most situations, the preservation of masonry units will be paramount and preservation of masonry materials will be secondary. However, a clear understanding of existing mortars will be a boon to any preservation project and will help guide the decision-making process.

The specifics of any repointing project will depend on the unique materials and conditions represented in the building to be repaired. As such, it is impossible to design a repointing protocol that will be appropriate for all situations. The general guidelines presented here can be used to point managers in the right direction when planning and evaluating proposed projects. They should encourage managers to develop a series of questions that must be answered if a project is to meet the standards required for preservation work performed on NPS buildings. A robust and carefully thought out process will ensure the goals of protecting sensitive SAAN resources are achieved.

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White Paper No. 8

Conservation of Historic Decorated Lime Plaster: Preventive and Remedial Treatments

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ABSTRACT: The San Antonio Missions are a World Heritage Site, in part, because of the authenticity of its buildings with an extraordinary amount of decorated lime plaster, which contribute to the historic and artistic significance of the Mission complex. The principal goal of architectural finishes conservation at the San Antonio Missions is to preserve, in situ, the surviving colonial-era lime plasters, protect them from further damage or loss, and safeguard their many values for specific cultural groups as well as the broader public. This white paper is intended to guide site stewards and park managers by: (1) providing a context for understanding the importance of lime plaster as a building material; (2) characterizing the architectural finishes of the missions, as well as common deterioration modes, and; (3) providing a methodological framework for planning plaster conservation, including preventive and remedial treatments.

KEYWORDS: Lime Plaster, Conservation, Wall Painting, Preventive, Remedial

1.0 INTRODUCTION

Angelyn first became involved with the San Antonio Missions in 1994, when she conserved some of the decorated interior plasters[5] at the convento at Mission San José (Bass, 1994). The convento is a ruin, and these plasters were limited to a few fragments that are protected by their location on the south elevation of the north wall. When we undertook the documentation of colonial stuccos on the exterior of the church at Mission Concepción nearly 20 years later (Conservation Associates, 2012),[6] we were surprised at the sizeable extent of the historic plasters. Colonial-era finishes survive on at least 60% of the surfaces that were originally plastered, and include incised designs and paintings (see Figure 8.1; Conservation Associates, 2012). The plasters at the San Antonio Missions, both decorated and plain, are character-defining features of the buildings, express the importance of these ecclesiastical spaces in 18th-century life, and are prone to loss as the result of age and weather exposure. The San Antonio Missions World Heritage Nomination highlights material authenticity as one of its key assets (National Park Service, 2014); the historic plasters surviving on the mission churches help to convey the age of the buildings and contribute to the historic and artistic significance of the group.

The principal goal of architectural finishes conservation at the San Antonio Missions is to preserve, in situ, the surviving colonial-era lime plasters and protect them from further damage or loss. Preservation methodology includes characterizing the building materials, identifying the causes and mechanisms of deterioration, and developing remedial and preventive treatments to inhibit further deterioration. This white paper will: (1) provide a context for understanding the importance of lime plaster as a building material; (2) characterize the historic architectural finishes of the missions, as well as common deterioration modes, and; (3) provide a methodological framework for planning their conservation. We will use the decorated exterior plasters at Mission Concepción as a point of departure to explore some of the issues that arise during assessment and treatment.

Decisions about what to preserve and how best to do

[5] Different terms/nomenclature are used for architectural finishes, including *plaster, stucco,* and *render.* All are composed of binders and aggregates, which are applied wet to a substrate, which then hardens by setting and curing. For this paper we will use the general term "plaster" to describe the colonial-era, lime-based finishes on building interiors and exteriors.

[6] The project was led by Ford, Powell & Carson: Carolyn Peterson, Principal in Charge, and Anna Nau, Project Manager

it are influenced by current use(s), the dynamic values attributed to the spaces, and the ways in which these values are understood by worshippers, local communities, park visitors, historians, and building stewards, to name a few. The conservation approach taken on the building exterior and some of the interior spaces that open to the exterior (such as the library) is similar to that on an archaeological site, with the goals of minimal intervention to preserve the physical integrity original materials and artwork so that the architecture communicates its age through its materiality and appearance.

Conserving historic decorated plasters is specialized work requiring experienced conservators. The craft skills one develops as a mason or a plasterer, for example, have little overlap with those needed to conserve historic plasters. In planning for conservation, treatment choices need to protect the building structure and preserve architectural finishes, as well as strike an aesthetic balance between renewed surfaces and the patina of the historic plaster. **Including an architectural conservator on the planning team** is one of the most effective ways to ensure that preservation plans properly reflect conservation goals at each stage of the project. In what follows, our goal is not to provide 'how-to' instructions for preserving historic plasters, so much as to impart useful information to resource managers looking to arrange for conservation services.

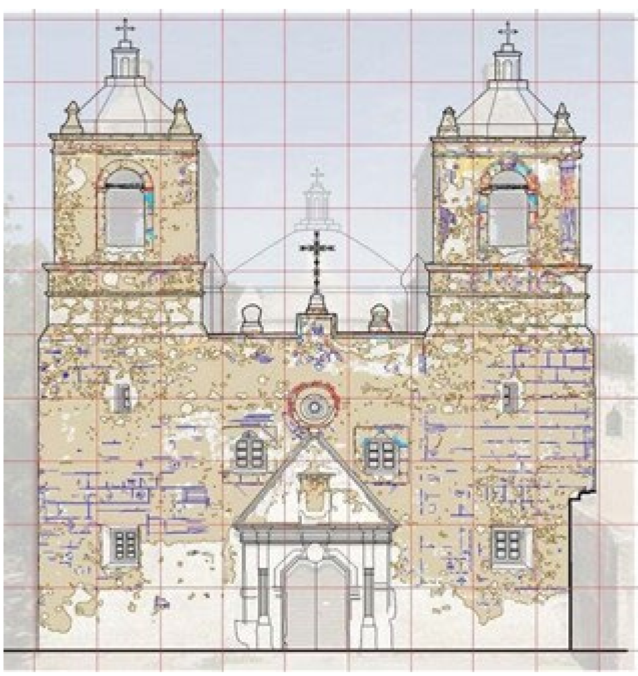

Figure 8.1: Of the five San Antonio Missions, Mission Concepción retains the most intact historic fabric. Colonial-era finishes survive on at least 60% of the surfaces that were originally plastered, much of it on the primary (west) façade, which was decorated over most of its surface. This façade retains numerous incised designs and traces of paint. The drawing, which is keyed to a HABS drawing, shows the location of the extant historic plaster and decorative elements (incising and painting) and quantifies the area of each. Approximately 1486 ft2 (138 m2) of historic plaster, with 86 ft2 (8 m2) of decorative painting, and 951 LF (290 m) of incising remain. This type of documentation provides a snapshot of the extent of the surviving plasters and decorative features, and is useful for monitoring and interpreting the site to visitors. (Conservation Associates, 2012)

2.0 LIME PLASTERS AT THE SAN ANTONIO MISSIONS

The San Antonio Mission churches, established in the 1730s, are constructed of limestone and/or tufa masonry, and were covered in lime plaster and decoratively

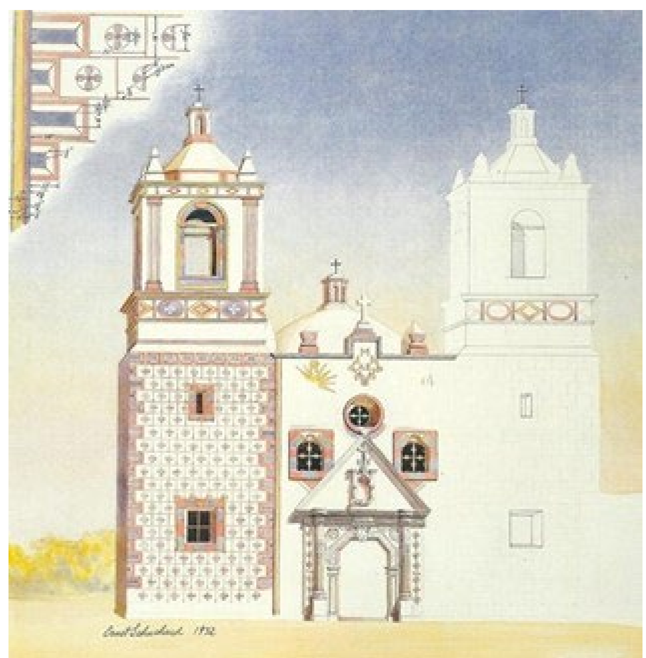

Figure 8.2: In the 1930s Ernst Schuchard made watercolor paintings and annotated black and white photographs documenting the incised patterns and paintings at Mission Concepción (pictured here) and San José. He attributes most of the decorative plaster to the ca. 1770s. Only fragments of the decorative scheme Schuchard documented in the 1920s–30s survive today. (Ernst F. Schuchard Papers, Collection 926, The Daughters of the Republic of Texas Library)

painted (see Figure 8.2). Colonial-era plasters are typically composed of lime and (mostly) carbonate aggregates in mixes that vary with position in the finishes stratigraphy. Extruded bedding mortars and base-coat plasters have gravel-sized aggregates, while finish layers have a larger proportion of lime combined with fine to medium sands (Conservation Associates, 2012). On the main block of the Concepción church, there appear to be three distinct exterior plaster layers: a base-coat and up to two finish layers over a bedding mortar extruded from the joints and struck off to level defects in the ashlar blocks. On the bell towers, there are typically two plaster layers consisting of a base-coat and a finish (see Figure 8.3).

The main block is divided into five wide, overlapping horizontal bands from the original application of the plaster in lifts related to scaffold positions. Mix proportions vary from lift to lift, which contribute to their differing states of preservation (see Figures 8.4 and 8.8). The interior plasters at the San José convento are similarly composed of lime and rounded calcareous aggregates, although in other mission churches of New Spain, it is not unusual to encounter interior plasters that make use of different binders (gypsum or clay, for example).

The primary façade, bell towers and dome drum at Concepción were finished with painted designs (see Figure 8.5). The artwork includes incised lines (as a preparatory drawing), and painting that was applied both as buon fresco and secco[7] (see Figure 8.6). The designs are a unique blend of formal and vernacular influences: ornamentation is representative of Renaissance and Baroque traditions interpreted by regional architects from the Franciscan missionary college of Querétaro, Mexico. European, Native, and Latin American builders and artisans constructed the buildings with materials and painted them with pigments and binders (see Figure 8.7) that were likely sourced locally.

Analysis of the paints at Concepción indicate they are essentially oil-based, with pigments that include red and yellow ochres, charcoal black, and calcium carbonate (Conservation Associates, 2012). Similar palettes appear at Espada and San José, and the San José church and

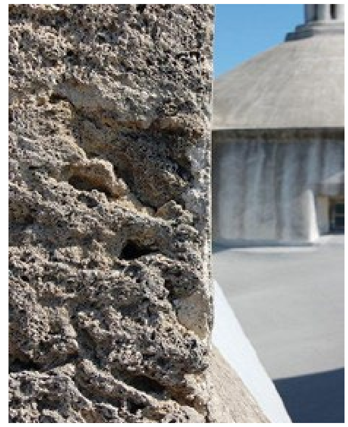

Figure 8.3: This loss at the southwest corner of the north tower reveals a plaster stratigraphy consisting of an extruded mortar that fills joints, a base-coat plaster that levels larger voids, covered with a thin finish coat forming a beautifully executed corner. On the bell towers, there are typically two distinct plaster layers; on the main block, there are two to three. (Conservation Associates, 2012)

Figure 8.4: Weathering of the plaster on the south facade of the south tower at Mission Concepción church is severe on north-facing exposures, less so on the south. The south façade plaster on the south tower, seen here, is approximately 77% intact, including several surviving fragments on the chamfered tower pedestal, while there are large losses in the same zone on the west façade. Note the large losses in the frieze, many of them located below gaps in the moldings and other horizontal elements, resulting in water infiltration, detachment and loss of the plaster, and concentrations of biological growth along these paths.

Originally, the west façade and bell towers above parapet level were completely plastered. The north, east, and south elevations of the church, along with the north and south towers below the chamfered pedestals, were left largely unfinished. On the south elevation of the south tower (photo right), the plaster return terminates in a neat line along the southwest corner and has the same lift boundaries as are visible on the west façade (left). There is also some 19th century graffiti in this area. (Conservation Associates, 2012).

[7] True fresco or buon fresco is a wall painting technique in which finely ground, alkaline-resistant pigments in water are applied to the wet plaster (intonaco). The pigment is absorbed by the lime, and through carbonation, the color is fixed in the lime substrate, making it quite durable. With fresco secco, pigments are mixed with an organic binder and/or lime to form a paint that is applied to a dry plaster.

convento feature geometric and floral designs, as well.

3.0 CONDITION ASSESSMENT

At Concepción, our primary goal in planning and implementing treatments was to preserve as much of the colonial building materials as possible, as well as the patinas that convey their age.[8] In all cases, **best practices for decision making, designing, and implementing preventive and remedial treatments should be based on a thorough understanding of the materials, causes and mechanisms of deterioration, and extent of the damage** (ICOMOS, 2003).[9] To identify the problems to be addressed and avoid unnecessary interventions, the assessment process should include: a) in situ inspections of the plaster and substrate, b) characterization studies and analyses of the plaster and paint materials and deterioration products, and c) documentation of the location and extent of the materials to be preserved, along with areas of deterioration.

3.1. Inspection

Typically, inspection should focus on substrate and plaster condition, the type(s), location, and condition of any decoration, deterioration conditions, how they vary with façade/exposure, the materials and quantities affected, and sampling (plasters, paints, and soluble salts) for characterization (see Figure 8.1). Inspection needs to include the means for accessing towers and upper stories, may require tools for measuring deviation from plumb, straight, and level, as well as some means of moisture measurement. Inspection results can be recorded in the field by annotating drawings, photographs, and LiDAR scan graphics.

3.2. Characterization and Analysis

Characterization studies provide information on plaster composition, mix proportions, physical and mechanical characteristics, and deterioration mechanisms. Testing is a function of the information needed by the investigator, and the number and size of the available samples. **For plasters, petrographic analysis of thin sections is often a useful place to start,** and will yield information on binder/aggregate proportion, particle size distribution, particle morphology, deterioration phenomena, and the conversion and mixing of plaster ingredients (e.g., unhydrated binder relicts, charcoal, unreacted pozzolanic amendments, etc.…). Additional instrumental analyses can include x-ray diffraction analysis (XRD) to identify crystalline binder/aggregate minerals and soluble salts; scanning electron microscopy with energy dispersive spectroscopy (SEM/EDS) to characterize microstructure and the elemental composition of crystalline and amorphous materials; Fourier-transform infrared (FTIR) spectroscopy for identifying organic and polymeric components; and wet chemical analyses.[10]

Using the inspection results and knowledge of the materials, the investigator relies on experience and measurement to arrive at an understanding of deterioration processes, based on the environmental and structural loads to which the materials are subjected. This typically includes a review of the preservation history of the building or site, alerting the investigator to deterioration history, previous interventions, and the introduction of substitute materials. Computer modeling can be useful for estimating the responses of specific materials and assemblies to changes in loading conditions (Woodham, 2020). Modeling results can be confirmed by field measurement, using datalogging instruments, several of which are described in Paper No. 1 in this volume by Donald W. Harvey, Jr., P.E.: Diagnostics and Monitoring—Structural.

3.3. Documentation

To understand damage distribution, rates of change, and the quantities affected and/or requiring treatment, investigators **conduct archival research to locate historic photographs and other relevant documents such as past archaeological and conservation**

[8] Conserving the historic plasters on the exterior of the Concepción church at Concepción requires renewing some of the plaster surfaces on tower domes, tops of parapet walls, window sills, and the tops of projecting moldings, as well as compensating plaster losses where the ingress of water continues to cause erosion. The aesthetic integration of these repairs requires some toning of the new work to blend it with the surrounding grey patina; however, it does not involve reinstatement of the original painted scheme by inpainting the historic plasters.

[9] The ICOMOS document also discusses the importance of weighing the management and use context of the site, and the values to be preserved.

[10] Acid digestion procedures for analyzing mortars are frequently used in the characterization of plasters, but these analyses are likely to have limited utility for lime plasters with calcareous aggregates and, depending on the specific tests, may require large samples.

Figure 8.5: There are two layers of decorated plaster at the oculus on the Mission Concepción church. Each layer has a slightly different decorative scheme in oil-based red, yellow, and blue/black paints. In this photo, tool marks are visible on the surface. The absence of a dirt layer and the unweathered condition of the lower paint layer suggests that it was not exposed for a long period of time before it was replastered.

Plaster deterioration conditions captured in this photo are typical of those found on the west façade: partial loss of finish layers, erosion of base-coat plaster, and exposure of tufa masonry units; separation of finish layers from each other and/or the substrate; friable base-coat plaster with large round caliche aggregate (just above the painted fragments); and biological growth on the surface. Previous repairs (center left and upper right) overlap the colonial plasters and have a noticeably different color and texture. (Conservation Associates, 2012)

Figure 8.6: Details of the incised and painted decorative elements on the Mission Concepción church. Incised lines served as a preparatory drawing of sorts, and paint was applied to the dry plaster (fresco secco). Analysis of paint samples taken from the primary façade and bell towers indicate the paints are essentially oil-based, and the pigments include red and yellow ochres, charcoal black, and calcium carbonate. The incised and painted diamonds and oval patterns in tower friezes (left) are still visible on the south façade of the south tower, although the paint has largely been lost. There is a similarly decorated band above the belfry windows and on the north interior wall of the convento at Mission San José. On the right is a detail of the incised and painted floral designs on the primary facade of Concepción. (Conservation Associates, 2012)

Figure 8.7: In a lithograph based on a c.1847 drawing by Edward Everett of Mission Concepción, there is painted decoration in both panels of the tower bases, the painted pilasters are visible on belfry façades, and the floral decoration of the central pedestal on the west façade can just be seen, though not in detail. Archival documents like this one are useful for determining the location and extent of decorative plaster, and evaluating change in condition and integrity over time. (Texas A&M University, Cushing Memorial Library, Edward Everett Collection)

On the right, many of the existing deterioration patterns are already apparent in this c.1890 image, including plaster losses along the tower chamfer and pedestals, extensive losses on the west façade near grade, the distinctive erosion patterns around the oculus and below the north tower window, and discoloration of the limestone portal to the bottom of the faceted door arch. Note the painted decoration below the central pedestal of the parapet wall and the missing north finial. (8B: NPS 7-81; Catholic Archives, Austin, TX)

treatment reports (see Figure 8.7). Also needed are means of documenting the location and distribution of the surviving plasters and surface features, and the type(s) and extent of deterioration. Methods we have used with good results include: high-resolution rectified photography, repeat photography, infrared thermography (IRT), and reflectance transformation imaging (RTI). Architectural drawings, high-resolution photographs, and images from LiDAR scans can serve as templates for mapping condition information. At Mission Concepción, a field team annotated high-resolution images, working in a grid of 4 square-meter units (see Figures 8.1, 8.8 and 8.9).

The photo templates were used to: a) delineate the location of colonial stucco, paint, and incising; b) record plaster deterioration conditions, and; c) highlight areas of urgently needed stucco conservation and masonry substrate repair for each elevation. The graphics produced by these means can also be used for conservation treatment documentation and monitoring change in condition over time (see Figures 8.1 and 8.9).

3.4. Plaster Deterioration

Plaster deterioration at Concepción is fairly typical of lime plaster on porous stone substrates, and is a function of:

- The physical properties of the plaster: for example, the uppermost lift on the west façade is the most leanly bound (has the lowest binder proportion) and is the most prone to erosion;
- Level(s) of weather exposure: south-facing façades are in the best condition, while north-facing façades are in the poorest[11], and east and west-facing façades display a gradient from good on the south to poor on the north. On the west façade, frequent dampness has resulted in disaggregation and loss of the plaster within 6–7 feet (1.8-2.1 meters) of grade (see Figures 8.7 and 8.8), and water infiltration, especially in areas just below roof surfaces, moldings, and window sills where gaps or losses channel water runoff, has resulted in significant loss of plasters and mortars;
- Substrate condition: including loss of bedding

[11] About 77% and 84% of the original plasters survive on the south façades of the south and north towers, respectively. By comparison, about 17% of the original plaster survives on the north façade of the north tower. Damage distribution is similar in the convento at San José (Conservation Associates, 2012).

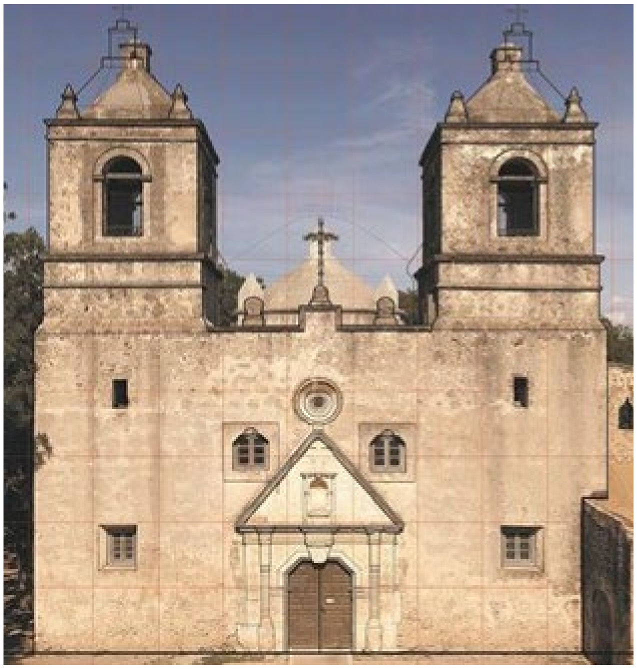

Figure 8.8: At Concepción, high-resolution digital images were taken to create baseline maps keyed to the survey forms. In order to maximize the surface information captured in the elevation photos, each elevation image was created by stitching several images (216 images were used for the front façade, for example) into a rectified, high-resolution gigapixel composite. To minimize distortion, the camera was mounted on a programmable robotic mount to capture each façade as a series of individual images (organized by column and row). A virtual grid was placed over the composite image to divide the space into regular units for documenting historic plaster, the decorative scheme (see Figure 1), and physical condition. Note deterioration is concentrated in a band about 2 meters high at the base of the wall, in a second horizontal band that includes the parapet wall (center) and tower bases, and generally below horizontal projections.

Also visible in this image are the plaster lifts that form horizontal bands across the elevation. The lifts are typically about 2 meters tall, and result from the application of the stucco in sections related to scaffold positions. The lift boundaries are visible where the lower edge of each layer is covered by the upper edge of the next as the crew moved down the building. Lifts 1 and 2 have different mix proportions, which may contribute to their differing physical properties and states of preservation. Lift 1 (top of the main block under the chamfer) has a lower binder / aggregate ratio than Lift 2, and has been more susceptible to the effects of weather. (Conservation Associates, 2012; photo by Neil Dixon) mortars, damage of masonry units, and deformations in parapets, cornice and other projecting moldings, especially in the towers,

- Which results in undercutting, loss, and fragmentation of the finishes, and;
- Structural movement: including foundation settlement, displacements in vaults and domes, and out-of-plumb/level conditions resulting in cracks in and buckling/deformation of the plasters on both the building interior and exterior.

General historic plaster deterioration conditions at the mission churches include separation of the plaster from the substrate, delamination between plaster layers, erosion and disaggregation of weather-exposed base-coat plasters, plaster loss and fragmentation, undercutting of edges bordering losses, and paint flaking, fading and loss (see Figures 8.5, 8.6, 8.10 and 8.11). As a result, exposed surfaces on a typical façade might include the tufa substrate, eroded bedding mortars and, base-coat and finish plasters, and finish plasters (some of which retain incised and painted designs). Learning to distinguish between these through dark surface patinas requires practice.

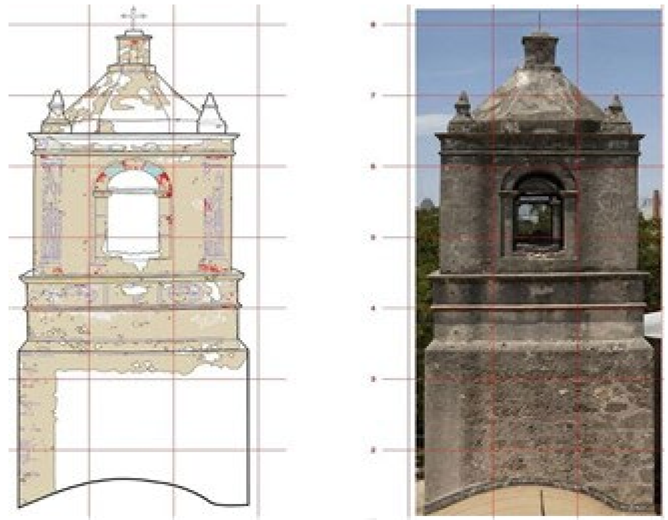

Figure 8.9: On the right is a high-resolution photograph of the south elevation of the south tower; on the left, an AutoCAD rendering of the incised and painted designs extant in 2012. Both images have a virtual grid of 4 square-meter units to assist in locating and recording the features and deterioration conditions. The oval and diamond frieze decorations on this façade are more complete than anywhere else on the building (see also Figures 8.6 & 8.7). Column flutes painted red, with blue and red capitals, flank the belfry arch with its incised and painted voussoirs. (Conservation Associates, 2012; photo by Neil Dixon)

4.0 TREATMENT PLANNING AND IMPLEMENTATION

Plaster conservation generally falls into two treatment categories: preventive,[12] which are indirect measures to manage the deterioration risks and inhibit further loss, and; remedial, where direct interventions are carried out to stabilize the plasters and repair some of the damage that has occurred. **In most cases, priority should be given to preventive treatments.** Examples of these are renewing water repellent surfaces on domes, vaults, and the tops of parapets and moldings to prevent the ingress of water, monitoring/modifying drainage at roof and ground levels, trimming encroaching vegetation, managing visitation, and controlling interior environments through passive measures (like closing doors during weather events). Where passive or preventive measures alone are insufficient, remedial treatment of the plaster should be considered. Until fairly recently, preserving decorated architectural finishes on archaeological sites routinely involved removing them from their context to a protected interior environment, such as a museum. Today, **international charters and standards for professional practice emphasize in situ conservation and minimal intervention.**[13]

They focus on preserving the integrity of the decorative scheme, and retaining the values inherent in the physical fabric. When assessing treatment options, conservation materials and treatments should:

- Have long-term stability, and be physically and visu-

[12] In 2008, ICOM-CC developed terminology to characterize the conservation of tangible cultural heritage, which includes definitions of 'preventive' and 'remedial' treatments. http://www.icom-cc.org/242/about/terminology-for-conservation/#.YJALQy2cau5

[13] Minimal intervention is not to be confused with 'not doing much'; instead, it is conservation principle that involves restricting repairs or treatments only where they are needed, using the least invasive materials and methods possible (such as preventive treatments), and maximizing preservation of the physical materials and their varied uses and values. Article 3 of the Burra Charter (revised 1999), calls for a cautious approach, stating that "conservation is based on a respect for the existing fabric, use, associations and meanings. It requires a cautious approach of changing as much as necessary but as little as possible."

Figure 8.10: Before (left) and after emergency stabilization (reattachment by grouting and edging of the fragment) of the south tower belfry arch, west elevation. The plaster was buckling and detached, with a void over 25 centimeters deep. The fragment was secured in place by injection grouting; the applied edging mortar supports the edges of the fragment and was toned to blend with the patina of the existing plaster. In a later phase of treatment, a compensating plaster will be applied over the exposed masonry. (Conservation Associates, 2012)

ally compatible with the original materials;

- Not adversely affect the original materials or prevent future treatment;
- Not change the character and/or appearance of the original decoration, and in most cases, should respect its age value;[14]
- Address the causes of detrimental change;
- Be selected/formulated based on desired long- and short-term performance and working properties (Getty Conservation Institute, 2010);
- Make use of traditional materials where compatible with the plaster and substrate;
- Incorporate new materials cautiously after obtaining positive results in laboratory and field tests.

Remedial treatments should be considered where there is imminent danger of loss, and when thorough assessment and analysis have led to the development of a **minimally invasive** treatment strategy that focuses repairs only where they are needed.

The conservator developing and applying treatments should possess a level of architectural knowledge that is typically acquired from a combination of formal education and practical experience,[15] as well as advanced craft skills appropriate to the treatment materials and techniques. This should include a working understanding of the physical/mechanical properties of the building materials and artwork, and of the physical and aesthetic impacts of their treatment on the resource and its many dynamic values.

At Concepción, remedial conservation treatments on both interior and exterior decorated surfaces have included a) reattaching delaminating plasters by injection grouting, b) edging fragile plasters bordering losses and filling losses with compensating plaster, c) cleaning and protecting decorated surfaces, and d) consolidating disaggregating plasters and substrates exposed to weather or damage by soluble salts.

4.1. Injection Grouting for Plaster Reattachment and Stabilization

At Missions Concepción and San José, grouts formulated from hydraulic lime and ceramic microspheres have been successfully used to stabilize loose historic lime finishes.

[14] Age value is not limited to the age of a place, but also includes surface patina and other evidence of use acquired over the course of its existence (Lamprakos, 2014)

[15] An example of the essential competencies required for architectural conservators hired by the US Department of the Interior, National Park Service can be found at https://www.nps.gov/training/npsonly/RSC/archcons.htm.

Grouting involves injecting a fluid mortar[16] into voids to re-establish adhesion between detached plaster and the substrate, or between delaminated layers. At both sites, groutable voids were found in deep cracks, large deformations, and along fragment edges[17] (See Figure 8.10) (Conservation Associates, 2013; Biçer-Şimşir, 2013; Matero and Bass, 1995).

4.2. Edging and Loss Compensation

Historic plasters typically survive in fragmentary form, especially in areas of high exposure to prevailing weather. The goals in edging and selective loss compensation are to support the fragile edges of surviving fragments, fill voids to reduce erosion and loss of the masonry substrate, and in some cases, to improve the legibility of the element geometry.[18] The mortars/plasters that were developed for filling losses at the San Antonio Missions are typically formulated from natural hydraulic or hydrated limes; binder selection depends on the depth of the loss, and the strength and durability required of the repair.[19] **Repair mixes should be physically, chemically, and aesthetically compatible with the historic plasters; have low shrinkage and moderate strength; contribute negligibly to the soluble salts in the system; and be durable enough to withstand the weather but relatively easy to remove if the need arises.**

Portland cement binders are not recommended because of their excessive hardness, low plasticity, reduced water vapor transmission rate, and the salts they convey to the surrounding building materials. Aggregates for repair mortars at Concepción and San José include oolitic sands and gravels sieved from caliche beds (the rounded aggregates are key to achieving compatible color and texture), and crushed and sieved limestone fines. We also add a small proportion of ceramic microspheres as a marker so that on close examination the fills can be differentiated from the original materials.

4.3. Surface Cleaning

Surface cleaning, especially of decorated plasters, is a complex process involving multiple variables and, if not well researched and tested, can result in unintended consequences. The rationale for cleaning needs to be carefully considered, along with the likely outcomes, including aesthetic impacts and the requirements for maintaining the 'cleaned' surface. In general, **we do not recommend that historic plastered surfaces be cleaned unless there are compelling reasons to do so (preparing surfaces for consolidant treatments, for example).**

The decision whether to clean (and how much) should be made by a management team that has considered whether the plasters and paints are capable of withstanding mechanical or chemical cleaning;[20] the current use and importance of the site (what are the operative values? is there a patina that needs to be preserved?); the management context (can the cleaned surface be maintained? how frequently?); and the time frame (some cleaners and biocides require months to process).

At Concepción, we conducted a pilot cleaning treatment of surface biota on a tower facade in 2013 (Conservation Associates, 2013).

Areas that were dry- and/or wet-cleaned partially recovered the patina they had prior to treatment after a period of approximately five years, indicating that without regular maintenance (maintenance intervals will vary and need to be determined on a case-by-case basis), **cleaned surfaces will be re-colonized by lichens and other surface biota in relatively short peri-**

[16] At Missions Concepción and San José, grouts formulated from hydraulic lime and ceramic microspheres have been successfully used to reattach delaminating plasters.

[17] Not all voids require grouting; most plasters are capable of bridging small voids with little risk of collapse. Grouting blind voids (voids concealed behind an intact surface that are detectible by percussive testing or IRT, for example) frequently requires the creation of grout ports, a destructive process. Opening grout ports on numerous small voids is likely to result in surface damage that outweighs any benefit resulting from the treatment.

[18] Careful toning of the fills can result in a repair that blends in with the surrounding patinated historic surfaces, but inpainting or restoration of the historic painted plaster are not needed to improve the legibility of the painted designs at Concepción.

[19] The authors compare the performance characteristics of compensating plasters prepared with hydraulic and hydrated limes in Woodham, 2020.

[20] The tools for dry cleaning used should be selected according to the resistance of the original plaster and paint, taking care not to abrade or alter the surface, which often is more delicate than the soiling material(s) to be removed. Wet cleaning can involve the use of water-based solutions, organic solvents of varying polarity, and chelators for removal of metallic stains.

Figure 8.11: At left, loss compensation using a hydraulic lime-based repair mortar on the belfry arch, south tower, east elevation. The filled loss at the belfry window arch reestablishes the shape of that element; this fill is ready for toning. At right, the fill was toned while still wet to match the color of the surrounding plaster. As part of this pilot treatment, a portion of the historic plaster was cleaned; over a period of five years or so, cleaned surfaces were re-colonized by surface biota (Conservation Associates, 2013)

ods of time (see Figure 8.11).[21]

4.4. Consolidation

Many of the architectural finishes at San Antonio Missions, decorated and plain, are disaggregated and friable, and susceptible to erosion. Consolidation in this context is the addition of a binder to improve cohesion of loose or friable material.[22] The effectiveness of the consolidation depends on a number of factors including the nature and condition of the substrate, the properties of the consolidant and its compatibility with the substrate, the size of the area to be consolidated, and the application methods and environmental conditions during treatment (Otero, 2018).

Recently, the use of nanolimes (dispersions of nanoscale particles of hydrated lime in alcohol) in the consolidation of lime plasters and limestone has become fairly common (see Paper No. 6 in this volume by Frances Gale: Stone Masonry Preservation 1—Chemical). The goal of nanolime consolidation is precipitation of Ca(OH)2 in the near-surface pore space of the substrate, and the subsequent carbonation of the precipitate to form calcite, resulting in improvements in the mechanical strength and imbibition properties of the substrate. The successful use of nanolime to consolidate calcareous surfaces by the author,[23] and reported in recent conservation literature (Ziegenbalg, 2018; Baglioni, 2013), make it a promising candidate for use on undecorated lime plasters at San Antonio Missions.

5.0 CONCLUSIONS

The conservation of wall paintings and decorated plasters is a specialized area of heritage conservation. Since this work requires specific knowledge and skills, and extensive field experience, conservators and restorers should be professionally trained. This document does not provide detailed instruction about how to conduct the conservation work, but instead, guidance to help managers in Cultural Resources and Facilities Maintenance make responsible decisions in securing the services of architectural and wall paintings conservators. Careful documentation and characterization of historic plasters provides the data necessary to quantify the surviving plaster, characterize the materials, identify deterioration conditions, plan for their conservation, estimate project costs, and interpret conservation projects to the public.

[21] We should note that plasters cleaned in the convento at San José in 1994 were treated with a silane-based water repellent, and have been slow to recover the patina they had prior to cleaning. There was an opportunity to inspect sandstone test panels in areas of high exposure that were cleared of surface biota and treated with a water repellent. After 20 years, they are still relatively free of lichen growth, while neighboring areas have been recolonized (Bass, 1994; Bass, 2019).

[22] Another type of consolidation is the addition of a protective coating over the historic plaster as a finish, such as a limewash, that partially soaks into the underlying plaster and creates a breathable film on the surface that confines and shelters the lime plasters below. This type of consolidation is not reversible (it is retreatable, however) and significantly alters the appearance of historic walls.

[23] Bass used nanolime treatments to consolidate painted lime plaster fragments from San Bartolo, a Maya site, dating from 600–100 BCE, in Guatemala. Although we found the consolidation effect to be successful in a treatment testing program, it did leave a white haze on the surface, which prevented its use on painted and decorated surfaces.

Analysis and measurement allow for the pinpointing of problems to be addressed and a way to dial-in repairs to meet those needs, avoiding unnecessary interventions and their impacts on resource integrity and authenticity. **Conservation of historic plasters must be holistically coordinated with all building conservation needs plus the structural stabilization and repair of the masonry substrate,** and should include provisions for the aesthetic integration of the repairs. Repair materials must be physically and visually/aesthetically compatible with the historic plasters and substrate(s), and traditional materials that approximate the appearance and performance characteristics of the original materials are quite often the best choice.

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White Paper No. 9

Understanding Risks and Disaster Planning Processes for the San Antonio Area Missions

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ABSTRACT: This paper overviews best practices in hazard planning, with particular attention to the intersection of hazard planning and historic preservation. The paper underscores the importance of a planning process that is participatory with robust stakeholder and public engagement. It reviews current and future hazard risks and the development of site-specific risk assessments. Using the four phase emergency management cycle as a guide, the paper then reviews aspects of mitigation, preparedness, response, and recovery planning with greater emphasis on mitigation and recovery as long-term strategies to risk reduction and site restoration. Robust hazard planning for historic site preservation includes both site specific planning and the incorporation of historic preservation as both a goal and driver of broader community resilience. The paper concludes with additional resources for learning and training about hazard planning processes for historic site staff, volunteers, and community leaders.

KEYWORDS: Risk Assessment; All Hazards Planning; Disaster Recovery; Hazard Mitigation; Historic Sites

1.0 INTRODUCTION

The historic preservation and hazard mitigation fields have only recently intersected—even though integration provides benefits to both fields. An assessment of historic preservation plans and emergency management plans found that **the state historic protection plan for Texas made no mention of disaster or emergency planning. And conversely, the state's Hazard Mitigation Plan (HMP) did not discuss historic preservation** in the strategy nor include a historic preservation representative on the planning team (Appler and Rumbach, 2016). Texas, the state with the most federal disaster declarations, is not alone here; many states have yet to integrate these two fields. Integration of historic preservation and hazard planning can foster greater resilience of historic structures and the communities in which they exist. Protecting the San Antonio area's Missions in a changing environment offers both potential to protect the physical historical structures, and promote resilience in San Antonio and Texas by fostering shared community identity, providing meaning and memory for local residents, and contributing economic value through tourism, additional development, redevelopment, and private and public investment (Appler and Rumbach 2016).

This paper takes this "whole community" approach to hazard planning for the Missions that aims to protect the physical historic structures and improve resilience of their broader communities (FEMA, 2011). The Federal Emergency Management Agency encourages all aspects of a community—from businesses to individuals, nonprofits to religious institutions, government to civil society—to work together towards disaster resilience. Historical resources are a part of this whole community. Many authors in this overarching project will provide specifics on protecting the unique physical structures of the Missions. This paper then aims to provide overarching discussion about hazard planning processes, especially the social aspects of planning, to promote successful adaptation of the Missions for rising environmental, human-caused, and technological threats.

2.0 HAZARD PLANNING FOR HISTORIC PROPERTIES: A TEAM CHALLENGE

Hazard planning teams with whole community participation are central to the development and implementation of interagency emergency management plans that guide the roles, responsibilities, and community activities to address hazard needs. The central plans that guide local, county, Council of Governments (COGs), Regional Advisory Councils (RACs), and state emergency management include emergency operations plans (EOP) and hazard mitigation plans (HMP). EOPs describe "who will do what, as well as when, with what resources, and by what authority—before, during, and immediately after an emergency" (FEMA, 1996: Foreword). EOPs identify risk and potentially affected populations and property, as well as delineate the coordination of governmental and nongovernmental institutions and resources to carry out assigned tasks. HMPs also focus on coordination between various agencies and institutions but their emphasis is on outlining specific long-term strategies to reduce the identified hazard risk and promote resilience (FEMA, 2020). Additional but less common plans are pre-disaster recovery plans, which focus on coordination, resources, goals, and prioritized activities for restoration and redevelopment after a disaster (FEMA, 2017).

All hazard planning activities underscore the importance of pre-disaster organizational networks, coordination, and communication, which greatly improve disaster resilience (Kapucu, 2006). Bringing together diverse agencies, sectors, and constituents results in better hazard plans. Burby (2001), an expert in hazard mitigation planning, showed that **including public participation in hazard planning results in more efficient and effective (and accepted) plans than those conducted only by technical experts.** Masterson and colleagues (2014, pp. 34) outline six benefits of public participation and broad stakeholder engagement in resilience planning: 1) increasing public awareness of hazard risks and community processes; 2) accessing more and better data on risks and needs; 3) improving and expanding public understanding of risk reduction measures; 4) informing development and supporting implementation of mitigation or risk reduction strategies; 5) ensuring that hazard plans coordinate with other community plans and goals (such as historic preservation or economic development plans); and 6) increasing the people available to be leveraged as volunteers or resilience champions pre- and post-disaster. Gibson and colleagues (2019) further argue that participatory planning is especially critical for historic preservation hazard planning, and argue for broadening participation for inclusive practices that support diverse engagement. Greater participation also increases public support for their preservation goals and fosters greater support for historic preservation in general (FEMA, 2005). Participatory mapping has been used in Austin, Texas, as an example, to support historic preservation goals and provides a tool for engaging broader members of the public in preservation and hazard planning (Minner et al., 2016; Meyer et al., 2018; Van Zandt et al., 2020).

To achieve broad participation and thus better hazard planning, historic site leadership should implement two organizational networking activities: 1) become more engaged in local community hazard planning and 2) engage a broad constituency in their own planning process. First, historic sites join local city and county emergency management planning teams to ensure that their special needs are included. Without this engagement, these plans' goals may directly conflict with historic preservation goals. Engaging with emergency management as a member of a diverse cross-sector planning team improves plan integration across economic development, cultural preservation, and hazard mitigation (Berke et al., 2019). **The Missions, as central to the state's history, should also engage with the Texas Division of Emergency Management (TDEM), particularly the Mitigation Division and TDEM regional division 18 that covers the area.**

Second, historic sites should build a broad team of both technical experts and interested stakeholders to undertake site-specific emergency planning (FEMA, 2005; Masterson et al., 2014). Begin by identifying constituents at local, regional, state, and federal levels of historic preservation and emergency management, such as the state historic preservation office and local historical societies. Then incorporate Mission stakeholders including local businesses, local schools, local elected officials, local nonprofits, and members of the general public. Florida historic preservation stakeholders suggest formulating a large hazard response network of experts and volunteers who can support all mitigation, preparedness, response and recovery activities (NA, 2003). Their guidance includes whom to include, how to structure teams, and how to activate teams and support teams during their efforts.

3.0 WHAT IS A RISK ASSESSMENT?

Risk assessment is the first step that this broad planning team should undertake and it provides the fact basis of every good plan (Masteron et al., 2014). Risk assessments describe all the potential hazards (even rare, but damaging events) and the potential impacts of these events.

Bexar County is prone to (in order of frequency): drought, wildfires, riverine flooding and flash flooding, extreme wind events (including tornadoes), combined wind and flooding such as inland remnants of coastal storms (e.g., Erin in 2007), dam failures, hazardous substance spill/release, winter storms, energy/fuel shortages, water system failures, civil unrest, and terrorism (BCOEM, 2009; San Antonio Office of Emergency Management, 2014; Frasier & Landin, 2020). The most common disasters for the area (drought, riverine flooding, and flash flooding) are only expected to worsen with climate change.

Historic properties also have a unique risk of possible damage by emergency response activities, such as construction of temporary shelters or large construction equipment that may drive over or near sites. These concerns are the focus of Section 106 of the National Historic Preservation Act (NHPA) (ACHP, 2020). Federal agencies must consider potential impacts of response activities occurring within 30 days of a declared disaster on historic properties. **Consideration of historic preservation can be waived for life saving activities such as moving debris to rescue trapped people**, restoring a bridge that is an evacuation route or stopping an ongoing fire.

Risk assessments should also include an assessment of future environmental changes. Future impacts of climate change are accellerating and worsening current risks and also adding additional risks.

Pest and fungal changes, for example, that may affect historic properties as temperatures and consequently biological species diversity change should be added as a future risk to historic properties. Historic groups in England provide an example of incorporating climate change impacts including flooding, erosion, and biological species diversity into preservation planning (Heathcote, Fluck, & Wiggins, 2017).

With this general list of hazards in the county, a next step is to conduct location-specific risk assessments to provide detailed mapping of the sites and their unique hazards. Creation and maintenance of GIS layers is recommended. A GIS database should include polygons of each building, historic structure, monuments, and parking lots, and lines or point locations of walking paths, trees, and any additional features. FEMA flood layers of the 1% and 0.2% annual floods should be included, and are available through local agencies (San Antonio River Authority, 2020). A 1% flood (also known as a 100-year flood) is the area that has a 1% chance of flooding each year. These area's mortgaged properties are required to have flood insurance. The 0.2% (or 500-year) floodplain has a 0.2% chance of flooding each year, and does not require flood insurance on mortgaged properties, though it is recommended. These floodplains are based on historic modeling and are not perfect. In fact, structures outside of these floodplains regularly flood, with a large minority **(up to 50% in some areas) of flood damages occurring outside the 1% floodplains** (NRC, 2014). The floodplains represent a snapshot in time and are updated irregularly, often less than each decade. Meanwhile development change along the watershed continually affects the floodplain. The current Bexar County floodplains were completed in 2018. Rumbach, Bierbrauer, and Follingstad (forthcoming) completed these site specific GIS flood analyses of historic sites in Colorado, finding that nearly 17% of historic sites and 74% of historic districts intersected with the floodplain and those communities with the largest share of historical properties at risk had yet to have a plan to protect them from flooding.

Adding elevation and land cover to the site-specific GIS database can support further assessment of future hazards. For example, predictions of future flooding with climate change were completed for neighborhoods in Houston (Newman et al., 2016; Newman et al., 2020). Every tree and its species and age could be mapped to identify potential risk during wind events. Volunteer GIS can support these efforts through available apps such as Esri ArcGIS Survey 123 or custom built apps by vendors, faculty, or students that allow for data collection with geospatial information (Meyer et al., 2018). New digital techniques that generate digital replicas of historic structures can also add to the inventory and support risk assessment modeling offering unique co-benefits to preservation and education activities (Fortenberry, 2019).

Once hazards are assessed, the potential impact should be estimated. Determining impact in conjunction with probability of occurrence aids in prioritizing mitigation activities. FEMA offers several resources that can begin this process, such as simple risk assessment tables targeted for organizations (FEMA, 2014). Impacts should be specific to each aspect of a building (e.g., roof, vegeta-

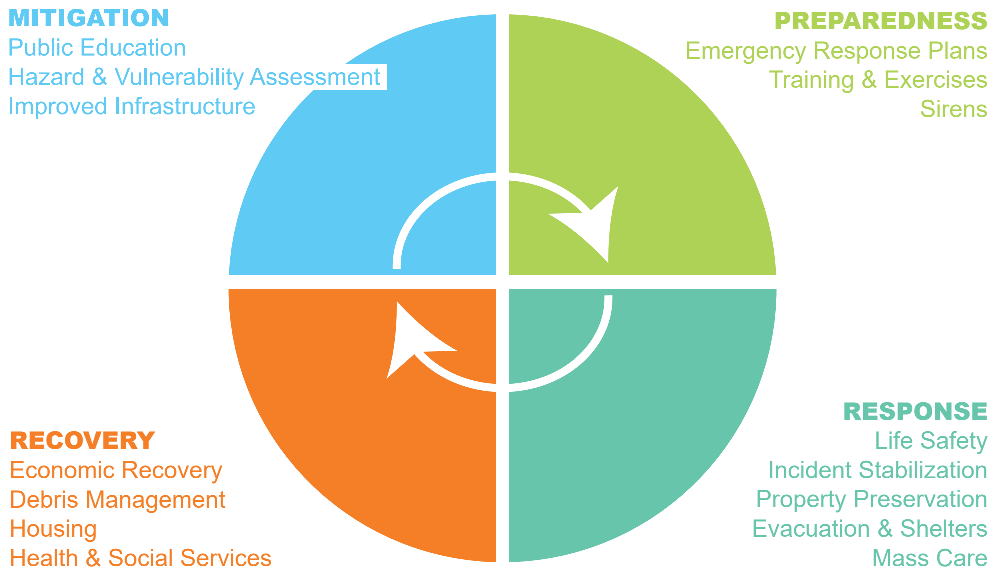

Figure 9.1: Emergency Management Phases and Common Needs (https://floodriskonthebend.com/flood-mitigation/)

tion, foundation, etc.) and also non-structural impacts including damage to artifacts, loss of employment and jobs, reduction in volunteer opportunities, and impacts on tourism and local economic revenue. For sudden-onset events, like tornadoes, the likelihood of injury or death to those at the site at the time of the event should also be estimated.

The final step is to rank hazards in terms of both the likelihood of the event and the potential impacts. This ranking will help when prioritizing mitigation actions, the first phase of emergency management planning.

4.0 ADDRESSING PRESERVATION OF THE SAN ANTONIO MISSIONS THROUGHOUT THE EMERGENCY MANAGEMENT CYCLE

Disaster management is commonly divided into four phases: mitigation, preparedness, response, and recovery. Mitigation and recovery are long-term phases requiring much time and funding to complete, whereas preparedness and response are short-term phases of intense immediate action to prevent or respond to an immediate hazard impact. Each phase may have its own plan, and all plan development draws together the same core planning team with additional team members who have expertise in each phase. Furthermore, each plan should **include public input.** All these plans are best made pre-disaster, when time can be dedicated to determine values and goals and garner input from stakeholders and the public.

4.1 Hazard Mitigation Considerations

Mitigation is defined as "a coordinated strategy of structural and non-structural activities and processes designed to reduce the damage to property, while minimizing the health and safety-related impacts associated with natural hazards and disasters" (Berke and Smith, 2009). The path from risk assessment to mitigation plan is:

Problem statements → Goals → Objectives → Actions.

FEMA (2005) recommends beginning with "problem statements" that succinctly describe each issue. For example "This Mission is prone to wildfires and lacks standard defensible space to reduce likelihood of fire damage." From this set of problem statements, goal statements are drafted that guide specific action. For example, "Support local Mission leadership to generate detailed site GIS maps and inventories of all assets" or "Minimize losses to Mission structures and economic viability due to riverine flooding." Each goal then is assigned objectives, and each objective is assigned actions that have associated budgets, timelines, and responsibilities. FEMA (2005) includes activities and worksheets for each of these.

Mitigation actions often fall into five different categories: prevention of the hazard impact (e.g., protection of wetlands to reduce flooding); **property and resource protection** (e.g., movement of historic assets to higher elevations to avoid flooding or upgrading sprinkler system in case of fire); **structural diversions** (e.g., floodwalls and levees); **public education and awareness**; and **natural resource protection.** Mitigation actions can offer co-benefits to other historic site goals. For example, nonstructural mitigation opportunities with landscape architecture can expand public use of open park space while also reducing flooding risk even in small areas (Newman et al., 2016). Low-risk actions to address both current and future climate change risks to historic structures include prioritizing needed maintenance, improving roof and ground drainage for extreme rainfall events, and expanding water harvesting and storage to address drought challenges (Heathcote, Fluck, & Wiggins, 2017).

With this list of all possible actions, stakeholder and public feedback should be used to help determine mitigation priorities. Community surveys, interviews, workshops, and other engagement activities can help assess how much the public and stakeholders know about hazard risks and the Missions. Prioritization—or a preservation hierarchy—of what to protect can result from simple ordering of questions such as: geographic context of significance (national, state, local); level of significance (low, medium high); public sentiment (low, medium, high); economic importance (low, medium, high); and degree of integrity (low, medium, high). Other ways to prioritize include cost-benefit analysis and review of social, technical, administrative, political, legal, economic, and environmental (STAPLEE) criteria (FEMA, 2005). Social assessment involves evaluation of public support for mitigation actions. Technical assessment includes feasibility and effectiveness of mitigative actions. Administrative refers to detailing staffing, funding, and maintenance needs for each mitigative action. Political assessment gauges the political will for historic preservation in general, and any particularly divisive historic places. Legal criteria assess who has the authority to order the mitigative action. Economic reviews cost and long-term financial contribution of mitigative actions for the site and community. Environmental involves assessment of the impact of mitigative actions on the natural environment and any required permitting and reviews.

The final and most important step of a mitigation plan is to assign responsible parties and funding sources for each prioritized action. Interagency agreements and reviews may be necessary, and should be assigned. Once completed, the mitigation plan should include a plan for review of progress and a plan update schedule (every 5–10 years) along with risk assessment and site analysis updates to incorporate new risks and reassess priorities.

4.2 Preparedness and Response Planning

The preparedness and response phases receive the most attention from the public and emergency management. Because of this, this white paper only quickly overviews these phases.

Preparedness and response planning focus on the immediate safety of life and property in the short-term period before and after a disaster. Preparedness activities are those that are short-term or temporary to reduce the impact of an immediate hazard. Sandbagging to prevent riverine flooding is an example. Response activities include life-saving activities such as rescue from collapsed buildings. EOPs address these needs for local communities, and Mission-related needs should be incorporated into these plans. **Historic preservation falls under Emergency Support Function (ESF) 11 (Agriculture and Natural Resources) and should be considered as part of ESF 14 (Long-term Recovery) of EOPs.**

Local emergency management is responsible for coordinating preparedness and response actions, thus planning and training exercises for the Missions should be undertaken with these agencies. Local emergency management can provide standard advice and feedback on training, plans, and activities. Section 106 of the NHPA is a unique aspect of historic preservation response planning, and the Missions should work conjointly with local, state, and federal agencies to ensure protection of historic resources from damage by response activities. As with all stages of hazard planning, the planning team should outline roles and responsibilities for each activity and develop a robust public engagement and communication plan.

4.3 Planning for Recovery

Disaster recovery is a long, challenging phase that holds the potential for social, physical, natural, and economic resilience or, conversely, distrust, frustration, and anger. Recovery is a time to institute resilience-building practices that also align with historic preservation. Recovery planning for historic sites includes addressing their physical regeneration and also how they fit into the broader community recovery.

The recovery is smoother with detailed pre-planning because quick, rash decisions post-disaster can have long-term, irreparable consequences. Pre-disaster recovery planning improves the efficiency of resource use and can speed the recovery process. This section overviews some aspects of pre-disaster recovery planning for both the Missions themselves and the local jurisdictions.

Historic sites are included as one of the eight core planning priorities for pre-disaster recovery planning under "natural and cultural resources" (FEMA, 2017). Best practices in recovery planning that apply when the Missions themselves are damaged include:

- Determining recovery leadership and roles and responsibilities of various staff and volunteers,
- Developing a communication and public engagement strategy,
- Outlining damage assessment protocols and debris and salvage procedures,
- Identifying potential funding sources,
- Brainstorming fundraising strategies,
- Identifying volunteer and professional needs,
- Identifying training programs for staff and volunteers,
- Outlining recovery goals specific to each site,
- Determining how to integrate mitigation into recovery goals,
- Ensuring recovery plan aligns with other site and community plans,
- Developing a monitoring strategy, and
- Undertaking pre-procurement of vendors or memorandums of agreement for pre-identified task support.

The pre-disaster recovery plan should prioritize recovery goals for the Missions along a continuum of what can be repaired to almost identical pre-event state to what aspects are irreplaceable. The recovery plan for aspects that cannot be repaired either due to cost or a lack of historical materials should identify what reproductions/substitutions are acceptable and what is best preserved in a post-disaster damaged state.

Those who have not undergone disaster recovery before underestimate the time, energy, and funding required for recovery (Meyer et al. 2019). Staff and volunteer burn-out is high. Further, **while the immediate post-disaster period floods a community with volunteers and in-kind, physical, and financial donations, these resources are quickly used and raising additional funding or volunteer interest is challenging.** Small organizations especially have challenges getting access to recovery resources (Watson, 2020).

Beyond physical site recovery, the recovery of the physical structures at the Missions should fit into the larger vision of community redevelopment and be incorporated into local recovery plans, if these exist. Mission recovery can even be a catalyst for the entire area if carefully aligned. For example, Montezuma, Georgia, and Cedar Rapids, Iowa, both made historical preservation central to the entire community's recovery plan and used grant funding to revitalize local development that refurbished and expanded the historical character in affected areas. Research on small business recovery has shown that small businesses are particularly vulnerable to closure post-disaster and that slow customer and employee return is more consequential for business closure post-disaster than structural damage (Watson, Thornton, & Xiao, 2019). Thus, Mission recovery and tourism return supports overall recovery for the area.

A pre-disaster recovery plan should outline timeframes for potential repairs, predict potential consequences, and include business continuity plans (DHS 2020). Economic consequences of short, medium, and long-term shut down of the Missions either partially or in entirety should be estimated.

If employees are also dealing with individual disaster losses, maintaining their employment is central to their own recovery but also they will be strained during the work day. **Service sector jobs, especially tourism-related, are those most often lost during disasters. Thus, slow recovery of the Missions can have cascading effects for household and community recovery.**

5.0 CONCLUSION

In conclusion, hazard planning for the Missions should be viewed as an opportunity to protect historic assets and also improve community resilience of San Antonio and the state. All hazards are local, calling on local leadership, stakeholders, and public to contribute with support from technical experts. Well-formulated hazard planning for the Missions will result in completion of Mission-specific plans, the inclusion of these historic sites into local, regional, and state plans, and a resulting organizational network that is more educated and prepared to improve the resilience and preservation of the Missions.

6.0 RESOURCES

The following resources offer more information for incorporating hazard planning into historical preservation.

Table 9.1: Hazard Planning Resources

Article/Site Name	Author(s)	Website
FEMA Office of Environmental Planning and Historic Preservation	FEMA	https://www.fema.gov/environmental-and-historic-preservation
Environmental and Historic Preservation Checklist	FEMA	https://www.fema.gov/media-library-data/1ea2c1025af0c4554ec4401503987cea/EHP_Checklist_508.pdf
Environmental Planning and Historic Preservation (EHP) Policy Guidance	FEMA	https://www.fema.gov/media-library-data/1533321728657-592e122ade85743d1760fd4747241776/GPD_EHP_Policy_Final_Amendment_GPD_final_508.pdf
Environmental and Historic Preservation (EHP)	FEMA	https://www.fema.gov/hmgp-appeal-keywords/9128
Unified Federal Environmental and Historic Preservation Review Guide	FEMA	https://www.fema.gov/media-library-data/1440713845421-9bdb5c0c8fe19ab86d97059ccb26e3b4/UFR_Applicant_Guide_Final_508.pdf
R6 Environmental and Historic Preservation (EHP)	FEMA	https://www.fema.gov/r6-environmental-and-historic-preservation
Integrating Historic Property and Cultural Resource Considerations Into Hazard Mitigation Planning State and Local Mitigation Planning How-To Guide	FEMA	https://www.fema.gov/pdf/fima/386-6_Book.pdf
Disaster Recovery Helping Historic Communities Recover from Climate- and Weather-related Disasters	National Trust for Historic Preservation	https://savingplaces.org/disaster-recovery#.XyCCQZ5Kg2w
Promoting Historic Preservation Across the Nation	Advisory Council on Historic Preservation	https://www.achp.gov/
National Archives	National Archives	https://www.archives.gov/
National Conference of State Historic Preservation Officers	NCHSHPO	https://ncshpo.org/
Tribal Historic Preservation Office	National Association of Tribal Historic Preservation	http://www.nathpo.org/

Article/Site Name	Author(s)	Website
National Park Service, Disaster Planning	National Park Service	http://www.nps.gov/stlpg
Foundation of the American Institute for Conservation	Heritage Emergency	http://www.heritageemergency.org/
Preservation Impacts and Disaster	National Center for Preservation Technology & Training	http://www.ncptt.nps.gov/
Disaster Preparing Your Historic Resources for Disaster	Historic Preservation	https://www.nps.gov/preservation-grants/downloads/DisasterChecklist2015.pdf
National Historic Landmarks Program	National Park Service	https://www.nps.gov/orgs/1582/index.htm
National Register of Historic Places	National Park Service	https://www.nps.gov/subjects/nationalregister/index.htm
State, Tribal, and Local Plans & Grants Division	National Park Service	http://www.nps.gov/orgs/1623/index.htm
Historic Preservation Easements	National Park Service	www.nps.gov/tps/tax-incentives/taxdocs/easements-historic-properties.pdf
ESHP Disaster Assistance Grants for Historic Resources	NC Department of Natural and Cultural Resources	https://www.ncdcr.gov/about/history/division-historical-resources/nc-state-historic-preservation-office/grants-historic-1
Disaster Planning for Florida's Historic Resources	1000 Friends of Florida	https://www.floridadisaster.org/globalassets/importedpdfs/disaster_planning_for_historic_resources.pdf

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White Paper No. 10

Construction Project Risk Management/Field Quality Control During Construction

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ABSTRACT: The long-term preservation of historic sites of every type is directly impacted by the quality of the maintenance and ongoing preservation work provided by construction trades. Development and utilization of formal, preservation specific, quality control policies and procedures can ensure that the project's required technical needs are matched with the staff assigned to plan and implement masonry conservation work. Success can be as simple as clearly communicating a project's historic preservation objectives to more complex challenges involving specific and specialized training, testing, and inspection procedures.

This paper presents strategies and best practices for risk management and field quality control of masonry preservation work at high-profile historic preservation sites like the San Antonio Missions National Historical Park, including those that remain open and operational during implementation. Understanding the risk potential of the work as related to the specific historic fabric, and how best to manage that risk from identification through trade implementation, will help achieve a long-term preservation solution for the historic site.

KEYWORDS: Construction, Risk Management, Quality Control, Masonry, Best Practices

1.0 INTRODUCTION

Irreplaceable historic fabric contained within the San Antonio Missions National Historical Park (SAAN) sites and structures is at one of the highest-level threats of damage or loss during the construction or preservation process.

Risk of loss or irreparable damage is higher during this phase of a project as intervention creates opportunity for improper repairs and mistakes or may open the project site to weather, vandalism, or impact from construction activities (including access plus multiple other threats) and must be actively and purposefully managed. A formal construction risk management plan is paramount to address these project issues.

Craft workers, through lack of understanding, experience, training, or improper implementation of details, can create either short-term quality failure or larger long-term negative impacts, sometimes non-reversible, to historic fabric. A formal construction quality control program and procedures should be developed and utilized throughout the project to ensure a positive outcome. Risks are heightened when the SAAN structures remain open to the public for tours and worship services as the line between construction and public access can become blurred. **Safety of the public within an ongoing construction site requires planning and active management to ensure operations, such as scaffold, do not become attractive hazards to the public of all ages.**

Risk management and quality control for SAAN must be developed with specific plans based upon best practices to achieve a desired positive long-term outcome for any of the varied construction project and include these steps:

- Define the task.
- Identify hazards.
- Assess hazards to determine risks.
- Develop controls and make risk decisions.
- Implement controls to manage the risk.
- Supervise and evaluate to manage the outcome.

2.0 GUIDANCE DOCUMENTS

The following guidance document should be referenced by park management when developing task or project specific risk management plans, including specific field quality control plans for preservation projects.

2.1 International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCOM) *A Guide to Risk Management of Cultural Heritage*

This comprehensive publication helps the preservation professional address and define the context, identify, analyze, evaluate, treat and monitor risk to culture assets. The Guide addresses many risk aspects that interrelate with potential construction operations.

https://www.iccrom.org/wp-content/uploads/Guide-to-Risk-Managment_English.pdf

3.0 CONSTRUCTION PHASE RISK MANAGEMENT

The goal of construction phase risk management is to identify potential problems before they occur and have a plan for addressing them in advance. Simple best practices of risk management allow for a sequential plan to be developed and put in place steps for project success.

First, define the task. Starting with the basics, what is the historic preservation task planned to be performed? Is this a small project to repair mortar erosion or rebuilding a section of wall? Is this the entire exterior masonry restoration of a larger portion of the building or the building itself? A clearly defined scope of planned work is critical to managing the work.

Next, identify real or potential hazards. It may help to develop two groups to assist in the identification process. First are those internal issues which include such items as the required bid process, potential qualified bidders, budget limitations, unique or specialized trade work, etc. Second are those external factors that may include items such as seasonal weather impact, operational status of the project (e.g. does it need to remain open for staff or public tours or worship?), site logistical limitations (getting on and off the jobsite), and similar factors. Developing this list is most effective in a group to include design team, facility operators, construction, and other stakeholders as each will likely see different potential hazards.

Then, determine the risks. Assess the identified project hazards to determine risks of each. Expand the list of hazards into a risk matrix as shown in Figure 10.1. Numerous publications and templates exist online to assist in developing a risk matrix.[1] It may be appropriate to show, in a graphical form with drawings or photographs, the area of the project impacted by the risk. Ultimately, this matrix will help you develop controls and make risk decisions. With the risks identified, one must determine how to manage these risk items with formal controls. Risk management can be effective if risk is recognized and steps taken to either eliminate, mitigate, transfer, or retain the risk. Who, how, and when is the best opportunity to control risk? Is there an option to eliminate the risk item? For example, suppose the weather conditions in which the masonry work will be performed are less than ideal. Is there the option of moving the schedule of the work to eliminate this risk? If the schedule cannot be changed, then by requiring a temporary enclosure, can we eliminate or at least minimize the risk?

As noted in Figure 10.1, the matrix should also be clear who is responsible to manage this risk issue and what is the potential impact to cost and schedule to the project to address the identified risk?

Certain historic preservation projects present some very unique risks with the potential for fire and structural conditions. Hidden conditions including unknown foundations or multiple prior-era structural modifications over time suggest more in-depth investigation to minimize or eliminate risks to associated work. This level of investigation, while commonly resisted as an expense early in the project planning, can be demonstrated to save a project considerable costs in project delay or design modification during the construction phase.

Implement the mitigation measures as the defined

[1] For example: Risk Register Templates: Asset and risk register template system for cybersecurity and information security management suitable for ISO 27001 and NIST (ESORMA Quick Start Guide) Paperback—January 6, 2021, by David White. The sample risk matrix in Figure 10.1 was generated from the website https://www.smartsheet.com/risk-register-templates

Risk Description	Impact Description	Impact Level	Probability Level	Priority Level	Mitigation Notes	Owner
Give a brief summary of the risk.	*What will happen if the risk is not mitigated or eliminated?*	*Rate 1 (LOW) to 5 (HIGH)*	*Rate 1 (LOW) to 5 (HIGH)*	*(IMPACT X PROBABILITY) Address the highest first.*	*What can be done to lower or eliminate the impact or probability?*	*Who's responsible?*
Seasonal wet/ rain period	Erosion of lime pointing mortar	5	5	25	Reschedule or provide adequate temporary protection.	Contractor
Dust from construction operations	Will impact worship services/ experience	2	5	10	Provide plastic protection to pews and additional cleaning in GC's.	Contractor or Owner
Continued public access during construction Phase 1	Potential safety and attractive nuisance interfacing with scaffold during construction	3	3	9	Develop hard line security barriers or small group guides.	Contractor or Owner
Impact to adjacent landscaping during construction	Not historic but will impact public perception of the project	2	2	4	Develop a logistics plan that keeps work clear of landscaping areas.	Contractor
Architect inspections during COVID	Ability to keep work moving in a sequential manner with limited site visits	3	4	12	Utilize iPad FaceTime app for scheduled and UNSCHEDULED meetings.	Architect

Probability						
	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
		Impact				

Figure 10.1: Sample risk matrix, adapted from table created from https://www.smartsheet.com/risk-register-templates

controls to manage the risk defined in the matrix. For example, consider utilizing specialty daily work activity permits to ensure knowledge of agreed work areas and conservation treatments.

Common in the industry for "hot work permits," activity-specific permits utilize a similar concept for planned work like mortar pointing or masonry cleaning activities to assure specific compliance with detailed specifications for the work at hand. This level of management, while it may be considered excessive for routine renovations on private property, can be appropriate for SAAN because it will help eliminate mistakes from workers assuming the same work as yesterday is to occur today or the arrival of new workers unfamiliar with the specific task at hand.

Other best practice tools used to help a project's success include a process to instill the risk plan to the individual workers. Consider a Historic Preservation Trades Orientation Program. This is a formal written program that helps educate the hands-on tradespeople regarding the historic importance and preservation sensitivity of the project. This personal approach to specific jobsite education can help develop an individual's understanding and proper implementation on the site.

Daily worker coordination "huddles" or safety meetings also can be used to address preservation activities before any daily trades work starts on the project. This allows workers to coordinate efforts in an area and deepens understanding of planned sequence and process of preservation.

Risk management is a continuous process. Success will not be achieved by simply putting a risk management plan in place during project planning, then not actively addressing the items on a daily basis. Risk must be actively managed.

If the project is of sufficient size and/or has sensitive historic fabric such as SAAN, then the assignment of a dedicated risk manager or quality control person should be included in the project risk plan.

This risk manager assignment may be combined with other duties of a project manager or site superintendent with the clear understanding of the role and responsibility. Most online or in-person training programs are not specific to historic preservation or the very specific unique project details potentially encountered at SAAN. Therefore, using a consultant or team member who can help establish this project-specific program may be beneficial.

3.0 HISTORIC PRESERVATION TRADES QUALITY CONTROL

The goal of a historic preservation trades quality control program is to ensure every time preservation trade work is performed, the same information, methods, skill, and controls are used and applied in a consistent manner. SAAN's historic preservation work is unique to construction, and therefore the quality control program must be specific and understandable for the trades implementing the work and the staff assigned to oversee its completion.

In industry, it is common to hear quality assurance and quality control utilized almost interchangeably. To be clear, quality assurance is process oriented and focused on defect prevention, while quality control is product-oriented and focused on defect identification. SAAN staff must look at both aspects of the quality program for overall Field Quality Control.

Field Quality Control starts before the tradesperson and tools hit the site.

First, hire competent people. Qualifications-Based Selection (QBS) is a must with procurement of historic preservation work. Require a submission with demonstrated past similar projects, named specific experienced trades workers assigned to lead and implement your project, a work plan that protects historic fabric and assures implementation of preservation practice, and a reasonable price.

Second, define the best process. Clearly defining the technical restoration or process in logical, detailed steps to achieve the best outcome is critical to achieving quality. Using past experience of practitioners in the field, detailed design phase investigation and pre-production mock-ups are all part of defining the best process.

This is like the road map to a destination, without which the tradesperson has no chance of success and the historic fabric has a high probability of being "lost." Ensure required submittals are properly submitted, reviewed, and shared with workers planning to do the work. Make sure preproduction mock-up techniques and findings are shared with all trades workers prior to production. Each of these are parts of the quality definition phase.

Third, site managers must be clear with SAAN employees plus all hired consultants and contractors of the desired outcomes. With the process defined and the outcome clearly delineated, the path to a positive outcome has the best chance of success.

Fourth, prioritize repeatability. Trade work, including historic preservation work, is typically based on productivity. Repeatable actions by the trade (i.e. limited variability) allow for the best quality outcome. Limiting variable factors, such as controlling a varied environment with temporary enclosures, or producing pointing mortar with consistent moisture content, all ensure repeatability.

Mock-ups are a powerful tool to help ensure repeatability. The most successful mock-ups include input from the design team, General Contractor/Construction Manager (GC/CM) and trade contractors to ensure compatible understanding of the desired outcome of the process and challenges understood by all team members to achieving the outcome.

A mock-up may address a single issue such as specific tooling of a mortar joint to more complex “system” mock-ups to include a section of wall addressing structural support, integral flashing, interface with roofing system, window systems or other components and how each needs to work with the parts to make a whole.

Fifth, supervise and evaluate to manage the outcome. The best of plans seldom just implement themselves successfully without supervision. Responsible personnel must be assigned to ensure trade workers understand and implement the specific details important to the current project and task. It is common to see a worker “do the same as the last project” without understanding the implications to “this” specific project. Supervision is also important to address in a timely manner changes that may be required due to discoveries or changes to conditions of implementation.

4.0 SPECIAL RISKS AND QUALITY CONTROL IN THE TIME OF COVID-19

COVID-19 has impacted preservation project risk definition, jobsite management and implementation of construction quality. Federal OSHA regulations[2] and CDC guidance[3] are in a state of flux with the ever-changing state of the pandemic. Construction work is generally considered essential and therefore workers can be active on project sites. Personal protective equipment for COVID has been generally accepted by trades workers, and such items as masonry dust respirators can provide worker protection.

A jobsite challenge is the commonly required face-to-face meeting with workers and consultants. Many specialty consultants have travel restrictions or corporate limitations on meetings. The use of iPad or similar technology can help resolve issues. However, the project team should consider the risk of not being on site for the level of inspection or interface required for the sensitivity of the project.

5.0 CONCLUSION

Investing time and effort early in project development to understand specific risks to a successful outcome allows the opportunity to identify potential problems before they occur and have a plan for addressing them in advance. Correcting mistakes costs time and money and, potentially more important, loss of historic fabric. A formal quality control program can help ensure every time preservation trades work is performed, the same information, methods, skill, and controls are used and applied in a consistent manner.

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[3] https://www.cdc.gov/coronavirus/2019-ncov/community/organizations/construction-workers.html

Glossary

GLOSSARY IS ORGANIZED IN FOUR TOPIC SECTIONS AND FOLLOWS ALPHABETICAL ORDER:

- Conservation Management
- Spanish Colonial Architecture/Landscape Features
- Building Technology
- Conservation Terms

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

GLOSSARY 1: CONSERVATION MANAGEMENT

Artifact: "An ornament, tool, or other object that is made by a human being, especially one that is historically or culturally interesting" (Collins English Dictionary, n.d.).

Best Practices: "Practices that apply the most current means and technologies available to not only comply with mandatory … regulations, but also maintain a superior level of … performance (National Park Service [NPS], 2006, p. 156).

Condition Assessment: Baseline document that details the current state of a building (or any cultural resource), identifies problems with building assemblies and material components and determines causes of the problems. The key goals of a condition assessment are to identify preservation needs of historically significant materials and built features in order to make appropriate choices for maintenance, conservation and improvements or even new uses. All condition assessments are based on field observations, while some also incorporate diagnostic testing or lab analyses of materials. A thorough condition assessment contains the following elements: 1) statement of historical significance; 2) Relevant information about changes in the buildings over time; 3) A summary of information from past condition assessments to use as comparisons for new observations; 4) Current description of materials and systems—exterior, interior, site drainage, structural, utilities, etc; 5) Assessment of identified problems with prioritized recommendations for treatment. In the US, condition assessments are an integral part of Historic Structure Reports (HSR).

Conservation: "Protect[ion] from loss or harm ... Historically, the terms conserve, protect, and preserve have come collectively to embody the fundamental purpose of the NPS— preserving, protecting and conserving the national park system" (NPS, 2006, p. 156).

Buffer Zone of UNESCO World Heritage: "an area surrounding the nominated property which has complementary legal and/or customary restrictions placed on its use and development in order to give an added layer of protection to the property. This should include the immediate setting of the nominated property, important views and other areas or attributes that are functionally important as a support to the property and its protection" (UNESCO, 2019, p. 30).

Cultural Landscape: "Settings we have created in the natural world. They reveal fundamental ties between people and the land–ties based on our need to grow food, give form to our settlements, meet requirements for recreation, and find suitable places to bury our dead. Landscapes are intertwined patterns of things both natural and constructed: plants and fences, watercourses and buildings. They range from formal gardens to cattle ranches, from cemeteries and pilgrimage routes to village squares. They are special places: expressions of human manipulation and adaptation of the land" (NPS, 1998).

Disaster: "a sudden event that causes a lot of damage, such as a very bad fire, storm, or accident" (Cambridge Dictionary, n.d.).

Ethnographic Resources: "Objects and places, including sites, structures, landscapes, and natural resources, with traditional cultural meaning and value to associated peoples. Research and consultation with associated people identifies and explains the places and things they find culturally meaningful. Ethnographic resources eligible for the National Register of Historic Places are called traditional cultural properties (NPS, 2006, p. 157).

Historic Fabric: "Those portions of a building fabric that are of historic significance" (Harris, 2006).

HSR (Historic Structure Report): Defined by the U.S. Department of the Interior as a document that "provides documentary, graphic, and physical information about a property's history and existing condition" and offers "a thoughtfully considered argument for selecting the most appropriate approach to treatment, prior to the commencement of work, and outlines a scope of recommended work" (Slaton, 2005).

Intangible: "Practices, representations, expressions, knowledge, skills—as well as the instruments, objects, artefacts and cultural spaces associated therewith—that communities, groups and, in some cases, individuals recognize as part of their cultural heritage. This intangible cultural heritage, transmitted from generation to generation, is constantly recreated by communities and groups in response to their environment, their interaction with nature and their history, and provides them with a sense of identity and continuity, thus promoting respect for cultural diversity and human creativity" (UNESCO, 2018, p. 5).

Integrity: "a measure of the wholeness and intactness of the natural and/or cultural heritage and its attributes" (Denyer, 2011). The conditions of integrity may be summarized as follows:

(i) The site "should contain all or most of the key interrelated and interdependent elements in their natural relationships."

(ii) The site "should have sufficient size and contain the necessary elements to demonstrate the key aspect of processes that are essential for the long-term conservation of the ecosystems and the biological diversity they contain."

(iii) The site "should be of outstanding aesthetic value and include areas that are essential for maintaining the beauty of the site."

(iv) The site "should contain habitats for maintaining the most diverse fauna and flora characteristics of the biogeographic province and eco systems under consideration." (UNESCO, 1996, p. 22).

Maintenance: "The upkeep of a building and its equipment so that the building can continue to perform its required functions" (Harris, 2006).

Management Plan of UNESCO World Heritage: "Parties to Convention are encouraged to prepare management plans for the management of each cultural and natural property nominated for inclusion to the World Heritage List. This requirement is reflected in the condition of integrity for natural properties and in the requirements concerning protection and management mechanisms for cultural properties" (UNESCO, 1996, p. 28).

Outstanding Universal Value of UNESCO World Heritage: "Cultural and/or natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity. As such, the permanent protection of this heritage is of the highest importance to the international community as a whole" (UNESCO, 2019, p. 20).

Periodic Reporting of UNESCO World Heritage: "Every six years, States Parties submit periodic reports for examination by the World Heritage Committee … Periodic Reporting serves four main purposes:

to provide an assessment of the application of the World Heritage Convention by the State Party;

to provide an assessment as to whether the Outstanding Universal Value of the properties inscribed on the World Heritage List is being maintained over time;

to provide up-dated information about the World Heritage properties to record the changing circumstances and state of conservation of the properties;

to provide a mechanism for regional cooperation and exchange of information and experiences between States Parties concerning the implementation of the Convention and World Heritage conservation" (UNESCO, 2019, p. 56).

Preservation: "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 limited and sensitive upgrading of mechanical, electrical, and plumbing systems and other code-required work to make properties functional is appropriate within a preservation project. However, new exterior additions are not within the scope of this treatment" (Grimmer, 2017, p.2).

Primary Source: "Documents, images or artifacts that provide firsthand testimony or direct evidence concerning an historical topic under research investigation. Primary sources are original documents created or experienced contemporaneously with the event being researched. Primary sources enable researchers to get as close as possible to what actually happened during an historical event or time period" (UCI Libraries, n.d.).

Reconstruction: "The act or process of depicting, by means of new construction, the form, features, and detailing of a non-surviving site, landscape, building, structure, or object for the purpose of replicating its appearance at a specific period of time and in its historic location" (Gibson, 2015a).

Rehabilitation: "The act or process of making possible a compatible use for a property through repair, alterations, and additions while preserving those portions or features which convey its historical, cultural, or architectural values" (Gibson, 2015b).

Restoration: "The act or process of accurately depicting the form, features, and character of a property as it appeared at a particular period of time by means of the removal of features from other periods in its history and reconstruction of missing features from the restoration period. The limited and sensitive upgrading of mechanical, electrical, and plumbing systems and other code-required work to make properties functional is appropriate within a restoration project" (Gibson, 2015c).

Risk Preparedness (Disaster Planning): "Activities and measures taken in advance to ensure effective response to the impact of hazards, including the issuance of timely and effective early warnings and the temporary evacuation of people and property from threatened locations" (UNESCO, Preparedness and Mitigation).

Ruins: "The parts of a building that remain after the rest has fallen down or been destroyed" (Collins English Dictionary).

Spanish Colonial: "Architecture, particularly in those areas of the American continents that have been subject to Spanish influence; greatly affected by local culture, customs, traditions, and availability of materials. Spanish Colonial architecture in the American southwest usually is typified by thick, solid adobe walls, often covered with a protective layer of stucco or plaster; a one-story building around an enclosed courtyard; a long, narrow, covered porch either facing the street or facing a patio; often, a balcony, commonly supported by columns at ground-floor level, each column usually topped with a bolster; commonly, flat roofs supported by round logs drained by waterspouts that penetrated the parapet surrounding the roof; low-pitched or medium-pitched roofs covered with red clay tiles, often with a substantial overhang, were also common; windows facing the street usually protected by ornamental grillwork; doors to the various rooms opened directly onto a covered porch or onto a patio" (Harris, 2006).

Tangible: (from Latin tangere, "to touch") something that can be touched or felt. It can be used in to indicate physical artefacts. Associated with heritage (tangible heritage), it indicates physical artifacts "produced, maintained and transmitted intergenerationally in a society. It includes artistic creations, built heritage such as buildings and monuments, and other physical or tangible products of human creativity that are invested with cultural significance in a society" (UNESCO, 2018, p. 5).

Texas Historical Commission (THC): "Serves as the State Historic Preservation Office (SHPO) as required by the National Historic Preservation Act of 1966 (NHPA), as amended. The NHPA directs all states to administer federal preservation laws and policies ...

Under the NHPA, the THC is required to:

Survey and inventory historic resources

Nominate significant historic resources to the National Register of Historic Places

Identify and mitigate resources potentially affected by federally controlled projects (Section 106)

Facilitate the federal Historic Preservation Tax Credit program

Administer the Certified Local Government program

Prepare and implement a comprehensive statewide preservation plan

Provide public information, education, training, and technical assistance in historic preservation

Provide funds to the public for preservation activities" (Texas Historical Commission).

Viewshed: the geographical areas that can be seen from a particular place or area from which a particular feature can be seen. (getty.edu) MRM

World Heritage Convention, UNESCO: "The Convention Concerning the Protection of the World Cultural and Natural Heritage is an international agreement that was adopted by the General Conference of UNESCO in 1972. It is based on the premise that certain places on Earth are of outstanding universal value and should therefore form part of the common heritage of humankind. The countries who ratify the Convention (States Parties) have become part of an international community, united in a common mission to identify and safeguard our world's most outstanding natural and cultural heritage. While fully respecting the national sovereignty, and without prejudice to property rights provided by national legislation, the States Parties recognize that the protection of the World Heritage is the duty of the international community as a whole" (UNESCO, Frequently Asked Questions).

Works Progress Administration (WPA): "A US government programme (1935–43) established by President Franklin D Roosevelt as part of his New Deal. Its name was later changed to the Works Projects Administration. It created millions of jobs for unemployed people during the Great Depression, mainly in building and the arts" (Oxford Learner's Dictionaries).

GLOSSARY 2: SPANISH COLONIAL ARCHITECTURE/LANDSCAPE FEATURES

Acequia: "A complex and expansive irrigation system comprising of dams, gates and irrigation canals" (sanantonio.gov).

Baptistery: "A building or part of one wherein the sacrament of baptism is administered" (Harris, 2006).

Convento: "In Spanish architecture and its derivatives, a convent or monastery usually containing living quarters, workrooms, storerooms, a balcony, and patio" (Harris, 2006).

Drain Spout (in Spanish: *canal*): "In Spanish Colonial architecture, a waterspout used to drain rainwater from an essentially flat roof; it projects through, and beyond, the face of the parapet around the roof" (Harris, 2006).

Espadaña: "In Mission architecture, a decorative gable end of a church having a multicurved mission parapet; the gable end often has a false front, designed to be impressive; it usually does not house a bell" (Harris, 2006).

Frontispiece: "1. The decorated front wall or bay of a building, 2. An ornamental porch or chief pediment" (Harris, 2006).

Labores: A Spanish word for the irrigated land area of an acequia system where crops are grown. (Cox, 2005)

Mixtilinear: (from classical Latin mixtus mixed + -i- + línea +r) Formed or bounded partly by straight lines and partly by curves

Mission: Settlement explicitly established for the purpose of religious conversion and instruction of Amerindian population to the Catholic faith. However, the mission system served as the primary means of integrating the Indians into the political and economic structure of the Spanish territories in the

Americas.

Oculus: "An opening at the crown of a dome" (Harris, 2006).

Pediment (in Spanish:*frontón*): In classically based architecture, it describes a crowning, centrally positioned triangular element found on a façade. It is located on a gable and – since Renaissance – it is used over doors, niches, or windows surmounted by cornices. In Baroque architecture, top of the pediment may be curved, curled, or broken. Pediments are widely used in Baroque churches of Northern New Spain (Giffords, p. 175).

Salomonic column (the Spanish term: *entorchado*): is a helical column, characterized by a spiraling twisting shaft like a corkscrew. Not associated with a specific classical order, most examples have Corinthian or Composite capitals.

Sacristy: "A room in a church, near the chancel, where the robes and altar vessels are stored, where the clergy vest themselves for services, and where some business of the church may be done; usually a single room, but sometimes a very large one" (Harris, 2006).

***Rancho* (Ranch):** "During the Spanish Colonial period in the Americas [the word 'rancho'] became associated with a place for raising cattle and other livestock (Bacich, 2019).

Retablo: "A votive offering made in the form of a religious picture typically portraying Christian saints, painted on a panel, and hung in a church or chapel especially in Spain and Mexico" (Merriam-Webster, n.d.).

GLOSSARY 3: BUILDING TECHNOLOGY

Adobe: "Made by pressing a soil/fiber mixture of clay and straw into bottomless wooden molds … and then drying the molded bricks under the sun. This material can easily reach compression strength values around 3 MPa. Vitruvius mentions mud brick buildings rising up to five stories high" (Torraca, 2009, p. 42).

Arch: "A typically curved structural member spanning an opening and serving as a support (as for the wall or other weight above the opening)" (Merriam-Webster, n.d.). "A curved member that is used to span an opening and to support loads from above. The arch formed the basis for the evolution of the vault" (Encyclopædia Britannica).

Ashlar: "Masonry composed of rectangular units of burnt clay or shale, or stone, generally larger in size than brick and properly bonded, having sawn, dressed, or squared beds and joints laid in mortar" (Harris, 2006).

Barrel Vault: "A semi-cylindrical or partly cylindrical roof structure of constant crosssection. It was widely used in masonry construction, particularly in Romanesque architecture" (Cowan & Smith, 2004, p. 26).

Binder: "(a) An adhesive or cementing material. (b) A soil consisting mainly of fine particles for binding a non-cohesive soil. (c) A masonry unit used to bind an inner and an outer wall. (d) A structural member, particularly of timber, which binds together components of a structure" (Cowan & Smith, 2004, p. 32).

Brick (Fired): "A solid masonry unit, usually of clay, molded into a rectangular shape while plastic, and then treated in a kiln at an elevated temperature to harden it, so as to give it mechanical strength and to provide it with resistance to moisture; after being removed from the kiln, the brick is said to be burnt, hard-burnt, kiln-burnt, fired, or hard-fired … Bricks differ in color, ranging from dark red to rose and salmon, and from pink to blue-black and purple, depending on the type of clay and on the temperature of the kiln in which they were burnt" (Harris, 2006).

Cement (the Spanish term: cemento): "1. A material or a mixture of materials (without aggregate) which, when in a plastic state, possesses adhesive and cohesive properties and hardens in place. Frequently, the term is used incorrectly for concrete, e.g., a "cement" block for concrete block ... 2. A calcined combination of limestone and clay, combined with an aggregate that reacts chemically when water is added; after this reaction occurs, the mixture hardens in place as it dries, resulting in a stonelike material (Harris, 2006).

Chinking: "The material used to fill chinks (i.e., long cracks, openings, or fissures), especially between logs that form the exterior walls of log cabin construction. Where the cracks are small, the filling material is often mud or plaster; where the cracks are large, the filling may include wood chips, pebbles, straw, or small sticks" (Harris, 2006).

Clay: "A fine-grained, cohesive, natural earthy material; plastic when sufficiently wet; rigid when dried; vitrified when heated in a kiln to a sufficiently high temperature; used in making brick, as wall infilling, and as daub in wattle-and-daub" (Harris, 2006).

Cross Vault or Groin Vault: "A vault resulting from the intersection at right angles of two BARREL VAULTs of identical shape" (Cowan & Smith, 2004, p. 77).

Dome: "A vault of double curvature, both curves being convex upwards. Most domes are portions of a sphere; however, it is possible to have a dome of nonspherical curvature on a circular plan, or to have a dome on a non-circular plan, such as an ellipse, an oval or a rectangle. In Classical architecture, domes were normally constructed of masonry" (Cowan & Smith, 2004, p. 94).

Drum (in Spanish: *tambor*): "A vertical wall supporting a dome or cupola" (Cowan & Smith, 2004, p. 98).

Extrados: "The outer or upper curve of an arch" (Cowan & Smith, 2004, p. 115).

Intrados: "The inner or lower curve of an arch" (Cowan & Smith, 2004, p. 164).

Hydraulic Mortar: "A mortar that is capable of setting and hardening under water" (Harris, 2006).

Keystone: "The stone at the CROWN of an arch. A VOUSSOIR arch becomes self-supporting only after the keystone has been placed in position. Hence it was frequently made larger, and especially decorated. Since the keystone need only resist the horizontal thrust, it is less heavily loaded than any of the stones lower down the arch" (Cowan & Smith, 2004, p. 169).

Gypsum: "A soft mineral consisting of a hydrated calcium sulfate from which gypsum plaster is made (by heating); colorless when pure; used as a retarder in portland cement" (Harris, 2006). "Calcium sulphate dehydrate ($CaSO4. 2H2O$)" (Cowan & Smith, 2004, p. 144).

Lime: "A white or grayish-white caustic substance, calcium oxide, usually obtained by heating limestone or marble at a high temperature; used chiefly in plasters, mortars, and cements" (Harris, 2006).

Lintel: "(a) In Classical architecture, the horizontal member which spans between the posts in TRABEATED construction. (b) A short beam, particularly one spanning across a door or window opening, and carrying the wall above it" (Cowan & Smith, 2004, p. 180).

Lime plaster (the Spanish term: *armagasa*): "A base-coat plaster consisting of lime and aggregate" (Harris, 2006).

Limestone: "sedimentary rock containing a large proportion of calcium carbonate ($CaCO3$). It is formed by the consolidation of calcareous ooze, which may be formed by organisms, by chemical precipitation, or by the weathering of pre-existing limestone. Most limestones are easily carved (see FREESTONE and PORTLAND STONE). In the building industry classification of building stones, the polishable limestones are called MARBLE. Limestone is a raw material for LIME mortar and for PORTLAND CEMENT" (Cowan & Smith, 2004, p. 178).

Lime mortar: "Mortar made of lime and sand. It was the general medium for laying stone and brick until the nineteenth century. However, it is water-soluble, and it has now been largely superseded by PORTLAND CEMENT mortar, which is water resistant, and also stronger. However, as cement mortar is stronger than many types of stone and brick, cracks due to foundation settlement, temperature and moisture movement are liable to pass through the stone or brick, rather than through the mortar joints. This causes irreparable damage, whereas a crack in a joint can be repaired by repointing. Thus an admixture of lime with cement mortar is often favoured" (Cowan & Smith, 2004, p. 178).

Mortar (Spanish: *mezcla*): "A plastic mixture of cementitious materials (such as plaster, cement, or lime) with water and a fine aggregate (such as sand); can be troweled in the plastic state; hardens in place. When used in masonry construction, the mixture may contain masonry cement or ordinary hydraulic cement with lime (and often other admixtures) to increase its plasticity and durability" (Harris, 2006).

Niche: "A recess in a wall, usually to contain sculpture or an urn; often semicircular in plan, surmounted by a half dome" (Harris, 2006).

Pendentive: "One of a set of curved wall surfaces which form a transition between a dome (or its drum) and the supporting masonry" (Harris, 2006).

Plaster: "Any pasty material of mortar-like consistency, used for covering the walls or ceilings of a building" (Cowan & Smith, 2004, p. 229. "Plaster must be applied to avoid damage to the core structure when the walls are hit by heavy rains. Traditional plasters are made of clay-rich soils mixed with long vegetable fibers; in external exposures they act as sacrificial protection layers that are periodically substituted when the superficial earth has been washed away and the fibers are visible. Inside the buildings, however, such plasters may well have decorations, in relief and with colors, which are intended to last; when the buildings were kept in good shape by an adequate maintenance, such decorations did indeed survive for centuries" (Torraca, 2009, p. 42).

Pointed arch: "An arch that is pointed at its apex, rather than rounded; common in Gothic and Gothic Revival architecture" (Mazurczak, 2016).

Portland cement: "The most common form of cement. It is made by burning together chalk or limestone and clay or shale, and grinding the resulting clinker into a fine powder. The result is a complex mixture of calcium silicates … and calcium aluminates, which sets into a hard paste when it comes into contact with water … The name Portland cement is due to J. Aspden, who patented the first artificial cement in England in 1824" (Cowan & Smith, 2004, p. 236).

Quoin: "In masonry, a hard stone or brick used, with similar ones, to reinforce an external corner or edge of a wall or the like; often distinguished decoratively from adjacent masonry; may be imitated in non-load-bearing materials. Occasionally imitated, for decorative purposes, by wood that has been finished to look like masonry" (Harris, 2006).

Rajuelas: Small slivers of stones tapped into mortar joints of rubble masonry walls for filling and strengthening purposes. Usually laid to create decorative effects (Giffords, 2007)

Rubble masonry: "Rough stones of irregular shape and size. They may result from quarrying, from the demolition of old buildings or (more rarely) from the natural disintegration of large pieces of rock" (Cowan & Smith, 2004, p. 261).

Sandstone: "Sedimentary rock containing a large proportion of rounded silica grains, generally ranging from 1–0.1mm in diameter. The sand is normally cemented into a solid mass by a matrix which may be composed of silica (siliceous sand-stone), of lime (calcareous sandstone) or of iron ore (ferruginous sandstone). The finer-grained sandstones are easily carved if the matrix is sufficiently soft (see FREESTONE). Sedimentary rocks composed of larger sand particles are called gritstones (Cowan & Smith, 2004, p. 263).

Soil: "The surface layer of earth, supporting plant life" (Collins Dictionary, n.d.).

Spalling: "A flake or chip, esp. of stone" (Collins Dictionary, n.d.).

Stucco (Spanish term: *estuco*): Today refers to a cement plaster applied to exteriors, although it once referred to high quality lime plaster used on interior walls (Giffords, 2007, p. 81)

Terrado: "In Hispanic architecture, a flat roof made of compacted earth that is sealed with a layer of plaster" (Harris, 2006).

Vault, Vaulting: "(a)… An arched masonry or concrete roof … (b) A room or passage with an arched masonry roof (Cowan & Smith, 2004, p. 323).

Voussoir: "A wedge-shaped stone or brick, used in the construction of an arch. The voussoir at the crown is called the keystone" (Cowan & Smith, 2004, p. 327).

Wash: "1. The sloping upper surface of a building member, as a coping or sill, to carry away water; said of any other member serving such a function. See also drip cap. 2. A manner of applying water color in a rendering" (Harris, 2006).

Whitewash (the Spanish term is: *jalbegue*): "A cheap finish for external walls formed by soaking QUICK-

LIME in an excess of water. A binder, such as casein, is sometimes added. Also called limewash (Cowan & Smith, 2004, p. 333).

Wythe: "(a) One leaf of a cavity wall. (b)A half-brick wall. Also spelled withe" (Cowan & Smith, 2004, p. 336).

GLOSSARY 4: CONSERVATION TERMS

Alveolization: "Formation, on the stone surface, of cavities (alveoles) which may be interconnected and may have variable shapes and sizes (generally centimetric, sometimes metric)" (Vergès-Belmin, 2008, p. 28).

Biological growth: "Colonization of the stone by plants and micro-organisms such as bacteria, cyanobacteria, algae, fungi and lichen (symbioses of the latter three). Biological colonization also includes influences by other organisms such as animals nesting on and in stone" (Vergès-Belmin, 2008, p. 64).

Capping or Coping: "A capping of stone, brick or concrete for the top of a wall. It frequently projects beyond either or both faces of the wall, partly for protection from the weather, and partly for decoration" (Cowan & Smith, 2004, p. 72).

Consolidation: Efforts to "restore the cohesion to stones that had lost it … whatever the consolidant chosen, the technique used to apply it must allow it to penetrate all deteriorated layers and to reach the sound core of the material, otherwise a solid crust would be formed over an incoherent base; this may look nice for a while, but the crust would soon spall off, causing damage worse than the one that might have been expected if no treatment had been performed" (Torraca, 2009, pp. 105–106).

Cristallization: Process by which a solid forms, where the atoms or molecules are highly organized into a structure known as a crystal. In masonry walls, salt crystallization induces granular disintegration and scaling of the stone and it is often detectable due to the presence of efflorescence and subefflorescence.

Efflorescence: "Generally whitish, powdery or whisker-like crystals on the surface. Efflorescences are generally poorly cohesive and commonly made of soluble salt crystals," (Vergès-Belmin, 2008, p. 48).

Erosion: "Loss of original surface, leading to smoothed shapes" (Vergès-Belmin, 2008, p. 30).

Reversibility: A guiding principle of architectural conservation that asserts, "alterations made to the building should be able to be removed in the future without significant damage to the building. Reversibility allows for the use of improved technologies as they are developed and the removal of inappropriate alterations. This principle encourages alterations of an additive nature and discourages the removal of material or architectural features. In addition, the permanent storage of any removed material or feature is important, to provide the opportunity for future replacement" (Tolles, Kimbro, & Ginell, 2002, p. 7).

Repointing: "The act or process of repairing the joints of (brickwork, masonry, etc) with mortar or cement" (Collins Dictionary).

Rising damp: "Water that moves into the walls of buildings from the ground and damages them" (Cambridge Dictionary).

Weathering: Any chemical or mechanical process by which stones exposed to the weather undergo changes in character and deteriorate (ICOMOS, 2008)

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