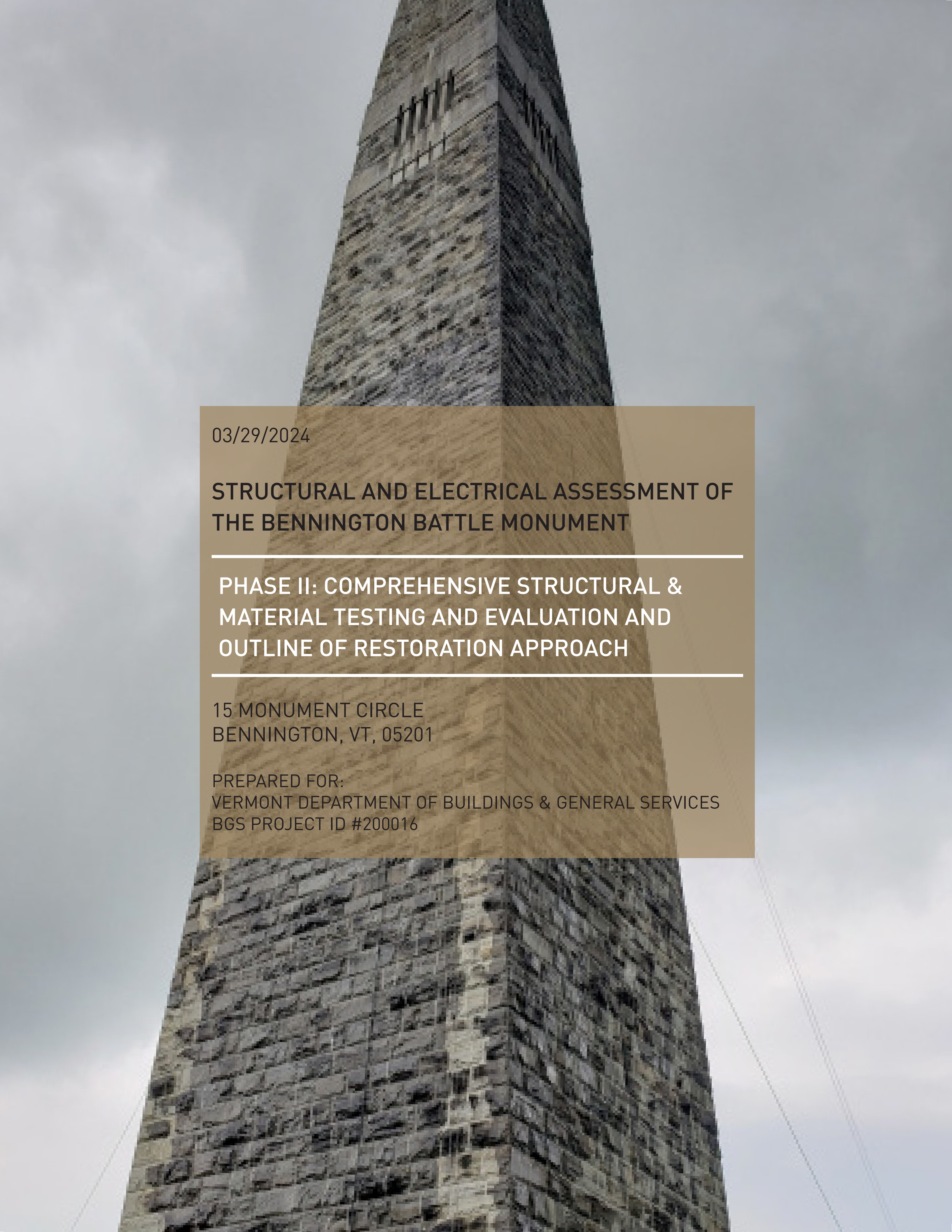

03/29/2024

STRUCTURAL AND ELECTRICAL ASSESSMENT OF THE BENNINGTON BATTLE MONUMENT

PHASE II: COMPREHENSIVE STRUCTURAL & MATERIAL TESTING AND EVALUATION AND OUTLINE OF RESTORATION APPROACH

15 MONUMENT CIRCLE
BENNINGTON, VT, 05201

PREPARED FOR:
VERMONT DEPARTMENT OF BUILDINGS & GENERAL SERVICES
BGS PROJECT ID #200016

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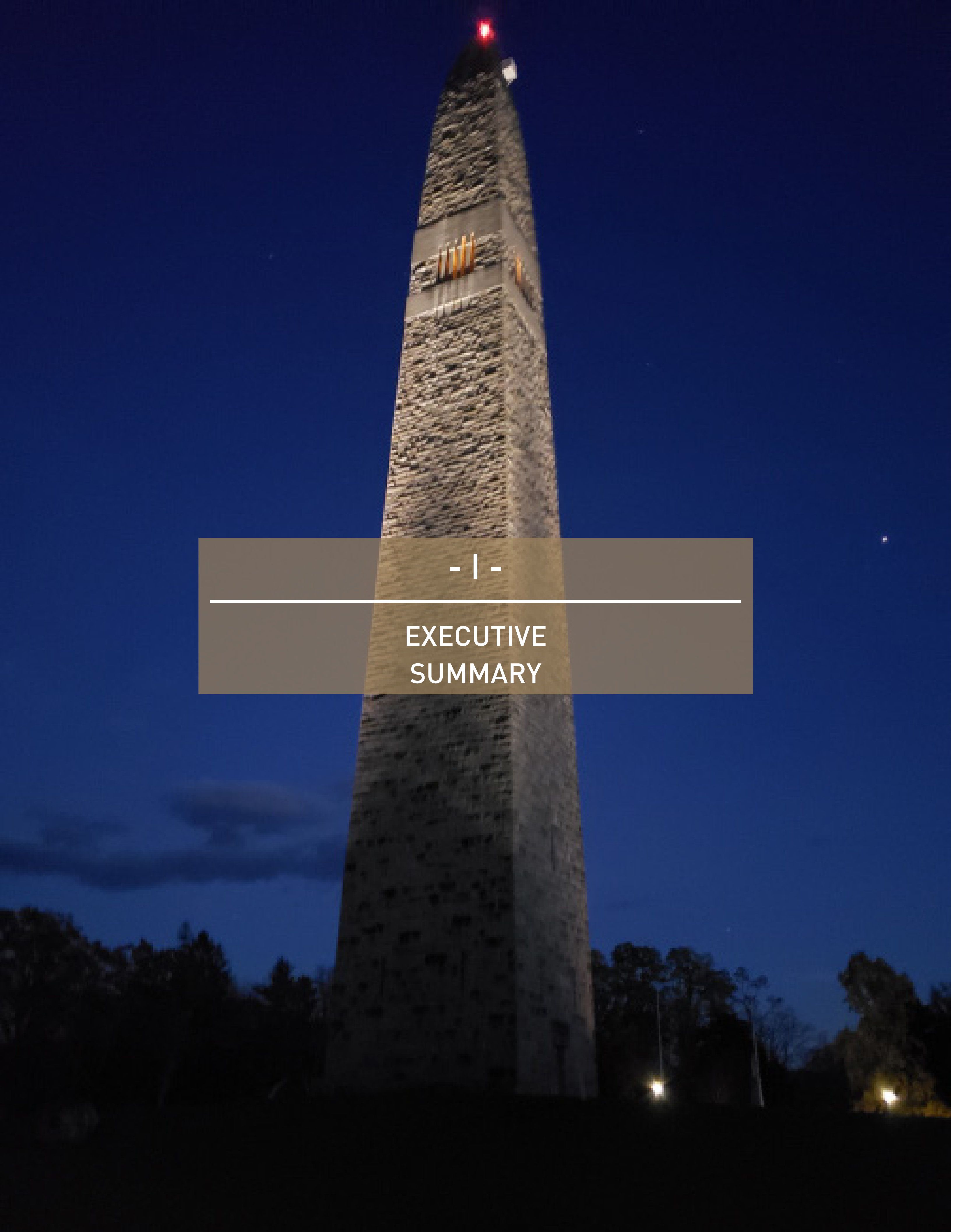

- I -

EXECUTIVE SUMMARY

Image 01. Battle monument, Bennington, Vt.. *Detroit Publishing Co.; 1905*

Executive Summary

The Bennington Battle Monument commemorates a site foundational to Vermont's unique cultural identity and statehood. Our team acknowledges with deep respect the work performed to date and for the exceptional stewardship by the State of Vermont of this historic architectural structure. The Monument is integral to not just the history of Vermont and its statehood, but the founding of our Nation as well. Construction of The Bennington Battle Monument began in 1887 and was completed in 1891. Several architects and designs were considered, though ultimately Boston architect John Phillip Rinn won the commission. Although initially the Bennington Battle Monument was cared for by the "Bennington Battle Monument and Historical Association," complete control of the monument (including the entirety of the property as well as the gift shop) was handed over to Vermont State in 1953 due to the monument falling into disrepair.

The Team of Stevens & Associates, Easton Architects, and Silman, are engaging with the State of Vermont Department of Building & General Services to lead the preservation, restoration, and conservation project for the Bennington Battle Monument. Following the initial Phase 1 research, documentation and physical assessment of the Monument, this Phase 2 report provides the findings and recommendations of detailed investigation and analysis by experts in numerous fields related to historic masonry, environmental controls, structural analysis and building infrastructure. The project goal of Phase 2 was to assess, analyze and synthesize all data prepared by the consultant team addressing the performance of the monument and the cause and impact of the deterioration mechanisms at work; and to propose next steps and and an outline to conserve and restore the structure based on the highest caliber of conservation science, preservation technology and restoration best practices to ensure the long-term preservation of this historic monument.

Historic Significance

The Bennington Battle Monument was constructed between 1887-1891 and opened in June of 1891. The cornerstone of the Bennington Battle Monument was laid on August 16, 1887. The Bennington Battle Monument capstone was placed, November 25, 1889.[1] The Bennington Battle Monument was dedicated August 19, 1891.[2] The monument weighs an estimated 19 million pounds. The 306-foot tall, unreinforced masonry obelisk is constructed of Sandy Hill Dolomite, a dolomitic limestone, and the monument is designated at the local, state, and national levels. In December 1969, it was nominated the U.S. National Register of Historic Places where it was entered in the National Register in March 1971.

Project Approach

The approach for the Bennington Battle Monument Conservation and Restoration project is centered on the development and implementation of a holistic restoration and conservation methodology for the original building materials, interior space and access, and character-defining features that will appropriately balance history, use and maintainability, which will lead us to accurately determine the most appropriate treatment recommendations. All treatment recommendations will comply with the Secretary of the Interior's Standards for the Treatment of Historic Properties (the Standards) and the guidelines set forth by the American Institute for Conservation (AIC). The implementation will be guided by scholarship and best practices for the treatment of heritage sites.

With the completion of Phase 2 presented here, the proposed work would likely be performed according to the following phases and sequence:

- Phase 1: Structural, Electrical and Elevator Assessment (Completed 12.16.2022)
- **Phase 2: Additional Recommended Scopes of Work (March 29, 2024)**
- Phase 3: Planning & Feasibility Study
- Phase 4: Schematic Design

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[1] John Spargo, An illustrated descriptive sketch of Bennington Battle Monument, with an account of Bennington Battle, August 16, 1777 (Bennington, VT: PUBLISHER, 1947), 9.

[2] Spargo, The Bennington Battle Monument, 121.

- Phase 5: Conservation and Restoration Documents and Technical Specifications
- Phase 6: Construction Administration and Oversight

Phase 2 Objective

The intended result of this second phase of work was to:

- Further investigate the conditions of the stone masonry identified in phase 1 in order to identify the key issues of the Bennington Battle Monument that need to be considered in our process of determining the most appropriate treatment approach and methodology for the monument restoration. This includes stone stress test analysis, construction assembly and wall make up, stone material testing, moisture monitoring results, petrography, mortar analysis, humidity and hygrographic analysis, and structural finite analysis.

The condition of the masonry and the mortar types were mapped as it relates to past repair campaigns, identification and location of cores, tests, and samples have been recorded on the drawings.

Past Research

In reviewing the documentation and archival history, numerous repair campaigns have been performed dating back as early as 1907 to address persistent issues of humidity, water infiltration and moisture on the inside of the Monument. There has not been, until Phase 1 completed in 2022, a full assessment of the Monument to understand the mechanisms of deterioration of the masonry walls; and testing and analysis of materials in order to develop appropriate repair techniques and perform effective, full-scale repairs. The previous work was done without a comprehensive understanding of the behavior of the Monument and its materials and the complexity of the issues challenging the integrity and stability of the building fabric. The documentation of large-scale cracking and water infiltration warrants a holistic restoration and conservation strategy that is urgently needed to halt the aggressive deterioration of the historic masonry.

Findings

Mechanisms of Deterioration

Critical to the success of the project is the acknowledgement of the continuum of deterioration. Masonry deterioration has occurred since the start of the construction and has been evident throughout the history of the Monument. There is some natural stone degradation that contributes fissures and cracking. Stress on the stone due to eccentric loading is also a contributing factor to the cracking of the stone. The most damaging factor to the degradation of the stone is water, water vapor and excessive humidity on the interior of the monument. Additional stress cracks, and water ingress are the result of past repair campaigns that introduced inappropriate mortar, sealant, caulk, epoxy, and other repair techniques that have resulted in exacerbating the deterioration.

Materials with Compromised Performance

Select materials and building components including select masonry and pointing mortar on both exterior and interior whythes of stone, stair and stair components, structural elements including some headers, and elevator components, lightning protection equipment and the absence of functioning mechanical ventilation, are near or have exceeded their serviceable life due to age, exposure to the elements, and natural degradation over time.

Poor Technical Design Performance

The mechanical and building infrastructure systems are aging and ineffective. The lack of natural ventilation and no introduction of mechanical ventilation in the structures contributes to the high relative humidity inside the monument, creating water in liquid form (condensation) and vapor form, which has a deleterious effect for the activation of salts within the masonry wall assemblies, contributes to an abusive frost jacking effect, and is aiding in the accelerated rate of deterioration.

Restoration and Conservation Treatment Recommendations

Our approach to the restoration, conservation and preservation treatments for the Bennington Battle Monument focuses on three key elements= Prevention, Mitigation, Adaptation.

The recommendations from Phase 2 have been categorized into two groups with potential execution dates noted in parenthesis:

- Treatment Recommendations (2024-2025)
- Schematic Design Work & Preservation Work Plan (2025)

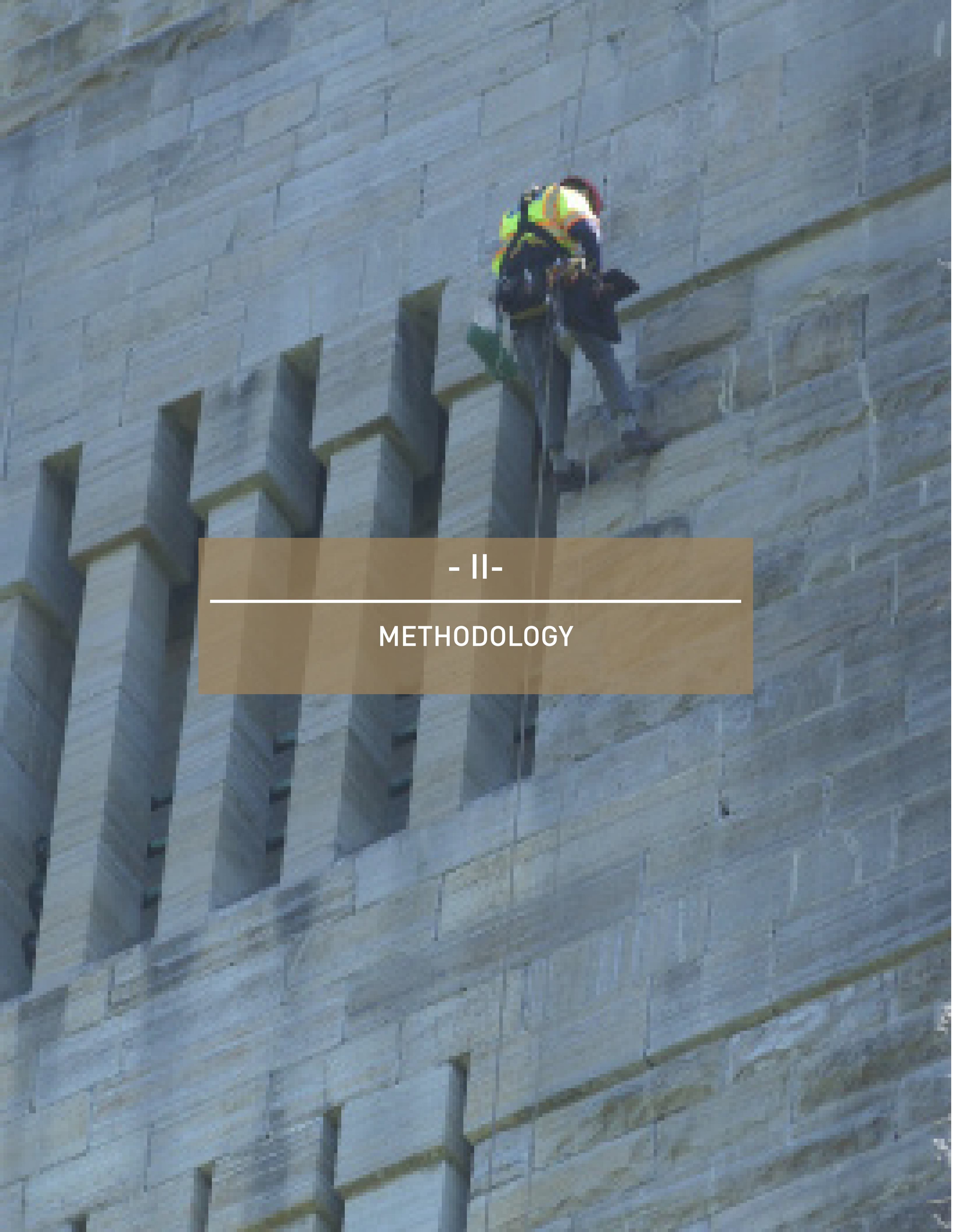
Project Success

In considering the project scope and financial commitment for a full preservation/restoration of the monument, it is easy to raise the question of what are the alternatives, especailly a project with a large price tag. Of coures, doing nothing, or the very minimal, is an option. But the State of Vermont has the gift of an important cultural heritage resource that was a major factor in the battle for the creation of our nation. Cultural heritage sites are more than physical landmarks and structures, it's what they represent that is intrinsic in its value to the site, an historic timeline, and its enduring legacy as a marker of time. As a steward to this monument, while the state is responsible for the maintenance of the monument, it also has the benefit of owning the history, the story, and the telling of this story.

This story is expressed as a unique obelisk that specifically represents the zenith of an important moment in our history, and create an emotional connection. There are the names and places associated with this emotional connection, from highways and roadways to state parks, hotels and motels, restaurants and bars. It is all based on memorializing and preserving the richness of our past so we can understand the reasons behind where we are today.

In this particular case, we embrace the legacy of Major General Stark (who also fought at Bunker Hill, and the Battles of Princeton and Trenton), Colonel Seth Warner (who also fought at Ticonderoga and at the Battle of Hubbardton) and the Green Mountain Boys, the Republic of Vermont, the negotiations with Quebec before British surrender, then the negotiations with the U.S. to enter the Union, with all of this representative of the Battle of Bennington as a key victory in our Revolutionary War, as much as it is of Vermont's battle for its own statehood, and the efforts of ultimately becoming the 14th state of the Union.

As the Vermont Historical Society professes "Every person and every moment create the story of Vermont. Through sharing these collective stories, Vermonters will increase their knowledge of our state's complex past, inform our present, and understand how our unique experiences impact and shape this ongoing narrative." The Bennington Battle Monument is part of this story, is a valuable link in Vermont's history, and a source of pride that can be continuously celebrated.



- II-

METHODOLOGY

Methodology

Our team specializes in providing restoration and conservation strategies for the maintenance and preservation of historic properties, developed through research and forensic analysis of historic fabric to determine the mechanisms of deterioration at work. Our project approach begins with research—both archival and in the field—to understand the history and evolution of the site, climate, and environmental conditions. A thorough understanding of existing conditions and building materials provides an essential foundation for this project; this knowledge informs strategic decisions for determining the restoration and conservation treatment recommendations.

Best Practices for Treatment Recommendations

Our restoration and conservation treatment recommendations are based on conservation science, best practices, and applicable standards to ensure long-term solutions to preserve this culturally significant monument. Our methodology and restoration approach are developed using accepted and established preservation theory and practices as advocated by:

- The Secretary of the Interior's Standards for the Treatment of Historic Properties
- The National Trust for Historic Preservation
- American Institute for Conservation

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PROJECT APPROACH

PROJECT APPROACH

Project Approach

Following a thorough internal study and review of the assessment of existing conditions and reports completed in Phase 1, and the engagement of a full complement of consultants prior to the commencement of Phase 2, we have synthesized all data and analyses delivered from our consultant team and developed a clear approach with treatment recommendations and considerations for next steps for project planning for the holistic preservation, restoration, and rehabilitation of the Monument.

Our methodology is based philosophically on accepted and established preservation theory and practice as advocated by The Secretary of the Interior's Standards for the Treatment of Historic Properties, the National Trust for Historic Preservation, and the American Institute of Conservation. As much original material as possible shall be maintained, interventions shall be the minimum necessary to ensure the extended life of all building and landscape features, and all restoration procedures shall be proven reversible where feasible and accurately recorded.

Our team of architects, preservationists and conservators specializes in providing restoration and conservation strategies for the maintenance and preservation of historic properties, developed through research and forensic analysis of historic fabric to determine the mechanisms of deterioration at work. It is precisely this specialty that is required for the comprehensive restoration program for the Bennington Battle Monument. Our project approach began with research—both archival and hands-on—to understand the history and evolution of the Monument site, including existing conditions, climate, and its impact on materials and the structures, and surrounding environmental conditions. A comprehensive understanding of the existing conditions and an analysis of the building materials provided our team with an essential foundation for the development of our restoration program; and this knowledge will enable us and the State to make informed and strategic decisions. This understanding allows us to comprise our overall approach to organizing this information in the following order:

Project Assessment & Report Synthesis Components

1. Structural & Material Testing and Performance Analysis
2. Building Systems including Thermal Dynamics & Hygrographic Analysis
3. Architectural Preservation Review and Analysis
4. Project Planning and Implementation Considerations/Rrecommendations

Items 1 & 2 refer to the assessment process, 3&4 address conclusions from the Architectural Synthesis which highlight the highest priorities for preservation and the critical planning and implementation decisions for the team to address for the project's success.

Structural & Material Testing and Performance Analysis

- Structural Modeling & Analysis
- Onsite testing
- Laboratory Material Testing

- Petrography and Mortar Testing

Building Systems including Thermal Dynamics & Hygrographic Analysis

- Existing stair and viewing platform (as components of the structure's circulation system)
- Existing elevator and shaft and electrical service/operation
- Moisture/water penetration testing and analysis
- Intervention of passive ventilation and potential for new active ventilation
- Existing electrical services
- Misc. building systems integration (lightning protection, emergency generator services, etc)
- Methods of dehumidification and ventilation- what sort of arrangements are we looking at?
- What size equipment?
- How feasible is this to be performed on such a building as this?
- What sort of energy requirements may be required?
- Will upgrades of the electrical system be required?
- How do we evaluate the utility of passive vs. active ventilation?

Architectural Preservation Review and Analysis

Primary Factors for Consideration:

- Waterproofing of exterior and interior
- Stone repair/replacement
- Crack repair
- Mortar and repointing
- Stone makeup- understanding porosity, density and sourcing
- Sensitive integration of structural recommendations (grouting, pinning, etc)
- Moisture control on interior (prevent salt leeching)

Principal Focus for Nest Steps in Project Planning and Implementation

- Completion of a Planning & Feasibility Study
- Mock ups/monitoring required-types, timing and sequence
- Development of strategies for work, and development of project scope(s) of work

- Practical components (covering, scaffolding, power, timing, cost, drying, procurement)

Phase 2 Objectives and Considerations

The purpose of the Phase 1 Assessment Report was to identify the key findings and recommendations of a year-long investigation conducted by Stevens & Associates in partnership with Silman. The investigation assessed the conditions of the stone masonry, interior steel framing, stairs, elevator, and the existing electrical systems, with the goal of understanding the unique issues that have caused distress in each component, and to provide thoughtful recommendations that will address the root causes of the observed distress.

The primary objective of Phase 2 was to complete additional recommended scopes of work to further identify the architectural, material and engineering conditions of the Monument as it stands today. This included in-depth stone testing and mortar analysis, extraction of stone cores and samples, petrography, building enclosure and hygrothermal review, mechanical engineering preliminary assessment, water infiltration and IR testing, architectural preservation review and analysis, masonry strength testing, structural finite element analysis, lightning protection and grounding assessment, preliminary geotechnical investigation, additional electronic crack and moisture monitoring, and non-destructive evaluation included rope access for documentation. This information has been synthesized to create a restoration strategy that is based on these findings, and the application of best practices for restoration, rehabilitation, repair, and conservation.

Synthesis of Data: Synopsis of Individual Consultant Reports

The strength of our team lies in the relationships we have established within the preservation community specifically and the architectural and engineering industries in general. Onsite assessment work and documenting and reporting is a shared language. Understanding the strengths of each consultant, providing them with the means to perform their work, and knowing how to interpret the language, implement the data and capitalize on the investment in time and material to perform the conditions assessment are the key components to a successful project.

In looking at the specific challenges presented by the Bennington Battle Monument, the type of structure, material, construction period and location all play a critical role in understanding the project and how the structure is behaving.

The Team's understanding of the task at hand enabled us to determine the appropriate restoration approach. The resulting investigative work included performing highly specialized material and structural testing. The key aspects of the Monument that demanded the expertise brought to the project are:

A. The Monument is the second tallest unreinforced masonry obelisk in the United States. The Team has detailed experience with this type of structure.
B. Structural analysis and evaluation of this type of masonry construction requires specialized knowledge and experience in the performance and material properties of such construction.

C. National Historic Landmarks. Our team has decades of experience working on high profile buildings and monuments across the country that require a customized team of experts.
D. Understanding the complex behavior and deterioration cycles that occur on such structures-especially including tall masonry structures. This informs our recommendations for restoration strategies for mass masonry buildings.
E. Understanding—through practical experience—the parameters for designing and implementing successful restoration strategies including pinning, grouting, stone sourcing and replacement, waterproofing, and moisture control.
F. Project planning and pre-schematic design leadership provides a thorough understanding of the complexities of the project.

CONSULTANT TEAM
STEVENS & ASSOCIATES
Civil Engineers and Architects, Project Manager

EASTON ARCHITECTS
Preservation Architects

SILMAN
Structural Engineers

ATKINSON-NOLAND & ASSOCIATES
Non-Destructive Evaluation and Testing

JABLONSKI BUILDING CONSERVATION
Stone petrography and mortar analysis

LANDMARK FACILTIES GROUP
Mechanical Engineers

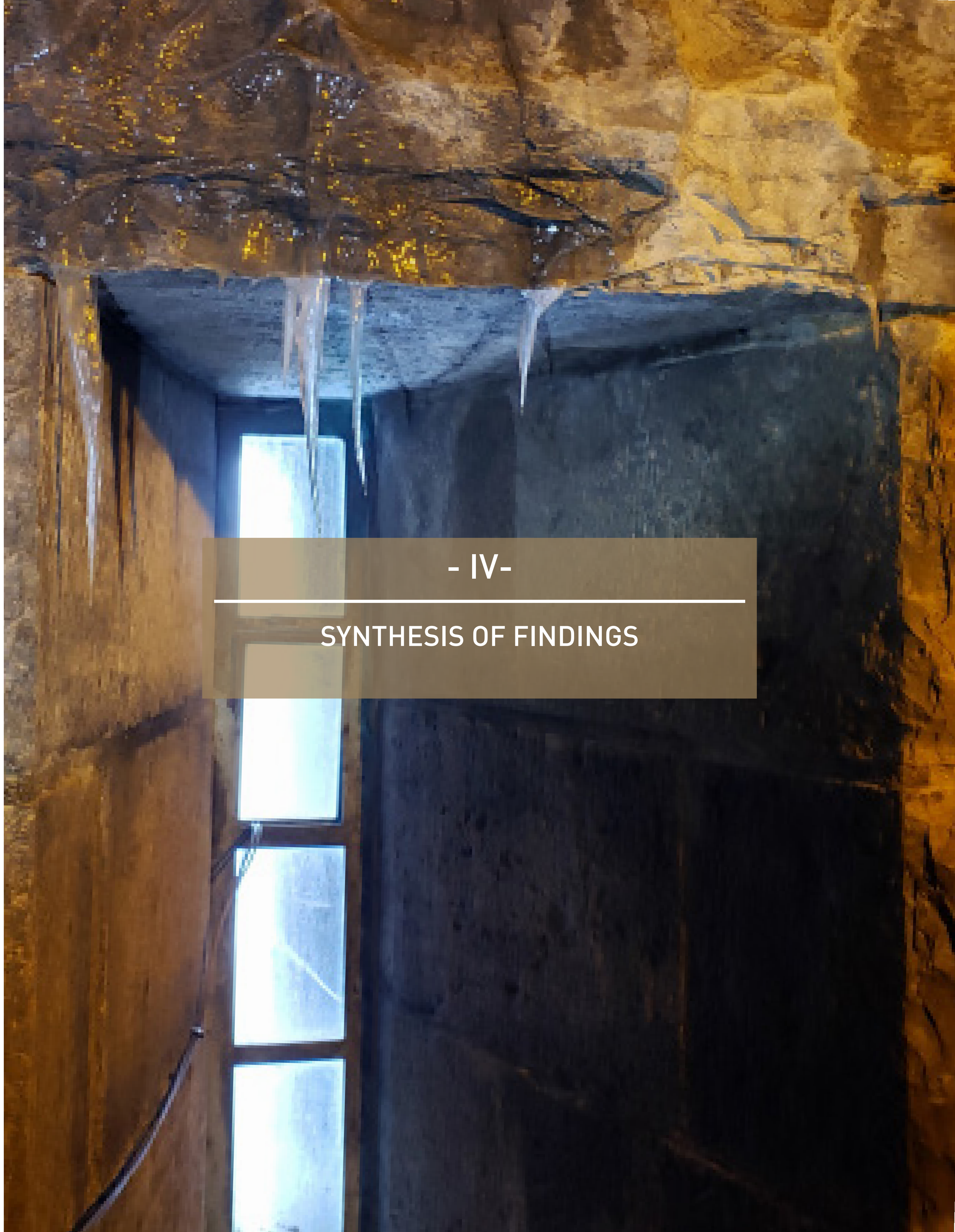
STEVEN WINTER & ASSOCIATES
Exterior building envelope consultants

LANGAN ENGINEERING
Geotechnical Engineers/Civil and Laser Scanning (Phase 1)

SMOKESTACK LIGHTNING
Lighting Protection Consultant

VERTICAL ACCESS (Phase 1)
Exterior Envelope Access and Assessment Consultant

LERCH BATES (Phase 1)
Elevator Consultant



- IV-

SYNTHESIS OF FINDINGS

Consultant Report Summaries

Silman: Structural Engineers (Full Report Appendix XX)

Phase 1 work performed by Silman provided beneficial information about the stone masonry of the Monument, including the general cross section of the wall, the pattern of visible cracking, the structural performance of the building relative to plumbness, measurement of overall forms of movement, and the structural performance of the building relative dead loads and lateral loads. The wide breadth of this phase of the investigation has allowed the design team to explore several potential causes of the widespread cracking observed throughout the stone masonry of the Monument. A singular cause for the cracking has not been identified, but rather a number of potential contributing factors have been established, including the following areas which will require further study and investigation:

1. Stone Material: The original stone used to construct the Monument may not have been the optimal choice for this type of structure. The stone was identified as dolomitic stone and is a harder and stronger stone than calciferous limestone, but it is nevertheless a sedimentary stone that is porous and permeable, and susceptible to moisture migration and freeze thaw damage. We recognize that this is not something that can be changed about the Monument. Preliminary analysis suggests that the strength properties of this stone may not be a primary concern, but rather the vulnerability of the stone to moisture related processes will need to be further understood to identify an effective restoration strategy.

2. Mortar: Original construction documents specified Rosendale and Portland cement-based mortars. Based on our limited sampling, the handful of previous masonry repairs appeared to utilize Portland cement-based mortars as well. Rosendale and Portland cement mortars tend to be harder and stronger than the expected strength of the dolomitic stone, though strength tests were not part of this phase of the investigation. Typically, in historic masonry construction, the desire is for the mortar to be the softer, sacrificial element in the wall assembly that will absorb and disperse localized stresses from the harder stones. These internal and external forces come from seasonal and even daily changes in volume and moisture expansion, thermal cycles caused by shifting of the stones, and freeze-thaw cycles. When the mortar is too hard, the stones become the softer, sacrificial component of the wall system.

Both the original mortar and repointing mortars on the monument do not appear to have the preferred qualities of a soft cement lime-based mortar. The compatibility of the Rosendale mortar is less clear as it had become obsolete for nearly a century as Portland cement became dominant in construction. The mortar is becoming relevant again as preservation projects have bolstered demand and more information is becoming available.

Further investigation is required for multiple reasons; firstly, to help establish if the original mortar selection was a leading cause of the frequent cracks and overall sub-optimal performance of the mortar, and secondly, to ensure that future repair mortars are compatible with the existing masonry and can be correctly specified to avoid perpetuating any incompatibility.

Silman's primary structural engineering scope of work in Phase 2 was to perform more detailed structural modeling of the Monument for global and local performance of the structure to investigate potential modes of failure and states of stress. Finite Element Modeling and hand calculations were further informed by incorporating the material condition, movement data, strength, stress, and stiffness provided by the additional testing performed in Phase 2.

During this phase, a structural analysis of the Monument was performed. Below is a synopsis of the methods used:

- Hand calculations (using spreadsheets developed by Silman for this project) were used to analyze building elements to verify whether they are sufficient to resist the global forces and stresses including seismic and wind forces.

- A three-dimensional analytical Finite Element (FE) shell model was created from the laser dimensional point cloud using the software SAP2000. This allowed for review of the stresses, forces, and deformed shape under different load conditions and combinations, including behavior under its own self-weight, wind forces, and a nonlinear pushover analysis.

- A three-dimensional analytical Finite Element (FE) solid model was created to achieve a more detailed understanding of the effects of cracks, specifically in situations with a reduction of cross section or a disconnected corner. By completing a linear gravity and lateral wind analysis, an evaluation of the potential increases of stress from such conditions was completed.

- The structural effect of reduced material cross sections was studied through hand calculations and the FE model. Specifically, we investigated the effects of having a structure in which the stresses were redistributed through a smaller area due to cracks in the Monument.

- Capacity of individual masonry units was determined (via lab and in situ) and compared against stress values from the hand calculations and FE models. This was done to understand if localized failures are occurring due to high localized bending and/ or shear stresses.

- Potential stress build-up due to thermal differentials in the masonry was calculated and compared against the structural capacity of the masonry.

During Silman's Phase 1 study, it was concluded that the Monument's walls were stable and that stresses were within allowable limits based on hand calculations using current codes and idealized assumptions about the wall construction. Based on the Phase 2 analysis, including updated wall calculations, Finite Element Models, capacity checks and thermal analysis, a synopsis of Silman's conclusions is summarized below:

- It was concluded in Phase 1 that loads in the wall exceed allowable tension and compression stresses under a full code-defined seismic event. However, based on updated material properties and assuming a uniformly built and loaded wall, this net stress exceedance scenario does not occur.

- Assuming a solely uniform distribution of loads across the wall section, no issues were seen under gravity loads or lateral wind loads in both the hand calculations and Finite Element Models, with both the tension and compressive stresses below the limit of the tested compressive stress value. It is important to realize that this is an idealized assumption, and real-world conditions may present higher than desirable stress concentrations.
- The hand calculations showed that a reduction in the cross section of the wall leads to an increase to the stresses at the base of the Monument. A reduced cross section with just the inner wall working showed the most significant increase in stress (with both tensile and compressive stresses exceeding allowable values under code-defined conditions). This is representative of the cracked behavior of the structure, as cracks can change the load paths of the Monument, and lead to significant stress concentrations, such as the ones seen here.
- The cracked shell and solid models showed no global issues when analyzed under gravity loads and wind loads under idealized conditions. No tension developed in the model during the application of wind loads.
- The nonlinear analysis showed that the forces needed before inelastic behavior (permanent deformation) occurred were well above any limits it would realistically see through code-defined wind and seismic forces. Nevertheless, this analysis highlighted the effect that such large-scale cracking has on the concentration of forces and stresses.
- Unsupported lengths of individual stone units allow beam action in the masonry. Once the masonry is cracked, stresses due to lateral loading such as seismic and wind are higher than the allowable bending and shear capacity of some geometries and spans of stone present on the Monument. Issues such as mortar deterioration or missing mortar can cause a loss of support resulting in bending type action that can increase stresses locally. The extent of mortar loss would have to be significant to crack the masonry, but if combined with other structural stresses such as thermal or gravity it could cause overstress.
- Thermal stresses due to temperature fluctuations experienced by the Monument can exceed the allowable tensile capacity of the masonry. This may be a cause of widespread cracking that must be considered when designing repairs.
- Although no single item was proven as the cause of the cracking, it is likely that multiple of these issues occurring at the same time, has led to a cumulative effect of forces and stresses.
- The cracks were reported very early on in the Monument's history, so a rare, large lateral loading event (wind or seismic) is unlikely to have caused initial cracking. Rather, it is most likely that the repetitive nature of climatic stresses experienced in the short-term, like freeze-thaw and temperature cycles, were the initial cause of cracking. However, loading and the localized re-distribution of loads that has happened over time or may happen in the future could worsen the cracking.

A key observation in Silman's report notes from a structural perspective, while all the items in the list above are contributing factors to the deterioration of the masonry, it is the local stress concentrations that appear to be the initial cause of cracking. The cumulative effects of lateral loading, mortar loss altering the load path, progressive cracking changing the connectivity of the cross section, thermal and freeze-thaw effects could cause overstress in the masonry.

Any one of these mechanisms acting alone is not sufficient to cause the widespread cracking observed in the Monument, but the buildup of various stresses has the potential to exceed the allowable capacity of the masonry. Cracks and deterioration are due to local stresses rather than global behavior of the Monument under self-weight or lateral loads. The presence of cracks creates higher areas of localized, concentrated stresses, which in turn can cause more cracks.

From a structural perspective, while all the items in the list above are contributing factors to the deterioration of the masonry, it is the local stress concentrations that appear to be the initial cause of cracking. The cumulative effects of lateral loading, mortar loss altering the load path, progressive cracking changing the connectivity of the cross section, thermal and freeze-thaw effects could cause overstress in the masonry. Any one of these mechanisms acting alone is not sufficient to cause the widespread cracking observed in the Monument, but the buildup of various stresses has the potential to exceed the allowable capacity of the masonry. Cracks and deterioration are due to local stresses rather than global behavior of the Monument under self-weight or lateral loads. The presence of cracks creates higher areas of localized, concentrated stresses, which in turn can cause more cracks.

Atkinson-Noland & Associates: Consulting Engineers *(full report see Appendix XX)*

Atkinson-Noland & Associates (ANA) was on site to conduct supplemental nondestructive evaluation (NDE), facilitate the installation of additional structural health monitoring sensors, and to conduct material tests at the stone masonry walls.

This scope expands upon the 2022 Phase 1 ANA work that included NDE and one year of structural health monitoring, with the findings summarized in ANA's report titled, 'Final Report – Bennington Battle Monument 6-30-2022'. The main objectives of the work included confirming typical wall sections and the nature of internal wall construction with additional NDE via rope access, investigating stone unit and masonry wall assembly material properties and in-situ stresses (goodman jack and flat jack test), and to install additional sensors to expand and extend the duration of the structural health monitoring program.

ANA conducted the NDE and material testing from areas where walk-up access was available. Vertical Access (VA) assisted by conducting all other exterior NDE and sensor installation from higher portions of the monument via rope access. ANA personnel were on site May 22-25, 2023, for the NDE and expansion of the structural health monitoring program, and from July 17-20, 2023 for the material testing portions of the scope. Personnel from Silman, Stevens & Associates (S&A) and Easton Architects (EA) were on site during portions of ANA's field work to discuss findings and identify specific areas of importance through the monument. Contractor assistance by means of stone core removals and housekeeping support was provided by Alegrone during ANA's field work. The following bullets summarize the general wall construction of the Monument:

- Stone masonry walls are constructed of two- to three-wythes of stone masonry with dolostone and limestone.
- At the thicker base, the wall is three distinct wythes of stone masonry and further to the top it transitions to two distinct wythes. The uppermost approximately 20 courses are single wythe.
- The exterior face wythe appears to consist of only dolostone units with consistent coursing.
- The interior face wythe appears to consist of a combination of dolostone and limestone with more dolostone present lower on the monument, and more limestone present higher on the Monument.
- The interior face wythe is uncoursed and not dressed.
- Project contract and specifications from 1887 indicate the walls are to be built with one fifth headers. Generally, bond stones appear to bridge between two wythes of stones
- Mortar formulation was determined to match most closely that of a Type K mortar.
- Collar joint mortar appears different in composition and is more like a poured concrete. They contain large, crushed stone aggregates and appear to be 3" to 6" thick indicating that it would need to be poured in place rather than troweled by hand

ANA performed the following nondestructive evaluation tests to ascertain baseline information, including wall thickness and construction, and internal whythe construction. This information becomes valuable in understanding what exists in between the exterior and interior stone coursing, and its assembly, to help determine the cause of cracking, movement, voids, and solid surfaces and infill. The following investigative tests were performed:

Microwave Radar Scanning *(page 4 of report)*

Surface penetrating radar (SPR) was used to assess internal wall construction of the monument's stone masonry walls. The primary goal of the SPR scanning on this mobilization was to determine if stone thicknesses at the interior and exterior face wythes at higher portions of the monument were consistent with the findings from Phase I NDE work. Another main goal was to determine the consistency of internal wall conditions at varying heights up the monument, related to internal voiding and/or any presence of rubble construction. Previous findings from Phase I determined that the walls are primarily solid multi-wythe stone construction with coursed masonry throughout the thickness of the wall and not containing a rubble core.

- Approximately 125 SPR scans were collected and saved at four (4) interior and four (4) exterior locations higher up on the monument.

- There is a clear shift in stone thicknesses at the interior face wythe higher up the monument to favor thinner stone units. This is expected as the overall wall thickness reduces up the height of the monument.
- At approximately 150-foot up the monument, full depth bond stones began to be visible in the SPR data
- Though the overall wall thickness reduces up the height of the monument, there are still a similar frequency of bond stones.

Videoscope Evaluation *(page 11 of report)*

A series of 3/8-inch diameter holes were drilled into mortar joints such that a fiberoptic videoscope could be used to make visual observations. The videoscope investigation intended to determine the size and frequency of internal voiding within the wall, if present, and to characterize the materiality and solidity of the masonry between interior and exterior face wythes. The Phase II videoscope probes were selected in locations higher up the monument at the interior and exterior to supplement previous videoscope findings from Phase I.

Goodman Jack Cores *(page 11 of report)*

A Goodman Jack core is an extraction method of in-situ stone to investigate the deformability of the stone along its thickness. The goodman jack test then uses a special probe in the core hole to investigate the deformability of the stone in-situ as-existing in the wall assembly. In the case of the Monument, ANA had two (2) 6'-0" x 3" diameter cores extracted for investigation. This provided an additional opportunity to observe internal wall conditions at greater depths than was previously possible with the videoscope evaluation.

General Observations at Goodman Jack Cores Holes
South Core

- Visible condensation at the top of the core hole unrelated to the material extraction.
- 1st interior collar joint was previously 100% solid but shows visible distress after testing. A ruptured membrane came from the test as it pressed into the soft mortar

North Core

- The stone was visibly intact before the testing, but loading the masonry resulted in a vertical fracture through the stone unit for the full depth of the unit
- Interior face wythe and exterior face wythe appeared to be intact solid stone units
- Center of the wall appeared mostly solid with stone to mortar interfaces generally solid with some slight delamination

Spray Testing *(page 17 of report)*

Water spray testing was conducted to evaluate moisture intrusion through the stone masonry assembly of the Monument. Testing involved spraying pressurized water through a spray rack at the exterior of the north elevation.

The spray test was successful in producing leaks at the interior of the monument over the course of the testing. The first leaks were noted approximately 60 to 90 minutes into testing. These were small trickles of water flowing through visibly cracked stones at the interior approximately 40 feet below the spray frame. An example of such a leak is included in Figure 25. With more time (90 to 120-minutes), wet spots began to become observable at interior mortar joints. The first leaks noted (60 to 120-minutes) were those lower down on the monument starting above stair landing 22, approximately 40 feet below the spray frame. With time, leaks were noted higher up the monument closer to the elevation of water application.

Spray test results were generally consistent with the stone assembly being largely solid with a set of small, narrow gaps or cracks present between stones and mortar fill as well as cracked stones for moisture to migrate through.

Summary of Non-Destructive Investigations *(page 21 of report)*

Further nondestructive evaluation of the stone masonry walls at various heights up the monument on the interior and exterior determined that as-built conditions appear consistent across all four elevations and across all heights evaluated. The masonry walls typically appear to be coursed masonry through the entire wall thickness with some limited stone/mortar rubble fill at the center of the wall. Mortar/concrete and small pieces of stone or large pieces of aggregate were used to fill gaps between stone units.

Bond stones were located with Surface Penetrating Radar (SPR) throughout the monument at select elevations and heights up the Monument. Starting at heights of approximately 150-feet above grade, bond stone units that were full depth through the thickness of the wall were observed with SPR scans. Below 150 ft the bond stones were not full through-wall units.

In-Situ Materials Testing: *(page 21 of report)*

In-situ material testing was determined to be necessary to understand the compressibility behavior of the masonry. This test method for determining the deformation properties of existing unreinforced solid-unit masonry concerns the measurement of in-situ masonry deformability properties in existing masonry by use of thin, bladder-like flatjack devices that are installed in cut mortar joints in the masonry wall. This test method provides a relatively non-destructive means of determining masonry properties.

In-situ Deformability Testing

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). Two cycles of loading were conducted for each test. The initial cycle is used to seat the flatjacks and the second cycle provides a more accurate measure of the compression behavior of the masonry. The results are then

directly applied as known variables in calculations for determining the masonry wall compressive strength and behavior, to assist in determining if the stone is failing under its own weight, or if it has yet to meet its compressive strength capabilities (*refer to Silman Report for additional analysis on compressive strength*)

- Investigated compression behavior of the existing masonry using the flatjack method of ASTM C1197, *In Situ Measurement of Masonry Deformability Properties Using the Flatjack Method*
- Involved removing bed joint mortar for insertion of two parallel flatjacks
- Maximum stress applied was 1550 psi, at which point the test was stopped

In-situ Goodman Jack Testing *(page 31 of report)*

The elastic modulus of the stone masonry assembly was measured at two locations using a borehole dilatometer inserted into the two (2) Goodman Jack core holes. The dilatometer uses a radially expandable membrane that is pressurized within a cylindrical hole drilled into the stone. During the test, the applied pressure and hydraulic volume pumped into the membrane are measured to generate a test curve. As the membrane tightens against the walls of the core and begins to push against the stone, a linear relationship is observed between the volume that can be pumped into the dilatometer (a corollary for the expansion of the core diameter) and the hydraulic pressure. From this linear elastic region, a relationship between the hydraulic volume and pressure is calculated to determine the modulus.

Laboratory Stone Material Testing *(page 35 of report)*

Six (6) locations throughout the Bennington Battle Monument were selected by ANA, Silman, S&A, and representatives from the State of Vermont for stone cores to be removed for laboratory testing. Core locations were marked on site and Alegrone subsequently used a core drill to extract the samples and turn them over to ANA. Four (4) stone cores were sourced from interior stones and two (2) cores were sourced from exterior stones. The two tests performed on these samples were *Compressive Strength Testing* and *Dynamic Modulus Testing*.

Compressive Strength Tests are used to determine a material's behavior under applied crushing loads and are typically conducted by applying compressive pressure to a test specimen (in this case, extracted stone cores) using platens or specialized fixtures on a universal testing machine. During the test, various properties of the material are calculated and plotted as a stress-strain diagram which is used to determine qualities such as elastic limit, proportional limit, yield point, yield strength, and, for some materials, compressive strength. In the case of these tests, compressive strength was provided for all the tests. ANA also got compressive *modulus* for a few specimens. The compressive modulus is a ratio (basically the same thing as elastic modulus or Young's ratio) that relates the compressive stress to how much compression happens, meaning how much a stone will actually compress under a given stress.

Both wet and dry samples were tested for compressive strength. The modulus of compression for dry stone was 40% higher than for the wet samples, and the maximum pressure sustainable for the dry stone

PETROGRAPHIC ANALYSIS - ANA

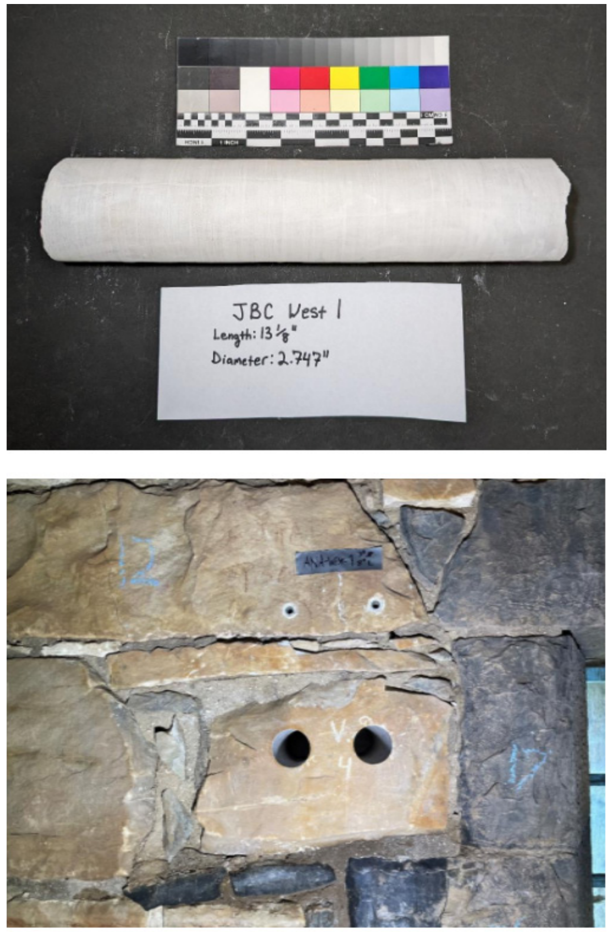


Image 03. Interior JBC-West-1

Image 02. Interior JBC-East-2

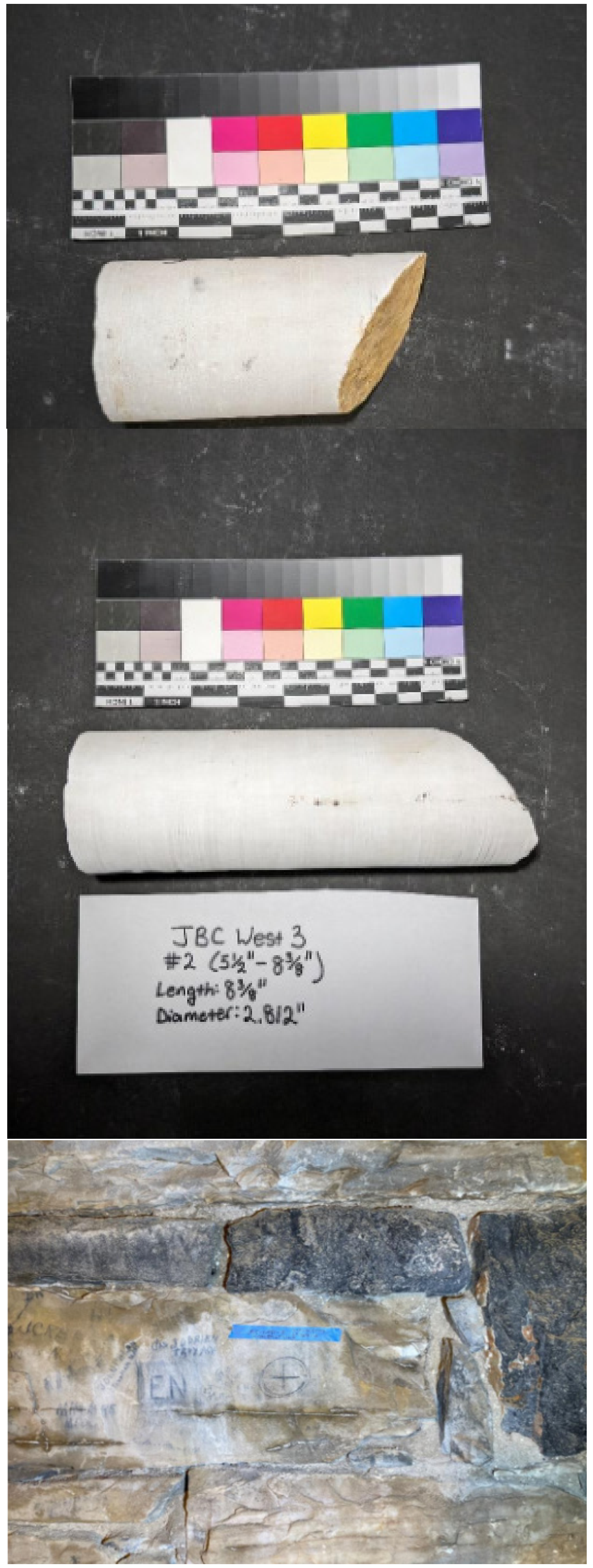


Image 05. Interior JBC-West-3 - 2 pieces

Image 04. Interior JBC-West-4

PETROGRAPHIC ANALYSIS - JBC

Image 07. Exterior JBC-North-5

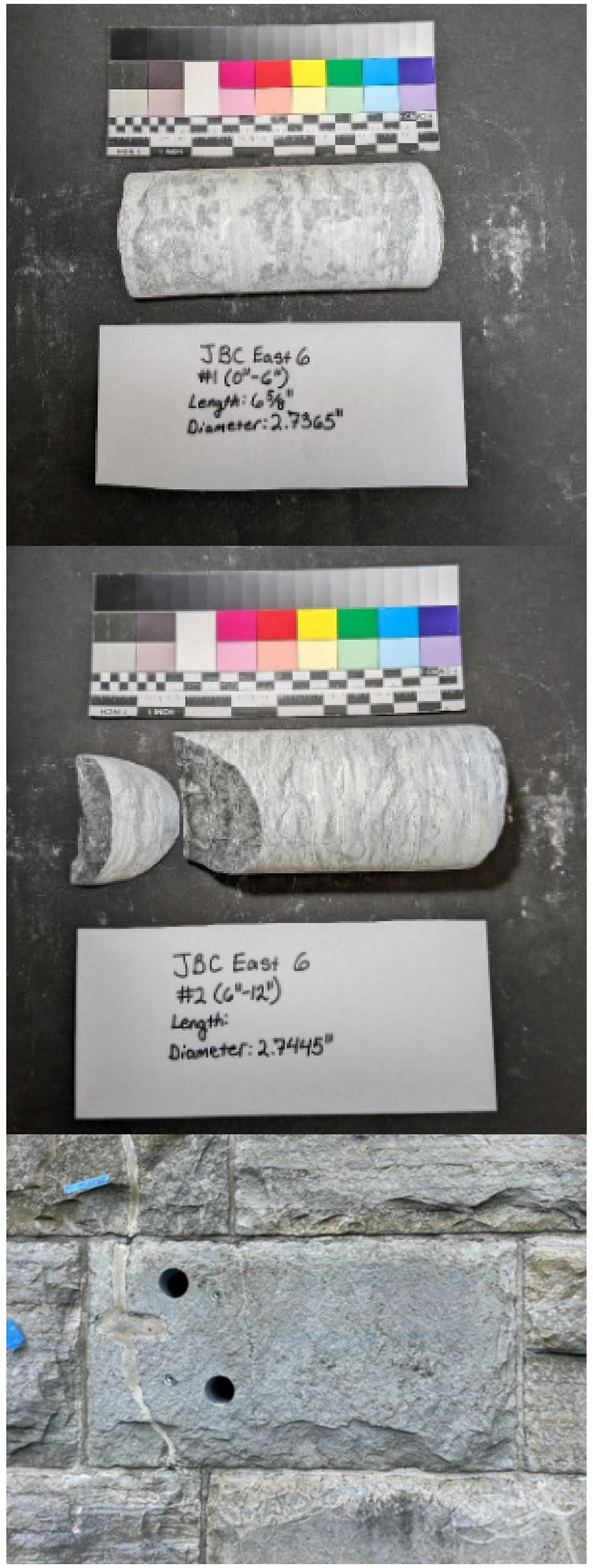


Image 06. Exterior JBC-East-6 - 2 pieces

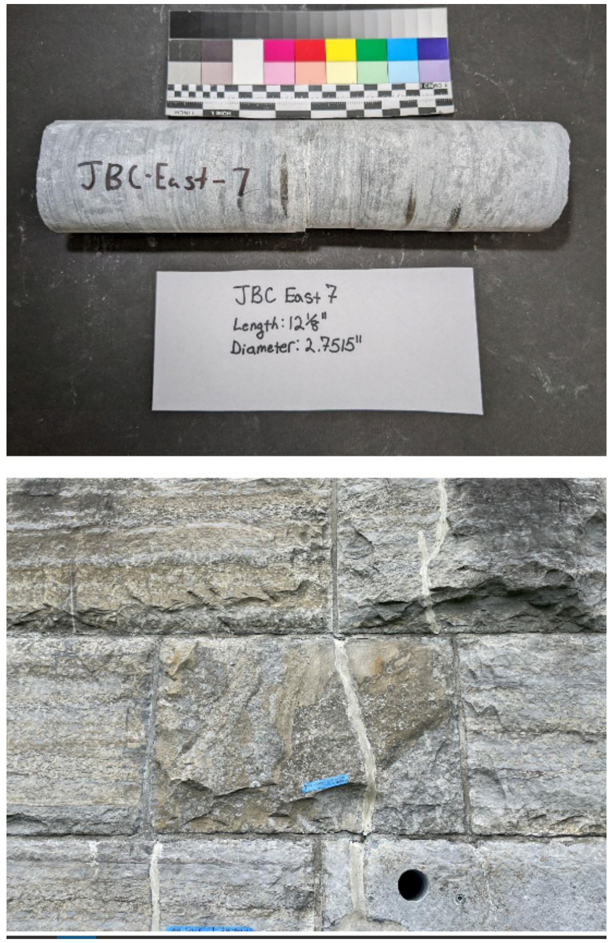


Image 09. Exterior JBC-East-7

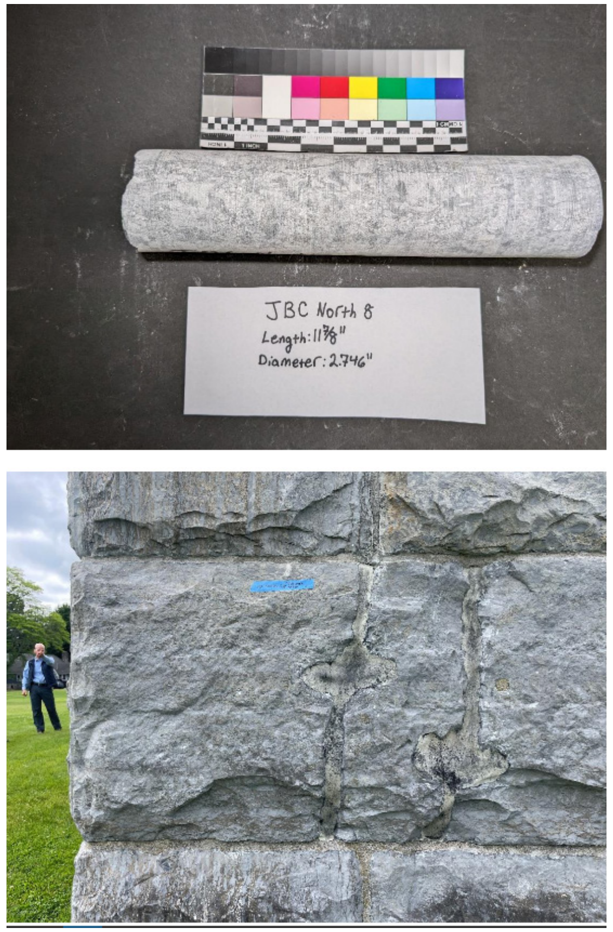


Image 08. Exterior JBC-North-5

GOODMAN JACK TEST

Image 15. Goodman Jack Test. *Stevens & Associates 07.17.2023*

Image 12. Flat Jack Test. *Stevens & Associates 07.17.2023*

Image 14. Goodman Jack Test. *Stevens & Associates 07.17.2023*

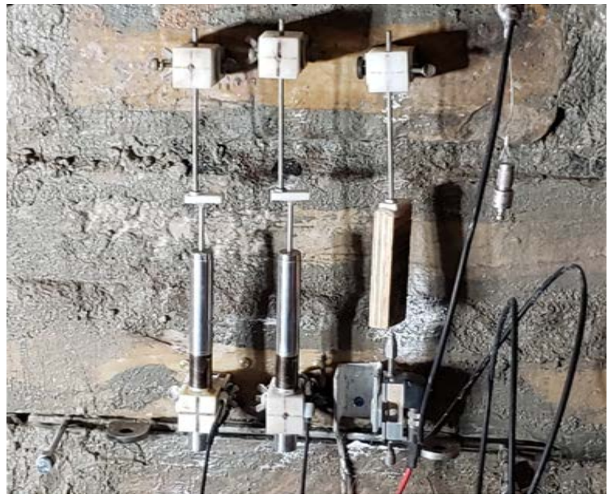


Image 11. Flat Jack Test. *Stevens & Associates 07.17.2023*

Image 13. Flat Jack Test. *Stevens & Associates 07.17.2023*

Image 10. Flat Jack Test. *Stevens & Associates 07.17.2023*

GOODMAN JACK TEST - Atkinson-Noland & Associates

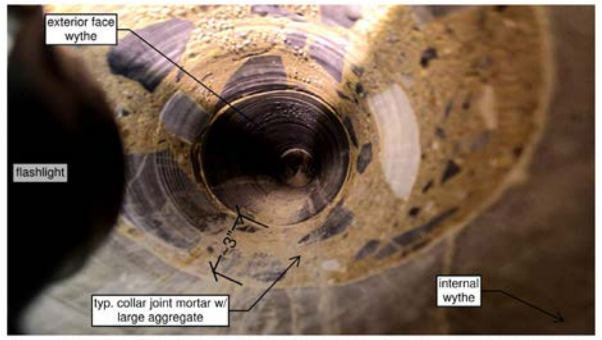


Image 17. CORE-SOUTH after Goodman Jack testing. *Atkinson-Noland & Associates*

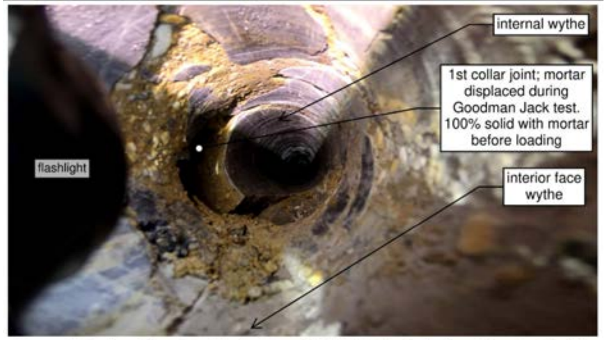


Image 23. CORE-SOUTH after Goodman Jack testing. *Atkinson-Noland & Associates*

Image 16. Internal wythe, CORE-SOUTH after Goodman Jack testing. *Atkinson-Noland & Associates*

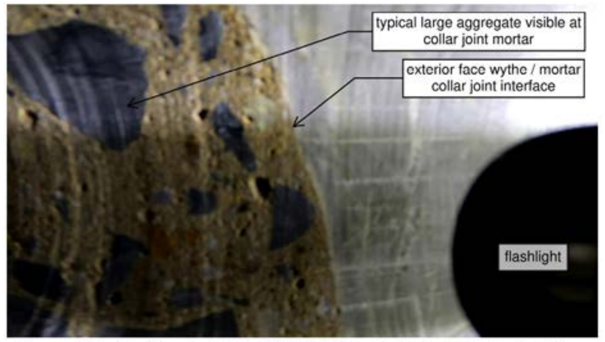


Image 20. Second collar joint, CORE-SOUTH after Goodman Jack testing. *Atkinson-Noland & Associates*

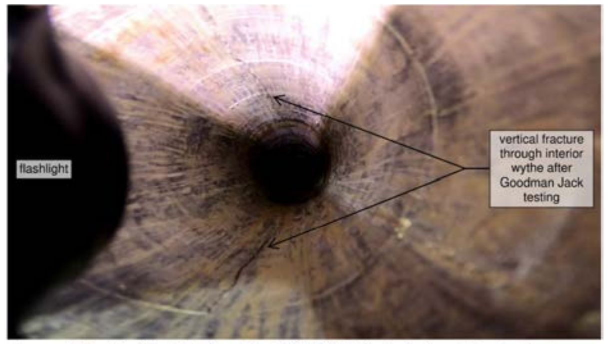


Image 18. Interior face wythe, CORE-NORTH after Goodman Jack testing. *Atkinson-Noland & Associates*

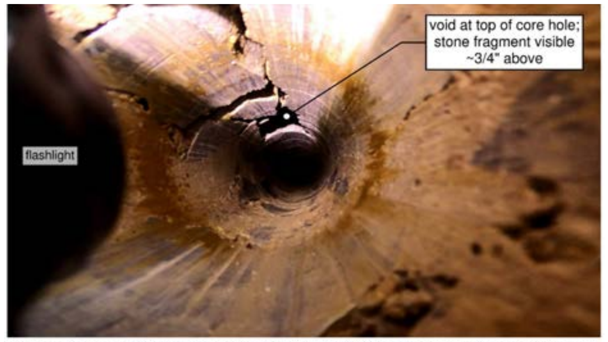


Image 21. Between interior and exterior face wythes, CORE-NORTH. *Atkinson-Noland & Associates*

Image 19. Between interior and exterior face wythes, CORE-NORTH. *Atkinson-Noland & Associates*

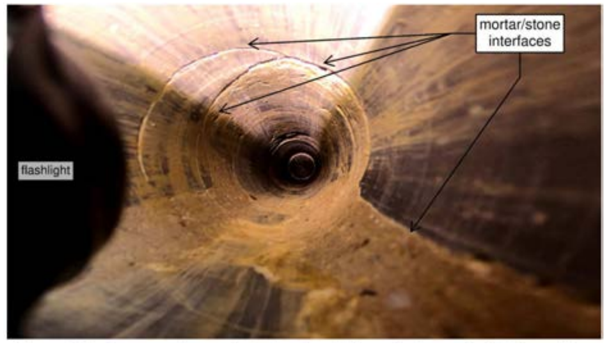


Image 22. Between interior and exterior face wythes, CORE-NORTH. *Atkinson-Noland & Associates*

HANDS-ON ARCHITECTURAL ASSESSMENT OF EXISTING CONDITIONS

SPRAY TEST - Atkinson-Noland & Associates

Image 26. North Elevation. *Atkinson-Noland & Associates*

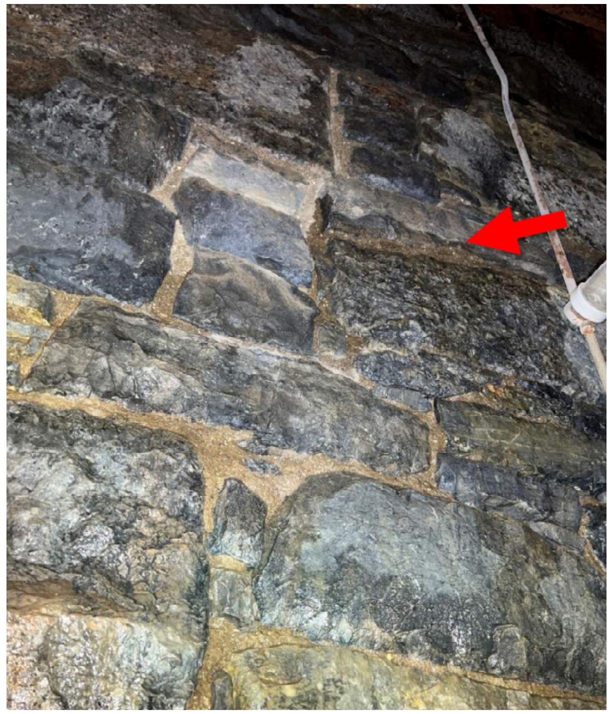


Image 25. Appearance of damp observed at mortar joint below interior stone work. *Atkinson-Noland & Associates*

Image 27. North wall following rainstorm with the prevailing wind coming directly from the north. The monument largely blocked wind driven rain from the leeward walls, with a small amount of moisture being blown and wrapping around the corners of the monument creating a clear line of moisture approximately half the length of a stone unit to the East and West elevations.. *Atkinson-Noland & Associates*

Image 24. Leak observed as a result of spray testing below crack at interior stone. *Atkinson-Noland & Associates*

SYNTHESIS OF FINDINGS

samples was 18% higher than the wet samples. As an observation, the wet stone is clearly compromised in its compressive strength, further defending the argument that a critical first step is drying the Monument.

Dynamic Modulus Tests apply a repeated axial cyclic load of fixed magnitude and cycle duration to a test specimen (in our case, the extracted stone cores). Test specimens can be tested at different temperatures and three different loading frequencies (commonly 1, 4 and 16 Hz). The applied load varies and is usually applied in a haversine wave (inverted cosine offset by half its amplitude – a continuous haversine wave would look like a sine wave whose negative peak is at zero). Dynamic modulus tests differ from the repeated load tests in their loading cycles and frequencies. The dynamic modulus test measures a specimen's stress-strain relationship under a continuous sinusoidal loading.

Test results charts are part of ANA's full report, located on page 37-38.

Jablonski Building Conservation: Materials Conservator *(full report see Appendix XX)*
Jablonski Building Conservation, Inc. (JBC) was contracted to analyze masonry materials and investigate deteriorated conditions at the Monument. The analysis included an on-site assessment of existing conditions, field testing of moisture properties, and laboratory analyses of stone, mortar, and salt samples removed from the Monument. The analysis was performed to identify the masonry materials and understand their deterioration mechanisms to inform repair work. A summary of the stone masonry as observed is as follows:

Methodology

To perform their work, JBC was onsite for a visual assessment June 20-23, 2023, and during this period performed a visual assessment of areas accessible on both the interior and exterior of the Monument, performed moisture measurements, and located and oversaw the extraction of eight (8) stone core samples, four (4) on the exterior and four (4) on the interior for testing. Eight (8) mortar samples were removed from selected areas of the Monument for testing, and seven salt samples were extracted for analysis using x-ray diffraction. Additionally, samples of stone and the large stone chip aggregate concrete from the deep cores recovered during the Goodman Jack tests were visually analyzed and tested. The following is a summary of the analyses and findings.

Materials Identification and Analyses

Stone-Exterior (Dolomitic Limestone)

- Minor superficial weathering considering the bulk of the stone to be cohesive and sound.
- Potential durability issue as the presence of pyrite, minor geological microcracks, and stylolites are found
- No deterioration related to this issue in the sample sent for analysis, but these could explain the delamination on the upper portion of the monument
- Microcracks pose a threat to moisture infiltration and ingress of salts and are susceptible to swelling during wet/dry cycles and to frost wedging

Interior (Calcitic Marble)

- Fine-grained calcitic marble; a locally quarried dolomitic limestone inferred to be from Southern Vermont
- As a calcitic marble, one great threat to the structural stability of the stone is granular disaggregation, or sugaring. These samples do not show evidence of sugaring and no potential durability issues were identified

Interior Dark Gray Stone (Dolomitic Breccia)

- Silicified dolomitic breccia described as clasts of uniform dolostone bound by recrystallized quartz. Locally quarried, though provenance could not be determined
- Sound and durable with no identified potential weaknesses within the bulk of the stone
- The veining is a potential weakness due to intrinsic properties iron oxide possess when exposed to wet/ dry cycles which may be the cause of the widespread cracking of the dark gray interior stone.

Mortar

- The natural cement mortars contain no lime as was typical of the time period.
- 1887 specifications indicated that the mortar joints were to be raked and repointed using Portland cement mortar after the stones had been laid in natural cement- a not uncommon practice of the time.
- The original natural cement mortars tend to have a moderate hardness and high permeability.
- Two later Portland cement-based mortars are also relatively permeable despite their cement-rich compositions.
- In one sample there is a minor incipient alkali-aggregate reaction (AAR) between the cement paste and the coarse limestone aggregate. Durability issues presented here are quite low.

Salt Identification-Potassium Salts

Carbonates

- Calcite is typically deposited from water that has passed through calcium hydroxide-bearing material including natural cement and Portland cement in mortars and concrete used to construct the masonry. When exposed to significant amounts of water, the free calcium hydroxide in these materials dissolves.
- Calcite deposits do not typically damage masonry. Rather, it is the underlying water infiltration causing the deposits that is likely to contribute to damage.
- Abundant calcite deposits also indicate depletion of the cementitious binder in mortar and concrete.

Nitrates

- Nitrates in this context can derive from the decomposition of organic materials.
- Danger of supersaturated salt solutions filling masonry pores in cold weather and subsequent crystallization and damage during dry periods and higher temperatures.
- Nitrate contribution to the deterioration of the Monument is likely limited and confined to the base of the Monument.

Summary of Observed Conditions

Exterior

- Main concern on the exterior Sandy Hill dolomite is the severe level of scaling and spalling with small to moderately sized fragments of the stone falling from the monument. No large spalls noted near the base.
- The second typical condition is vertical hairline cracks. Efflorescence is found along these cracks adjacent to previous repairs
- Previous caulk repairs are likely trapping moisture, leading to efflorescence and/or carbonate crusts as a result of wet and dry cycles
- Mortar loss is another typical condition; the bedding mortar is completely disaggregated on the interior of the joints.
- Biological growth is typical. It appears to be concentrated on the stone units with heavier rustication, the top third of the monument, and the northwest and southwest corners.

Interior

- The interior is in fair to poor condition, with the stone being damp to fully saturated. This is concentrated at the corners
- Large cracks and separation at the joints were noted at the corners running the height of the obelisk
- Cracks are a typical condition for both limestones on the interior.
- This includes vertical and horizontal cracks running along the bedding planes of the stone and “alligatored” cracking. The combination of these two in certain stones creates a polygon pattern
- Several window lintels have hairline vertical cracks at the center of the stone running the full height of the unit
- Due to dampness in the bottom third, efflorescence and disaggregated mortar are found along the corners of the monument. This is in a thin and patchy condition.

- In several locations the dark gray stone has eroded unevenly, leaving behind small, raised portions of unseated stone, likely due to the internal geology of the stone. This may have structural stress implications.

RILEM Surface Water Absorption Testing

RILEM Surface Water Absorption Tests were performed to analyze the rate at which water was absorbed by the exterior stone of the Monument. The goal was to gauge the absorptive capacity of the stone to understand how much water moving into the Monument is absorbed. This can help determine the rate of drying necessary of the stone, the interior of the Monument, and understand the variability of water that is absorbed versus water that is moving through the cracks and open joints.

Tests were performed only on the exterior of the Monument, as JBC attempted to perform RILEM surface water absorption tests on the interior masonry in order to understand and measure the porosity of the stone. However, all attempts failed because soiling, the friable surfaces of the stone and mortar, and the moisture already present in these materials prevented the adhesive putty required to hold the measuring tube in place from sticking to the surface. A general conclusion can be drawn that the interior stone is saturated to close to 100% capacity.

RILEM is an acronym for the International Union of Laboratories and Experts in Construction Materials, Systems and Structures (RILEM, from the name in French *__R__éunion __I__nternationale des __L__aboratoires et __E__xperts des __M__atériaux, systèmes de construction et ouvrages*) The organization was founded in June 1947, with the aim to promote scientific cooperation in the area of construction materials and structures. The mission of the association is to advance free-access scientific knowledge related to construction materials, systems, and structures and to encourage application of this knowledge world-wide.

Testing Methodology

A tube-like apparatus is used to measure the rate at which water is absorbed. This is affixed to the sample between the flat circular brim of the pipe and sample area. Water was added through the upper, open end of the pipe. The quantity absorbed was read from the tube every minute for five minutes, and the test was performed at four locations. All four locations were minimally absorbent; water is likely infiltrating at failed mortar joints.

Summary of Determinations:

- Based on BBM examination and nearby buildings constructed of similar materials, the conditions affecting the monument appear to be inherent to the properties of the Sandy Hill dolomite and locally quarried stone from Bennington, Vermont.
- The stone is in a petrographically sound condition
- The level of deterioration is consistent with the types of stone, age of the monument, and cycles of deferred maintenance.
- Moisture infiltration exacerbates many of the potential deterioration mechanisms

MATERIALS EXAMINATION - JBC

Image 33. Typical exterior condition. *Jablonski*

Image 30. Typical interior condition. *Jablonski*

Image 32. Typical interior condition. *Jablonski*

Image 29. Efflorescence and/or carbonate crusts below an earlier caulk repair. *Jablonski*

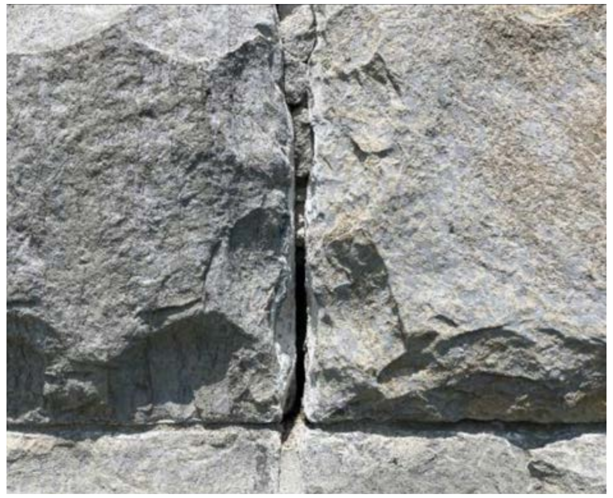


Image 31. Open joint near base of the monument. *Jablonski*

Image 28. Biological growth on surface of exterior stone. *Jablonski*

MATERIALS EXAMINATION - JBC

Image 39. Discoloration due to dampness in the corners of the observation platform. *Jablonski*

Image 36. Efflorescence and/or carbonate crusts along cracks and mortar joints. *Jablonski*

Image 38. Rust-colored crust on the surface of the dark gray stone. *Jablonski*

Image 35. Light efflorescence on the surface of the stone units and mortar joints. *Jablonski*

Image 37. Void between two stone units. *Jablonski*

Image 34. Uneven surface texture of dark gray stone unit. *Jablonski*

MATERIALS EXAMINATION - JBC

Image 45. Shallow spall. *Jablonski*

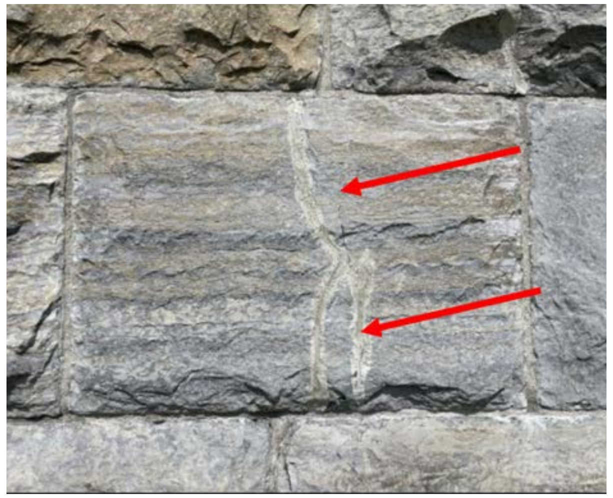


Image 42. Previously repaired crack and hairline crack extending from previous repair. *Jablonski*

Image 44. White growth along hairline crack. *Jablonski*

Image 41. Path of separation at the corner. *Jablonski*

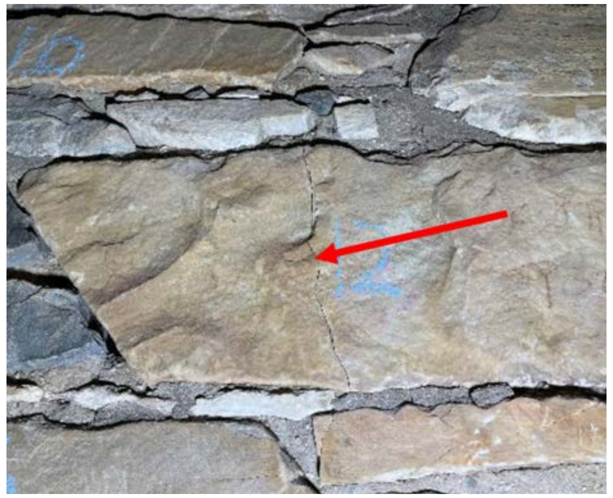


Image 43. Vertical crack. *Jablonski*

Image 40. Vertical crack running the full height of a window lintel. *Jablonski*

HANDS-ON ARCHITECTURAL ASSESSMENT OF EXISTING CONDITIONS

MATERIALS EXAMINATION - JBC


Image 51. Shallow spall. *Jablonski*

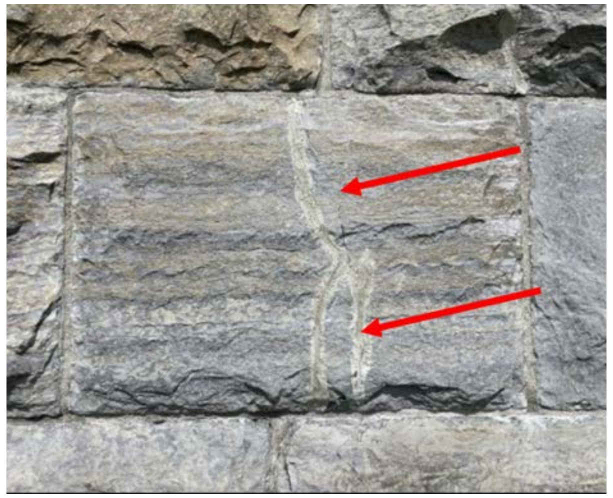


Image 48. Previously repaired crack and hairline crack extending from previous repair. *Jablonski*


Image 50. White growth along hairline crack. *Jablonski*


Image 47. Path of separation at the corner. *Jablonski*

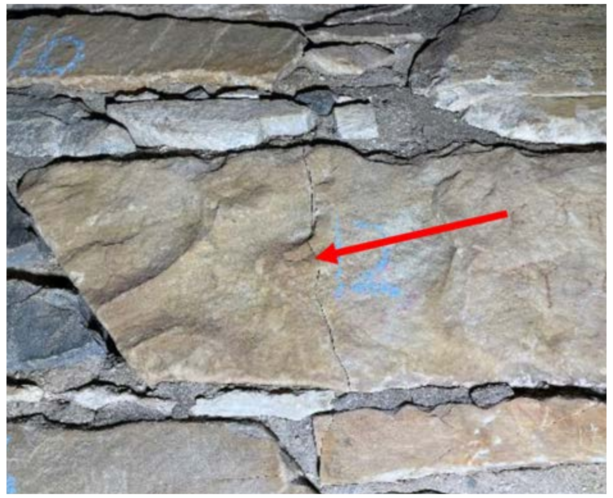


Image 49. Vertical crack. *Jablonski*


Image 46. Vertical crack running the full height of a window lintel. *Jablonski*

SYNTHESIS OF FINDINGS

- The top of the monument has seen the most repointing campaigns, and probably exhibits more of these deteriorations than the base of the monument which was studied.
- High cement content mortar is too hard compared to the stone, which could exert pressure on the stone to create microcracks and entrapment of moisture that can lead to cracking.
- The majority of the exterior mortar joints on the upper portion of the monument do not appear to be intact. Sandy Hill dolomite has a low water surface absorption rate (RILEM testing) which may cause infiltration openings in the exterior. These openings mean the interior stone and mortar have a high moisture content with the mortar particularly inundated.

A significant note is the observation that JBC states the stone cracking is not material, its structural. It was noted that a high percentage of the observed cracks are vertical through the stones and not along the natural bedding layers, suggesting that the forces cracking the stones are tensile likely caused by localized stresses. A differential moisture profile within the wall may also be contributing to the cracks due to the consistently wet interior stones being of a smaller face, marble, and as much as a third more open joints based on stone coursing. Flexural tension stresses may also be occurring locally near openings or where stones bridge missing or weakened mortar areas.

Landmark Facilities Group: *(full report see Appendix XX)*

Landmark Facilities Group (LFG) assessed the interior environmental conditions of the Monument, with both onsite work in May and June of 2023, and through intensive analysis of the data supplied from ANA. Understanding the interior environment of the Monument, the primary objective was to develop a method to reduce the saturation on the stone, and to reduce the overall relative humidity in the interior. The second objective was to provide an overview into the solution for managing the interior temperature and relative humidity, and the impact this solution would have on aiding the design team in developing the solution and duration for drying out the Monument.

Sources of Moisture within the Monument

There are two likely sources for the moisture found within the interior of the monument.

1. The first source is from water passing through the stone from the rain penetrating the exterior.
2. The second source is from condensation on the stone interior during certain periods of the year.

Since the stone has a large thermal mass, it likely stays cold enough to be below the outside air dew point well into the spring and summer. Since moisture in the air behaves like a gas, the moisture content of the air inside the monument will respond quickly to changes outside. As the higher dew point air hits the cold stone, it condenses. The ideal time for performing the internvetion to dey the Monument is likely April to September.

Analysis of Monitoring Data

The data provided by Atkinson-Noland Associates shows the stone temperature within 9” of the interior surface of the stone and the interior space temperatures are very closely correlated. It reaches a high temperature of about 75°F in August and a low temperature of about 10°F for a short period in February. The cyclical range of temperature over the seasons also correlates closely with the range of temperature of the outside air. This is not surprising considering saturated stone offers very little insulating value (even when 84” thick!).

The monitoring data for the interior air in the monument shows the relative humidity experiences wide swings from lows of 30% to highs of 100%. These swings are occurring very rapidly, most likely in response to changes in weather. Starting in Late May through September, the RH swings are less dramatic and have lower peaks and higher troughs. The highs are down around 85% and the lows stay above 40%. The RH reduction starts roughly when the stone reaches about 70°F in late May and continues until the stone temperature drops below 60° in the fall. The fact that the RH peak values drop as the space warms seems to indicate that the moisture content of the air inside the monument is somewhat stable and that the saturated stone is not an unlimited source of moisture that causes continuous saturated air inside the monument.

Requirements for Moisture Removal

The first calculation is based on a formula for estimating the rate of evaporation from poured concrete. The formula was developed by Paul J. Uno based on the Menzel formula and uses the air temperature, material temperature and the air RH to predict the pounds of moisture per square foot of surface area. As expected, the evaporation rate is very near zero when the stone is cold (at or below the dewpoint of the air in the monument) and increases rapidly as the stone is warmed.

Based on this formula, and using the data collected by ANA, we arrived at 2 estimates:

- Average evaporation rate: 14 gallons per hour
- Peak summer evaporation rate: 61 gallons per hour

The second approach was based on analysis of the temperature and relative humidity data collected by ANA and converting the readings into the humidity ratio. The humidity ratio is defined as the ratio of the mass of water vapor in humid air over the mass of dry air in a body of air. The result is the pounds of water in the air per pound of dry air.
The approximate volume of air in the monument is roughly 96,000 cubic feet
Density of dry air equals 0.078 pounds/cubic ft-mass of dry air in the monument is roughly 7,500 pounds.

Since the humidity ratio (W) is known from the T & RH data, the pounds of moisture in the air can be calculated by multiplying the pounds of dry air by the humidity ratio. Judging from the T & RH data, the desired humidity ratio for drying out the stone is approximately 0.0038 pounds of water in the air per pound of dry air. On a peak day this is roughly 109 lbs of water or about 13 gallons of water. Assuming the monument has an air exchange rate of about once an hour when the entry door is open, the moisture removal rate to dry the stone calculates to a removal rate of about roughly 13 gallons per hour.

Potential Volume of Water in the Monument

The testing to date has determined that the stone walls of the monument are saturated with water. The team has estimated the volume of stone comprising the monument roughly 150,000 cubic feet with roughly 5% of the volume being void spaces. If the stone is saturated as is believed, the water volume could be as high as 55,000 gallons.

Humidity Control

There are two primary means of removing moisture from the interior of the monument:
Natural Ventilation. Ventilation would involve introducing air at lower elevation of the monument and exhausting it at high elevation of the monument. Ideally this would be accomplished using the stack effect. Stack effect is the movement of air into and out of buildings and chimneys and is driven by air buoyancy.

Buoyancy occurs due to a difference in indoor-to outdoor air density resulting from temperature and moisture differences. The result is either a positive or negative buoyancy force. The greater the thermal difference and the height of the structure, the greater the buoyancy force, and thus the stack effect. If the air in the building is warmer than outside, this warmer air will float out the top opening, being replaced with cooler air from outside. If the air inside is cooler than that outside, the cooler air will drain out the low opening, being replaced with warmer air from outside. To develop a predictable ventilation rate in the winter, it may be necessary to introduce some heat within the monument to create a buoyant force.

Mechanical ventilation. Mechanical ventilation would require the use of a fan to exhaust the air from the structure. The most practical method would be to have a fan above the observation level drawing air from below the observation level and pressurizing the space above the observation level, so air was pushed out of the vents to the exterior. The challenges related to introducing ventilation are:

The observation level creates an obstruction to free ventilation between the bottom 200’ of the monument and the roughly 100’ above the observation level.

The ventilation would need to be controlled by monitoring inside air conditions and outside air conditions and only ventilating when the outside air had a lower moisture content than the inside air.

Dehumidification

Dehumidification would require a mechanical system to reduce the moisture content of the air and drain the moisture away from the interior. It may be possible to locate numerous dehumidifiers on the various stair landings below the observation level.

Sources of Heat

If it is determined that adding heat to the air in the monument to create a more predicable buoyant force for natural ventilation, the potential heat sources include Fuel Fired Boiler and Geothermal Heat Pumps.

Fuel Fired Boiler

A fuel-fired boiler would have to be located remotely and steam or hot water piped underground to the monument-similar to what was done in the past.

Geothermal Heat Pumps

It may be feasible to locate water-to-water heat pumps in the basement of the monument tied to a geothermal loop field in the ground surrounding the monument. Geothermal heat pumps are an efficient way to produce heat.

Steven Winter Associates: *(full report see Appendix XX)*

Steven Winter Associates (SWA) was engaged to analyze the hygrothermal properties- heat and moisture as it relates to movement through a building or structure- of the masonry walls of the monument, which are currently saturated. SWA performed an analysis of the masonry wall to study options to promote drying of the masonry. The basis for this evaluation was the utilization of WUFI Pro 6.7 software to simulate the existing masonry wall assembly and options to promote drying.

WUFI software simulates one-dimensional dynamic models; as described by its developer, it “allows realistic calculation of the transient coupled one- and two-dimensional heat and moisture transport in walls and other multi-layer building components exposed to natural weather”. WUFI is a German acronym that stands for “*Wärme-und Feuchtetransport instationär*”. This translates in English to “Transient Heat and Moisture Transport”. This software is typically used to analyze and optimize hygrothermal properties of proposed exterior wall assemblies and is used here to evaluate how climate may be manipulated to optimize drying of the currently saturated masonry.

The simulation parameters were established from the petrography results, mortar tests, RILEM tests and Goodman Jack tests, to establish the input for the dynamic modeling. The reports reviewed include:

- Structural Engineering Evaluation, prepared by Silman and dated December 15, 2022
- Materials Examination Report prepared by Jablonski Building Conservation, Inc., (JBC) dated October 2023
- Stone Masonry Evaluation prepared by Atkinson-Noland & Associates, Inc. (ANA), dated September 20, 2023
- Monitoring Data Summary, prepared by ANA, dated March 4, 2023.

For additional material selection parameters, and calibration data, please refer to page 3 of the SWA report. Of all the variables that were manipulated, reduction of interior climate relative humidity was most effective for reducing masonry total water content (refer to Appendix A - WUFI Analysis, South Masonry Wall - No Added Moisture + Reduced Interior RH models, Pages 9-14 of SWA Report).

This model includes a combination of both the elimination of additional moisture source and reduction of interior relative humidity from the existing 72% RH with a 50% amplitude to 60% RH with a 20% amplitude. The elimination of additional moisture source represents repair of exterior masonry wall

surfaces: repointing existing open mortar joints and repairing cracks that facilitate water infiltration. As water infiltration through the masonry wall is a primary contributor to elevated interior humidity, eliminating the additional moisture source is necessary to reduce interior relative humidity.

The most significant observation from the WUFI Model Analysis is to reduce interior elevated humidity by optimizing ventilation. This is in direct correlation with Landmark Facilities Group assessment, this may be achieved by passive or mechanical methods during optimal weather conditions, such as when exterior relative humidity is lower than interior relative humidity (generally during spring, winter and autumn). Consider strategies to improve ventilation and reduce humidity for a temporary period before repair campaign commences, temporarily during construction and by more permanent methods after completion of construction.

Langan Engineering: *(full report see Appendix XX)*

Langan Engineering was retained to provide a geotechnical engineering assessment on the grounds of the Monument to obtain necessary information on subsurface conditions and provide geotechnical related recommendations for a scaffolding system and covered walkway as well as verifying the depth to bedrock and the adequacy of the bedrock to support the loads imposed by the Monument that would be required for the proposed restoration work.

SUBSURFACE EXPLORATION AND FINDINGS

The subsurface exploration program consisted of drilling three geotechnical borings identified as B-1 through B-3 and installing a groundwater observation well in completed boring B-3. The borings were located at about 30 feet away from the monument. The borings were drilled by Cascade Remediation Services, LLC on 17 and 18 January 2024, under the full-time observation of a Langan engineer.

A groundwater observation well was installed in completed boring B-3. The well consisted of 10 feet of 2-inch-diameter Schedule-40 PVC slotted-pipe (screen) and a solid riser PVC-pipe extending to ground surface. The annulus around the pipes were backfilled with filter sand to about 2 feet above the screen and sealed with a 2-foot-thick layer of bentonite pellets. A protective flush-mounted steel well cap was installed at the ground surface.

SUBSURFACE CONDITIONS

The subsurface stratigraphy at the site consists of a layer of topsoil underlain by sandy clay, and then competent bedrock. A description of each stratum is given below in order of increasing depth.

Topsoil
A layer of topsoil was encountered immediately below the ground surface. The topsoil generally consists of brown fine to medium sand, with varying amounts of silt, and gravel and extends up to about two feet below grade.

Sand and Sandy Clay

Below the layer of topsoil, a layer of brown, fine sand, with varying amounts of clay, silt and gravel was encountered in B-3(OW) and extended to a depth of about 5 feet, corresponding to about el. 862. The sand is classified generally as SC (clayey sand) in accordance with USCS.

Bedrock

Bedrock was encountered beneath the sand/clay layer in all three borings and depth to bedrock was observed to be vary from about 7 to 12 feet below the existing ground surface.

Groundwater

Groundwater level was monitored in the observation well installed in boring B-3(OW). The ground water level was measured at the end of the second day of our subsurface exploration. The measured static groundwater was about 10 feet below grade corresponding to about el 857. In general, the groundwater level was recorded within about two feet of the top of bedrock surface, indicative of potential "perched" water conditions.

Laboratory Testing

Laboratory tests were performed on selected rock and soil samples to define physical and mechanical properties. The laboratory tests consisted of:

- Two Sieve Analyses (ASTM D 6913)
- Two Atterberg limit Tests (ASTM D 4318)
- Two Rock Unconfined Compressive Strength (ASTM D 7012)

Existing Monument

In review of the Elevation Plan prepared by Langan in Phase 1 (Drawing No. EL-01 to EL-04), dated 11 May 2022, it is understood that the basement level is at about El. 860. The subsurface profile observed during the subsurface investigation encountered bedrock at varying elevations from El. 856 to El. 861. When comparing the elevation of the below grade level now with the depth to rock within the borings, it is believed that the existing monument is bearing on bedrock. Based on the borings performed at the site and discussions with Silman, it is believed that the foundations of the monument were likely proportioned for an allowable bearing capacity of about 10 tons per square foot (tsf).

When structures are bearing on bedrock and load is applied, there is not a traditional settlement of the structure, but more of a compression of the rock surface. We note that since the monument is believed to be bearing on bedrock, we anticipate that when the monument was constructed it likely exhibited compression of the rock surface on the order of ½ inch or less. If additional loading is planned to be applied to the existing monument structure or foundations, we recommend that a test pit excavation be performed to identify the size, character and bearing material of the existing foundation.

The data provided, and the appendices in Langan's report support the structural approach that would be undertaken when the design of a scaffolding and covered walkway system is commenced. The considerations of ground water, uplift, seismic, bearing capacity on bedrock and additional loading on the

GEOTECH DRILLING

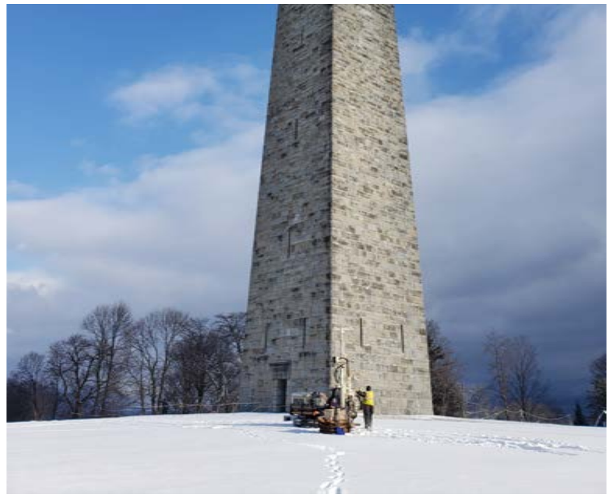


Image 52. Geotech Drilling. *Stevens & Associates 01.17.2024*

Image 53. Geotech Drilling. *Stevens & Associates 01.17.2024*

Image 54. Geotech Drilling. *Stevens & Associates 01.17.2024*

Image 55. Geotech Drilling. *Stevens & Associates 01.17.2024*

Image 56. Geotech Drilling. *Stevens & Associates 01.17.2024*

Image 57. Geotech Drilling. *Stevens & Associates 01.17.2024*

Monument (external anchoring, covering, stabilization, etc.) raise key issues for consideration, with the data providing the basis for the engineering design work required. This is addressed in our Project Planning Phase.

Smokestack Lightning: Lightning Protection Design *(full report see Appendix XX)*

On Wednesday September 13th, 2023, a representative from Smokestack Lightning Inc. completed a visual inspection of the lightning protection system at the Monument. The results of the inspection are based on compliance with NFPA (National Fire Protection Association) 780, UL (Underwriters Laboratories) 96a and LPI (Lightning Protection Institute) 175 standards for lightning protection system installations. NFPA 780 and Ula 96 work in tandem as standards, and essentially provide guidelines for lightning protection systems. The major point is that lightning protection is not a code requirement, but an option and the National Fire Protection Association and the Lightning Protection Institute provide guidelines for best practices for design, installation, and inspection.

There are five (5) major components that make up the lightning protection system. These are:

- Air Terminal
- Conductor
- Grounding
- Common Bond
- Surge Protection

The existing system consists of 1 class II copper air terminal/lightning rod and 2 class II copper conductors that extend through the interior of the monument and leave the structure below grade. Class II conductors interconnect and carry current between strike termination devices and grounding electrodes on structures higher than 75' in height. The bulk of the system components that are installed are in place and in good condition, but there are deviations from the standard and issues of corrosion and deterioration that need to be rectified for full compliance. The largest issue is the design of the system with a single air terminal at the peak rather than additional air terminals at lower levels.

Overall, the lightning protection system components are in good condition, but there are maintenance issues and deviations from UL, NFPA and LPI standard that need to be addressed for full compliance. The original design of a single air terminal does not comply with NFPA 780 requirements and could potentially allow for lightning strikes to the lower sections of the tower. This report recommends further investigation of the condition of the grounding components of the lightning protection system and repairs and upgrades for full compliance with NFPA 780, UL 96 and LPI 175 standards.

The primary question becomes to what level of standards does the state want to meet with the protection system, and to what degree do they want to upgrade/repair or replace the entire system. With the overall budget we are looking at, a newly designed and installed system would be advisable to provide the highest degree of structural safety for the Monument and provide the highest level of protection (or insurance if you will) for the investment in restoring the Monument.

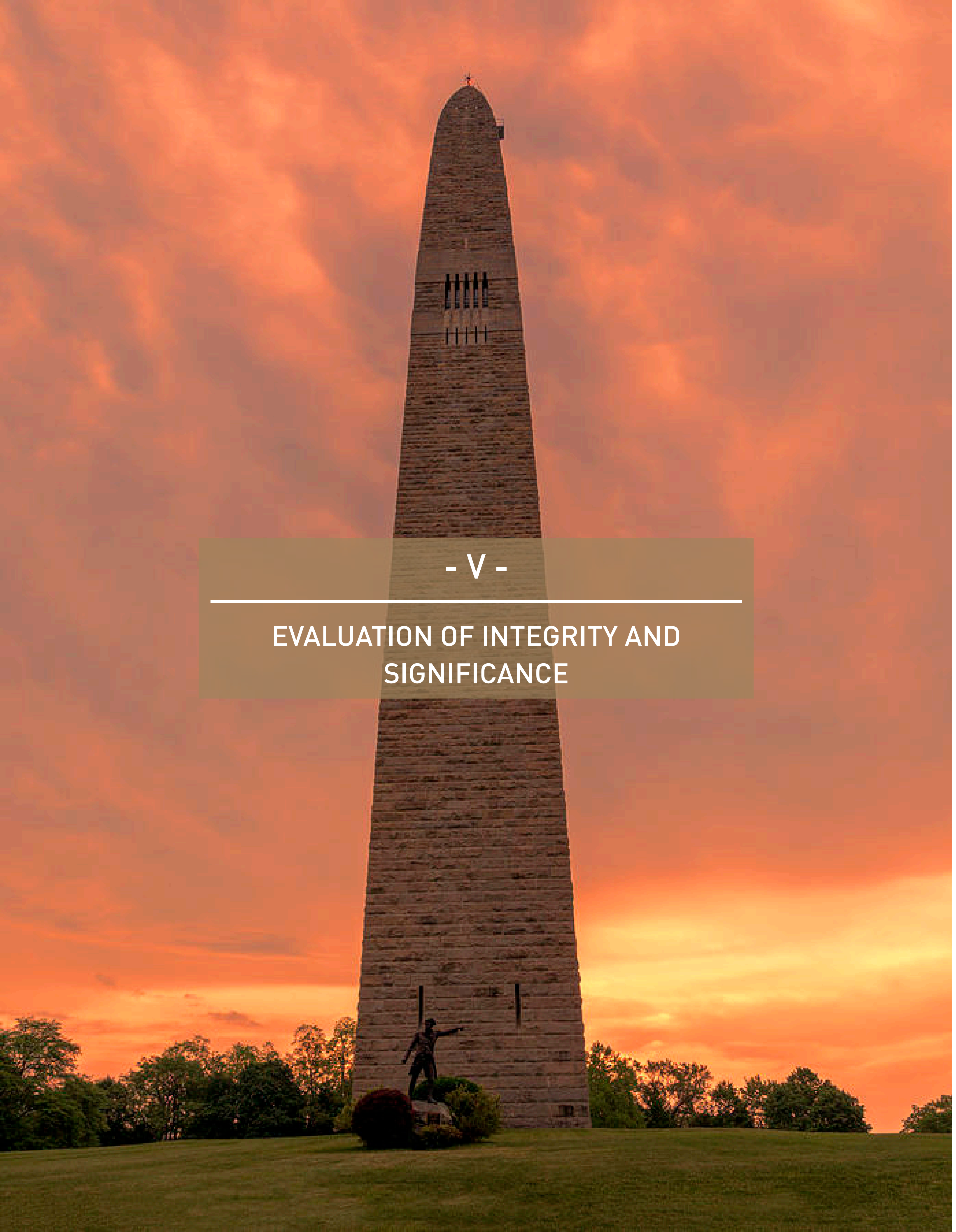
LIGHTNING PROTECTION

Image 58. ½" diameter class II copper air terminal mounted with bolted copper strapping to star finial. *Smokestack Lightning.*

Image 60. Bolted connection from air terminal to class II copper lightning conductor. *Smokestack Lightning.*

Image 59. Access ladder is directly over the main lightning conductor, bonded to the lightning protection system at the base of the ladder through a thru bolt into the tower. *Smokestack Lightning.*

Image 62. Conductors are protected by a copper conduit. *Smokestack Lightning.*



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EVALUATION OF INTEGRITY AND SIGNIFICANCE

Evaluation of Integrity and Significance

Introduction

The Bennington Battle Monument is an undeniably significant architectural structure with deep historical and cultural legacies, expressed in tangible and intangible ways. The design of all conservation and preservation work shall therefore be grounded in established preservation philosophy and concepts of significance, historic integrity, and precedents set by the site's unique development.

Significance – National Park Service

The Bennington Battle Monument is listed on the National Register of Historic Places, and it commemorates a significant battle during the Revolutionary War that ultimately led to our nation's independence. The monument possesses multiple levels of significance through its long, rich and varied histories from a pivotal battle ground for the American revolution, and as one of only very few unreinforced masonry obelisks in the country.

Integrity – National Park Service

The National Park Service's definition of Integrity is the ability of a property to convey its significance. Historic properties either retain integrity (that is, convey their significance) or they do not. To retain historic integrity a property will always possess several, and usually most, of the Seven Aspects of Integrity. Determining which of these aspects are most important to a particular property requires knowing why, where, and when the property is significant.

- **How does the National Park Service assess Integrity?**
- Integrity is the ability of a property to convey its significance.
  Historic properties either retain integrity (that is, convey their significance) or they do not.
- To retain historic integrity a property will always possess several, and usually most, of the seven aspects.
- Determining which of these aspects are most important to a particular property requires knowing why, where, and when the property is significant.

Integrity is evaluated according to seven aspects:

The Seven Aspects of Integrity

- *Location*: Location is the place where the historic property was constructed or the place where the historic event occurred.
- *Setting*: Setting is the physical environment of a historic property. It refers to the historic character of the place in which the property played its historical role. It involves how, not just where, the property is situated and its historical relationship to surrounding features and open space.

- *Design*: Design is the combination of elements that create the historic form, plan, space, structure, and style of a property. This includes such elements as organization of space, proportion, scale, technology, ornamentation, and materials.
- *Materials*: Materials are the physical elements that were combined or deposited during a particular period and in a particular pattern or configuration to form a historic property.
- *Workmanship*: Workmanship is the physical evidence of the crafts of a particular culture or people during any given period in history. It is the evidence of artisans' labor and skill in constructing or altering a building, structure, object, or site.
- *Feeling*: Feeling is a property's expression of the aesthetic or historic sense of a particular period of time. It results from the presence of physical features that, taken together, convey the property's historic character.
- *Association*: Association is the direct link between an important historic event or person and a historic property. Property retains association if it is the place where the event or activity occurred and is sufficiently intact to convey that relationship to an observer.

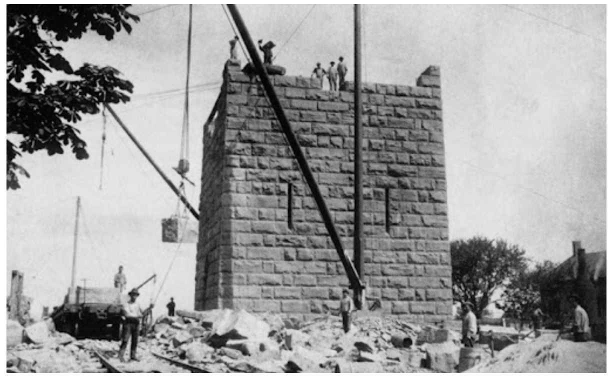

Image 64. Early stage of construction. Cranes on the ground are used to lift masonry units during the early stages of construction.

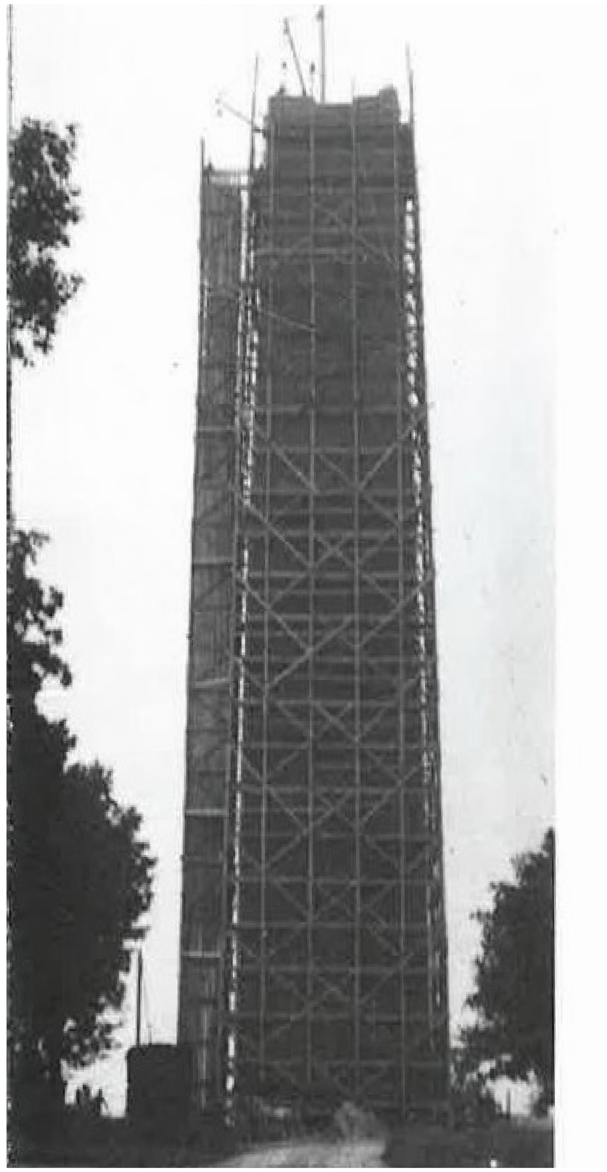

Image 67. Photograph of the Monument. Cranes are added at higher elevations, placed within the BBM's footprint. *Bennington's Battle Monument: Massive and Lofty*

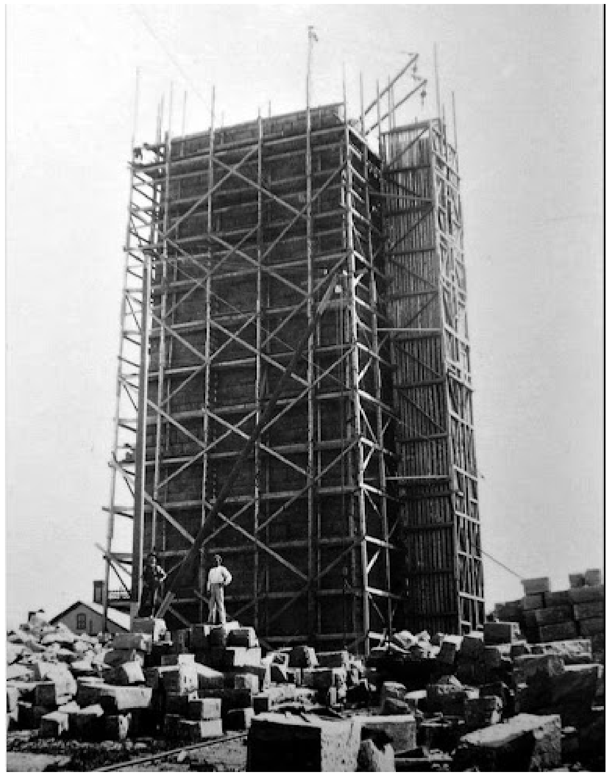

Image 66. Scaffolding surrounds the monument when its height clears the limits of cranes.

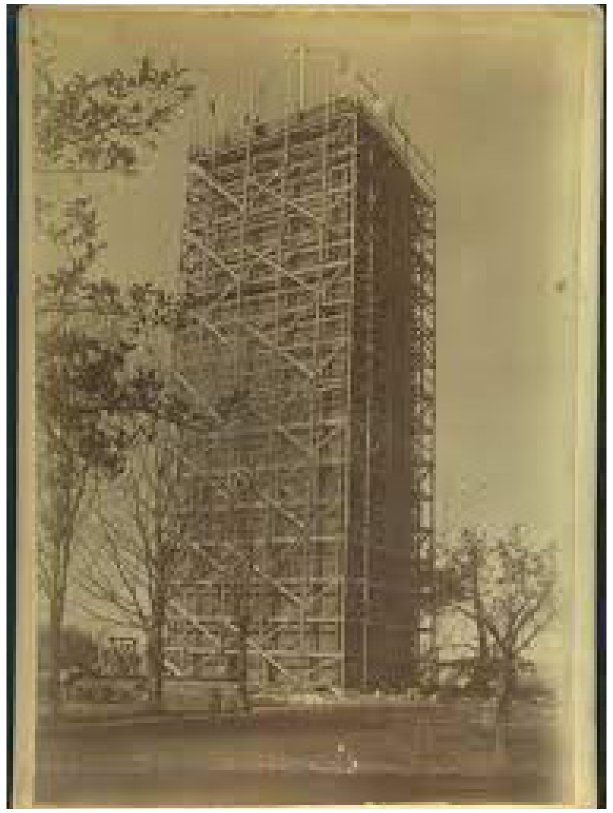

Image 65. The Monument in a later construction stage. Scaffolding continues to rise.

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ARCHITECTURE & PRESERVATION

Architectural Restoration and Preservation

The development of Primary Factors of Consideration is important in understanding the key components that are contributing to the deterioration of the Monument, we can apply the information gleaned from the tests and analyses and draw conclusions on what is the best course of action for the restoration, rehabilitation and repair and maintenance of the Bennington Battle Monument.

Based on the observations, analyses and results of the consultant team, it is now possible to organize a preservation methodology for the preparation of a Restoration Project Approach with directives on developing a prioritized scope of work that provides a comparative analysis of the physical with the archival information to be used to synthesize these elements into a clear preservation philosophy and methodology that will balance aesthetic concerns with technical.

Our own charting of the previous repair campaigns and the current assessment of the deterioration of the Monument enables us to be particularly attentive to patterns of behavior or failure as a method of determining large-scale or persistent building conditions. Based on information gathered in these reports, we can now identify opportunities and constraints and evaluate their relevance to the project objectives and budget. Recommendations will be prioritized by *Immediate Life Safety Hazards, Stabilization, Full Scale Restoration, and Ongoing Maintenance*. The analysis shall address and clearly present the key issues identified including:

- Life safety hazards and required stabilization
- Deferred maintenance - major renovation/restoration
- Preventive maintenance/minor repair or replacement
- Restoration and preservation issues
- Physical constraints imposed by the original fabric
- Appearance
- Regulatory requirements such as the State Building Code (IBC), State Historic Preservation Office (SHPO) and the National Park Service (NPS)
- Time and schedule constraints
- The facility's ongoing operational requirements

The primary factors for consideration are categorized as follows: *Masonry; Moisture & Humidity; and Building Systems/Vertical Access.*

PRIMARY FACTORS OF CONSIDERATION: MASONRY

Phase 1 provided charting of the exterior and interior damage to the Monument, including cracks, spalls, and previous repair campaigns that are contributing to the deterioration, and this work was completed by Vertical Access in the beginning stage of Phase 2. In general, a singular cause of cracking has not been identified, but rather several potential contributing factors have been established, including the following:

Stone

- The dolomitic stone is harder and stronger than calciferous limestone but is nonetheless sedimentary stone that is porous and permeable. Cracks and fissures natural to the stone have occurred over time, and also as a result of quarrying, which is not atypical. These cracks are non-structural, but a potential outlet for water transmission.
- Some stones laid with their bedding plane, others laid against, or vertical, allowing for stresses to "slice" through the bedding plane, instead of being "stacked."
- Cracking on the exterior stones and deterioration of the mortar joints is widespread on all four sides of the Monument. South and West faces of the monument have the most cracked stones and prevalent surface loss (exfoliation). Possibly because of exposure to prevailing winds and harsh weather, as well as solar energy.
- Cracks through single stones are common on all elevations at all heights.
- Crack systems were commonly observed below the observation deck level, and typically extended through five to ten horizontal courses.

Mortar

- While the original specification for the Monument specified a hard Portland cement mortar, none of the tested samples or visual observations found evidence of this original mortar still being present. Testing revealed all the mortar samples to be a soft Rosendale natural cement mortar. The material conservator confirmed that the type of mortar used during construction was appropriate for the Monument. However, significant mortar loss is present on the Monument due to freeze-thaw cycles, thermal action, and deferred maintenance. Improper prior mortar repairs with caulking and hard mortars may have contributed to damage of the masonry. Additionally, a moderate alkali-aggregate reaction (AAR) was observed in mortar removed from the interior of the wall.
- While AAR is often deleterious to masonry, if the scale of the reaction observed in the select sample is representative of the overall Monument condition it is not a cause for concern. While it is not believed that issues with mortar type or open joints were the cause of initial cracking, they do allow for significant moisture ingress that can contribute to a variety of deterioration methods over time. Continual appropriate maintenance and regular repointing campaigns will be necessary to keep water out of the Monument.
- Both the original mortar and repointing mortars on the monument do not appear to have the preferred qualities of a soft cement lime-based mortar. This doesn't allow the mortar to be the "sacrificial" material and instead binds the stone to the mortar, transferring stress to the stone.

Freeze-Thaw Cycles

- Visual observation of the exterior found that a high percentage of the previously repaired cracks are no longer protected from bulk moisture migration because the sealants used 30 years ago are failing. Thus, water ingress into and through the stone wall remain trapped, and subject to the cycling od freezing and thawing resulting in masonry deterioration and frost jacking.

Moisture and Humidity

- Damp interior; continuous water infiltration; freeze/thaw cycle and frost jacking

Local Stresses

- High percentage of the observed cracks are vertical through the stones and not along the natural bedding layers, suggesting that the forces cracking the stones are tensile likely caused by localized stresses.
- A differential moisture profile within the wall may also be contributing to the cracks due to the consistently wet interior stones being of a smaller face, marble, and as much as a third more open joints based on stone coursing.
- Flexural tension stresses may also be occurring locally near openings or where stones bridge missing or weakened mortar areas.

Headers & Wall Construction

- At the lowest level of the monument, data suggests the header stone (40" to 60" thick does not extend all the way through the wider wall. The general stiffness of the wall is different where there are full through-wall header stones as opposed to "Cross-headers."
- Interior bonding was done with a cement aggregate, essentially tying the whythes together and prohibiting natural expansion and contraction. This unreleased force can contribute to cracking.
- More crack systems were observed in the lower portion of the Monument- this is further addressed in our graphic charting of the cracks and where previous repair campaigns occurred. (and referenced in our section *Impact of Previous Repair Campaigns*)

Loading

- Silman's analysis indicates that a current code level extreme seismic event would cause tension and compression stresses beyond the assumed allowable stresses of the masonry. By code it is not required to seismically upgrade the structure, but any repair options should consider performance-based design for future earthquake loads.

PRIMARY FACTORS OF CONSIDERATION: MOISTURE & HUMIDITY

- Temperature and humidity monitors with over one-year in data have monitored the conditions of the monument.

- Two of these monitors exist in the interior side of the masonry walls, and one exists to measure interior climate conditions.
- The two installed in the walls have rested at 100% RH for their monitoring period, with the one mounted on the wall inside averaging 72% with fluctuations between 15% and 100% RH.
- To reduce interior humidity, the first step will be to reduce water infiltration which is the primary source for interior atmospheric humidity.
- To reduce water infiltration through the masonry walls, design repairs are required to minimize infiltration liquid water while maximizing water vapor transmission to enhance outward drying of the masonry walls.
- In general, the upper half of the Monument typically has more signs of moisture than the lower elevations. An exception is that the below grade basement walls were observed to be damp in all visits, especially in the fall and spring. In the winter, a large area of ice was observed along the middle of the south wall below the sub-observation level and extending multiple landing heights down.
- Readings of moisture meters report a 100% relative humidity for extended periods of time and have rarely decreased. This held true over the summer months when Bennington was experiencing moderate drought conditions.
- ANA's tests in May, 2022 show that the relative humidity sensors, TH02 and TH03, that are sealed within the stone masonry walls, are showing values greater than expected.
- After one week they normalize at a 100% relative humidity and show the wall to be waterlogged after a few weeks of measuring.

PRIMARY FACTORS OF CONSIDERATION: BUILDING SYSTEMS:

HEATING/ELECTRICAL/ACCESS

Elevator:

- The original Otis machine from 1956 is leaking oil and makes a noticeable ticking noise that is believed to be bearing chatter. These may forecast a seized bearing, which could be a major and costly service event.
- Various sensors in the shaft consist of magnetic tape and copper contacts that usually need to be serviced or replaced every few years. These sensors malfunction multiple times a year despite being replaced and/or cleaned annually. The elevator shuts down when these sensors malfunction.
- Many parts are replaced semi-annually or annually due to high moisture conditions even when components should last much longer.

- Moisture intrusion from foundation walls in the basement disturbs the equipment.

Stairs:

- Seven metal framed floor levels, thirty-three staircases and landings, and steel framed elevator shaft.
- The main stairs were constructed in 1891 with selected repairs in 1987 and are best characterized as emergency stairs/ a fire escape as they do not meet dimensional requirements for standard egress stairs for public use.
- Coatings have failed and steel members show corrosion especially in embedded locations and bolt holes.
- Cast iron elements have brittle cracks where loading has compromised the base metal. Floor plate cracks, tread cracks, missing bolts, broken treads and deteriorated flanges, gaps in framing connections, unsupported beams, broken floor panels, differing riser slopes have been observed.
- Steel channels are not detailed to restrict corrosion and significant metal loss and failure.
- Bearing conditions of steel members have been compromised as the mortar decayed and has allowed the stone bearing shims to become unrestrained and, in many cases, dislodged.
- Stair landings supported by varying bearing conditions. Corrosion noted on all conditions, and loss of support was occasionally noted, primarily at stone ledger supports.
- Spiral staircase has a few brittle cracks and lateral ties to horizontal walls are heavily corroded.

PRIMARY FACTORS OF CONSIDERATION: BUILDING SYSTEMS:

HEATING/ELECTRICAL/ACCESS

- Rolled steel, such as supporting beams, is more prone to lamellar corrosion that causes expanding and flaking leading to rust jacking between the rolled steel beams and cast steel plates.
- Corroding beams induce stresses on the cast steel plates occasionally leading to fracture.
- UT Testing showed stair stringer beams near embedded corroded beam were nearly 12% less thick than original material.

Electrical:

- The current terminal, as originally designed, is in good condition but has flaws at connections across the monuments. The lack of fail-safe further puts the monument at risk for sever damage in a lightning strike that would overwhelm the system as currently in place.
- There is no backup electricity system in case of global failure.
- There is no surge protection on the main electrical service panel in the monument

- Several generations of abandoned and failed light fixtures throughout the monument.
- Not all emergency light fixtures work, creating unsafe conditions.
- Stairwell is not adequately illuminated to NFPA 101 performance requirements.
- Unclear if the newer emergency lighting battery unit equipment is suitable for cold weather operation.
- Several different wiring and conduit systems.
- Conditions of existing systems vary from serviceable and good, to rusted, deteriorating, and abandoned.

HVAC/Heating:

- There are no HVAC systems in the Monument today, though the abandoned remains of a former steam fed heating system still exists. These were fed via a boiler in the visitor center, which was removed, the pipes capped and extant between the two buildings.

Impact of Previous Repair Campaigns

The next factor to consider is the adverse effect previous repair campaigns have had on the performance, and deterioration, of the Monument. Our team is respectful of the stewardship the State of Vermont has shown to the Monument since its completion, and hindsight is not necessary, and no criticism of the maintenance is intended, insinuated, or directed. We are currently the benefactors of tremendous gains in material science investigation, conservation analysis, structural and building integrity modeling, and the continuous development of advanced restoration strategies, techniques, material and building technology, and workmanship. While the past cannot be undone, we can ensure that best practices will be applied now and in the future. We have charted the previous repair work performed on the building on elevation drawings in an to advance the theory of deterioration caused by this repair work. This can assist us in evaluating the result of natural degradation versus the impediments of the repair techniques that has exacerbated and accelerated the degradation.

- Previous repointing/mortar repair campaigns focused on the exterior and interior of the upper third of the monument. These replacement mortars, as well as other campaigns on the Monument, were too hard for the masonry, leading to cracking.
- Previous repair campaigns of the monument are not recommended by contemporary conservation standards, particularly caulk repairs and hard cementitious repairs.
- These campaigns removed traces of the original mortar, though forensic samples reveal that a black-colored mortar was found in joints as well as along the windows of the main shaft.
- Many cracks have been previously repaired by infilling the cracks with a bead of sealant. Other crack repairs include cementitious mortar repairs in wider or routed out cracks, and epoxy injection repairs in narrower cracks.

- Hazardous conditions involving sizable pieces of stone and loose material from failed patch repairs that are loose and have fallen.
- Sealant used for repairing a high percentage of cracks is failing, cracking, and separating from the stone surfaces. The failed sealant traps moisture within the wall and slows down the natural drying process.
- Wider cracks repaired with mortar are failing.
- Biological growth is noted in a percentage of mortar joints.
- Bronze U-shaped straps, or “staples,” are visible on the surface of cracked stone units. Oriented horizontally and generally covered with a urethane sealant, though some are encased in mortar.

Drawings

The chart on page 63 and subsequent drawings through page 69 represent a chronology of the past repair campaigns, with a graphic overlay to the existing conditions that were noted in Phase 1 by Vertical Access. The purpose of this analysis was to visually note any correlation between documented damage and the location as it relates to repair work. As of this DRAFT we can tentatively confirm that spalling, salt leeching, eroded/missing mortar, exfoliation, and surface deterioration is related to the earlier repair campaigns.

Image 72. TYpical exterior rock-faced, coursed Sandy Hill dolomitic limestone ashlar. *Jablonski*

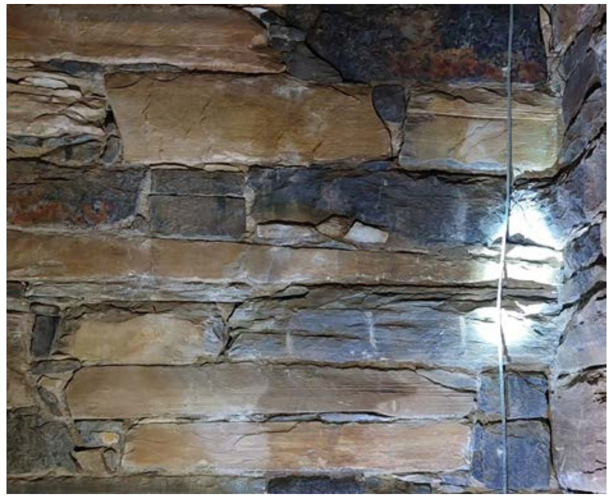


Image 73. Typical interior marble

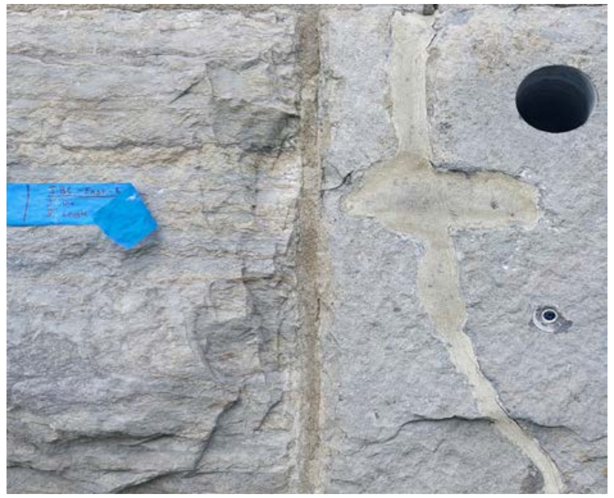


Image 74. Caulk repiar and current core hole

Image 75. Bronze staple condition through crack. *Easton Architects*

Image 79. Spall removed from the exterior stone masonry. *Vertical Access*

Image 78. Spall removed from the exterior stone masonry. *Vertical Access*

Image 76. Delamination in a stone at the upper portion of the monument. *Vertical Access*

Image 77. Exterior of monument with cracks highlighted in red. Note that most cracks fall below a vertical mortar joint. *JBC.*

Image 84. Cracked and failed parge coat applied over the face of a stone. *Vertical Access*

Image 85. Failed mortar joint at upper portion of monument. *Vertical Access*

Image 82. Cracked and spalled cementitious patch repair. *Vertical Access*

Image 83. Carbonate deposit (White material) below an epoxy crack repair. *Jablonski*

Image 80. Scaling in a stone at the upper portion of the monument. *Vertical Access*

Image 81. Heavy accumulation of carbonate material leached from a cracked and deteriorated mortar joint. *Jablonski*

Image 86. Original heating system and piping. *Stevens & Associates*

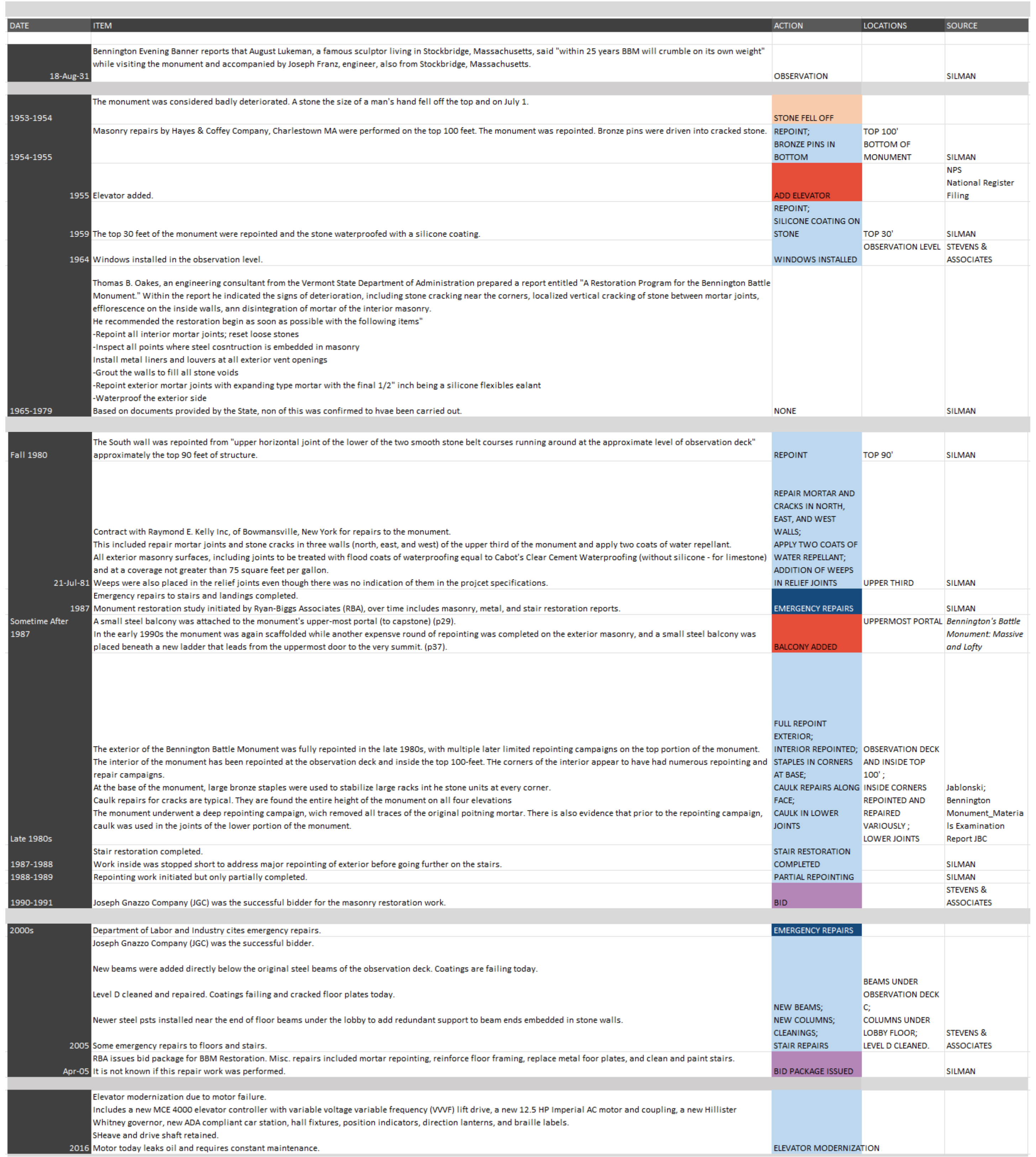
Image 90. Cracks creating an "alligatored" pattern, with white efflorescence along the cracks. *Jablonski*

Image 87. Corner condition at top of monument. *Stevens & Associates*

Image 91. Section through sample ANA-South-4 showing large, crushed limestone aggregate in paste of cement. *Jablonski*

Image 88. Ladder to Level A, above elevator mechanical room. *Stevens & Associates*

Image 89. Typical condition of stair support meeting masonry. *Stevens & Associates*



DATE	ITEM	ACTION	LOCATIONS	SOURCE
18-Aug-31	Bennington Evening Banner reports that August Lukeman, a famous sculptor living in Stockbridge, Massachusetts, said "within 25 years BBM will crumble on its own weight" while visiting the monument and accompanied by Joseph Franz, engineer, also from Stockbridge, Massachusetts.	OBSERVATION		SILMAN
1953-1954	The monument was considered badly deteriorated. A stone the size of a man's hand fell off the top and on July 1.	STONE FELL OFF		
1954-1955	Masonry repairs by Hayes & Coffey Company, Charlestown MA were performed on the top 100 feet. The monument was repointed. Bronze pins were driven into cracked stone.	REPOINT; BRONZE PINS IN BOTTOM	TOP 100' BOTTOM OF MONUMENT	SILMAN
1955	Elevator added.	ADD ELEVATOR		NPS National Register Filing
1959	The top 30 feet of the monument were repointed and the stone waterproofed with a silicone coating.	REPOINT; SILICONE COATING ON STONE	TOP 30'	SILMAN
1964	Windows installed in the observation level.	WINDOWS INSTALLED	OBSERVATION LEVEL	STEVENS & ASSOCIATES
1965-1979	Thomas B. Oakes, an engineering consultant from the Vermont State Department of Administration prepared a report entitled "A Restoration Program for the Bennington Battle Monument." Within the report he indicated the signs of deterioration, including stone cracking near the corners, localized vertical cracking of stone between mortar joints, efflorescence on the inside walls, ann disintegration of mortar of the interior masonry. He recommended the restoration begin as soon as possible with the following items" -Repoint all interior mortar joints; reset loose stones -Inspect all points where steel cosntruction is embedded in masonry Install metal liners and louvers at all exterior vent openings -Grout the walls to fill all stone voids -Repoint exterior mortar joints with expanding type mortar with the final 1/2" inch being a silicone flexibles ealant -Waterproof the exterior side Based on documents provided by the State, non of this was confirmed to hvae been carried out.	NONE		SILMAN
Fall 1980	The South wall was repointed from "upper horizontal joint of the lower of the two smooth stone belt courses running around at the approximate level of observation deck" approximately the top 90 feet of structure.	REPOINT	TOP 90'	SILMAN
21-Jul-81	Contract with Raymond E. Kelly Inc, of Bowmansville, New York for repairs to the monument. This included repair mortar joints and stone cracks in three walls (north, east, and west) of the upper third of the monument and apply two coats of water repellant. All exterior masonry surfaces, including joints to be treated with flood coats of waterproofing equal to Cabot's Clear Cement Waterproofing (without silicone - for limestone) and at a coverage not greater than 75 square feet per gallon. Weeps were also placed in the relief joints even though there was no indication of them in the projcet specifications.	REPAIR MORTAR AND CRACKS IN NORTH, EAST, AND WEST WALLS; APPLY TWO COATS OF WATER REPELLANT; ADDITION OF WEEPS IN RELIEF JOINTS	UPPER THIRD	SILMAN
1987	Emergency repairs to stairs and landings completed. Monument restoration study initiated by Ryan-Biggs Associates (RBA), over time includes masonry, metal, and stair restoration reports.	EMERGENCY REPAIRS		SILMAN
Sometime After 1987	A small steel balcony was attached to the monument's upper-most portal (to capstone) (p29). In the early 1990s the monument was again scaffolded while another expensve round of repointing was completed on the exterior masonry, and a small steel balcony was placed beneath a new ladder that leads from the uppermost door to the very summit. (p37).	BALCONY ADDED	UPPERMOST PORTAL	*Bennington's Battle Monument: Massive and Lofty*
Late 1980s	The exterior of the Bennington Battle Monument was fully repointed in the late 1980s, with multiple later limited repointing campaigns on the top portion of the monument. The interior of the monument has been repointed at the observation deck and inside the top 100-feet. THe corners of the interior appear to have had numerous repointing and repair campaigns. At the base of the monument, large bronze staples were used to stabilize large racks int he stone units at every corner. Caulk repairs for cracks are typical. They are found the entire height of the monument on all four elevations The monument underwent a deep repointing campaign, wich removed all traces of the original poitning mortar. There is also evidence that prior to the repointing campaign, caulk was used in the joints of the lower portion of the monument.	FULL REPOINT EXTERIOR; INTERIOR REPOINTED; STAPLES IN CORNERS AT BASE; CAULK REPAIRS ALONG FACE; CAULK IN LOWER JOINTS	OBSERVATION DECK AND INSIDE TOP 100' ; INSIDE CORNERS REPOINTED AND REPAIRED VARIOUSLY ; LOWER JOINTS	Jablonski; Bennington Monument_Materials Examination Report JBC
1987-1988	Stair restoration completed. Work inside was stopped short to address major repointing of exterior before going further on the stairs.	STAIR RESTORATION COMPLETED		SILMAN
1988-1989	Repointing work initiated but only partially completed.	PARTIAL REPOINTING		SILMAN
1990-1991	Joseph Gnazzo Company (JGC) was the successful bidder for the masonry restoration work.	BID		STEVENS & ASSOCIATES
2000s	Department of Labor and Industry cites emergency repairs.	EMERGENCY REPAIRS		
2005	Joseph Gnazzo Company (JGC) was the successful bidder. New beams were added directly below the original steel beams of the observation deck. Coatings are failing today. Level D cleaned and repaired. Coatings failing and cracked floor plates today. Newer steel psts installed near the end of floor beams under the lobby to add redundant support to beam ends embedded in stone walls. Some emergency repairs to floors and stairs.	NEW BEAMS; NEW COLUMNS; CLEANINGS; STAIR REPAIRS	BEAMS UNDER OBSERVATION DECK C; COLUMNS UNDER LOBBY FLOOR; LEVEL D CLEANED.	STEVENS & ASSOCIATES
Apr-05	RBA issues bid package for BBM Restoration. Misc. repairs included mortar repointing, reinforce floor framing, replace metal foor plates, and clean and paint stairs. It is not known if this repair work was performed.	BID PACKAGE ISSUED		SILMAN
2016	Elevator modernization due to motor failure. Includes a new MCE 4000 elevator controller with variable voltage variable frequency (VVVF) lift drive, a new 12.5 HP Imperial AC motor and coupling, a new Hillister Whitney governor, new ADA compliant car station, hall fixtures, position indicators, direction lanterns, and braille labels. SHeave and drive shaft retained. Motor today leaks oil and requires constant maintenance.	ELEVATOR MODERNIZATION		

Image 92. Chart documenting repair campaigns

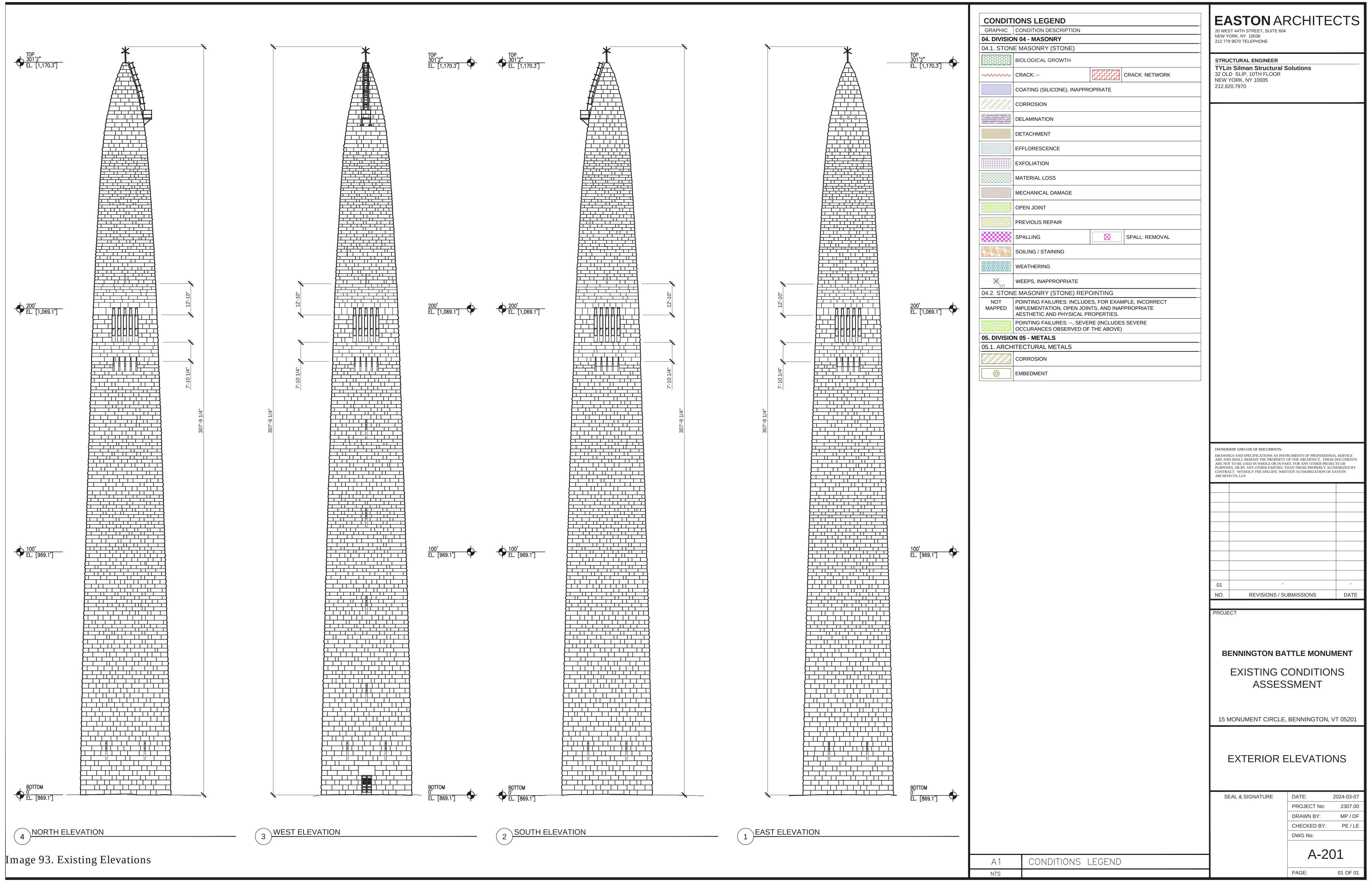


Image 93. Existing Elevations

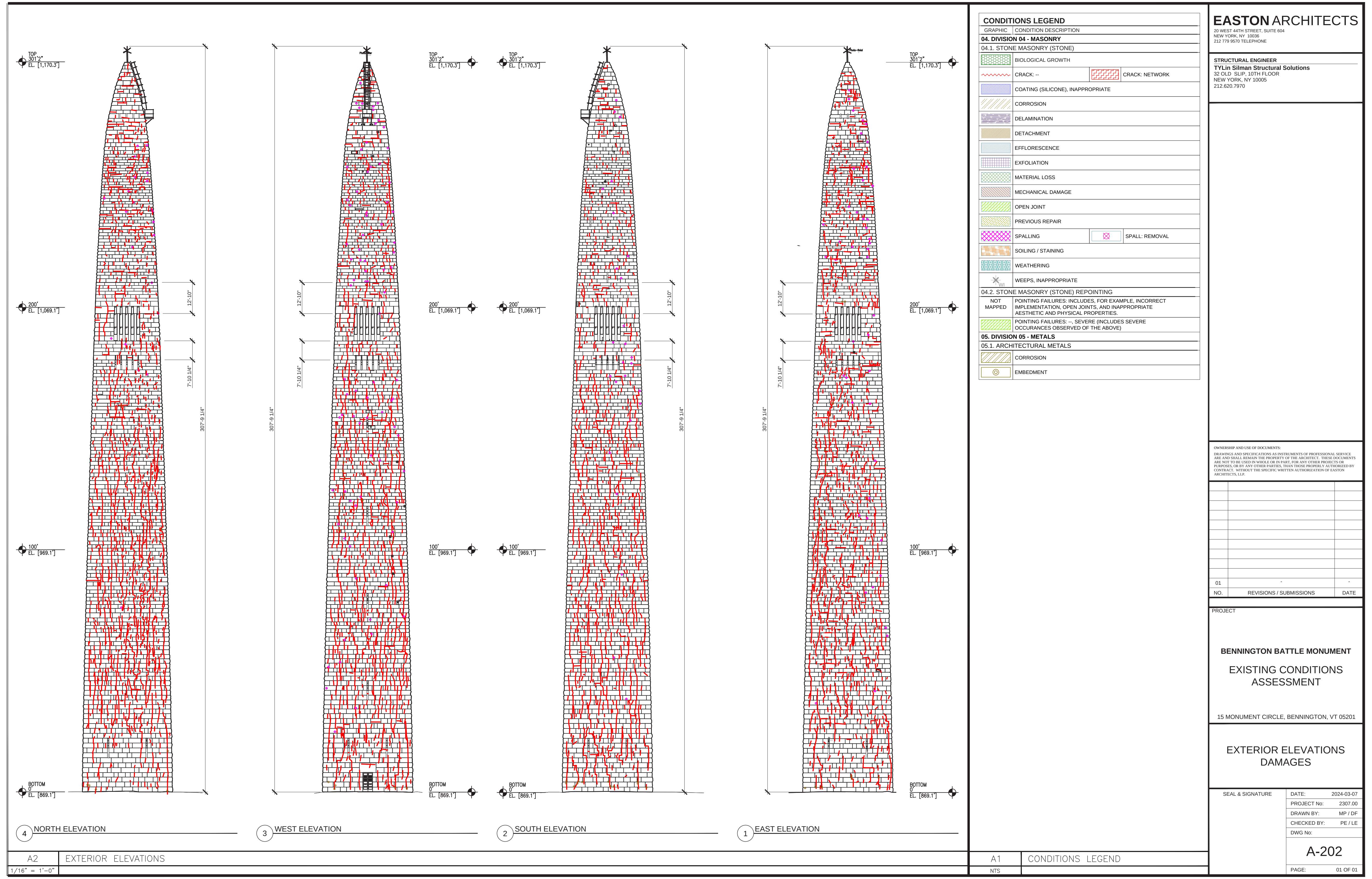


Image 94. Existing Conditions

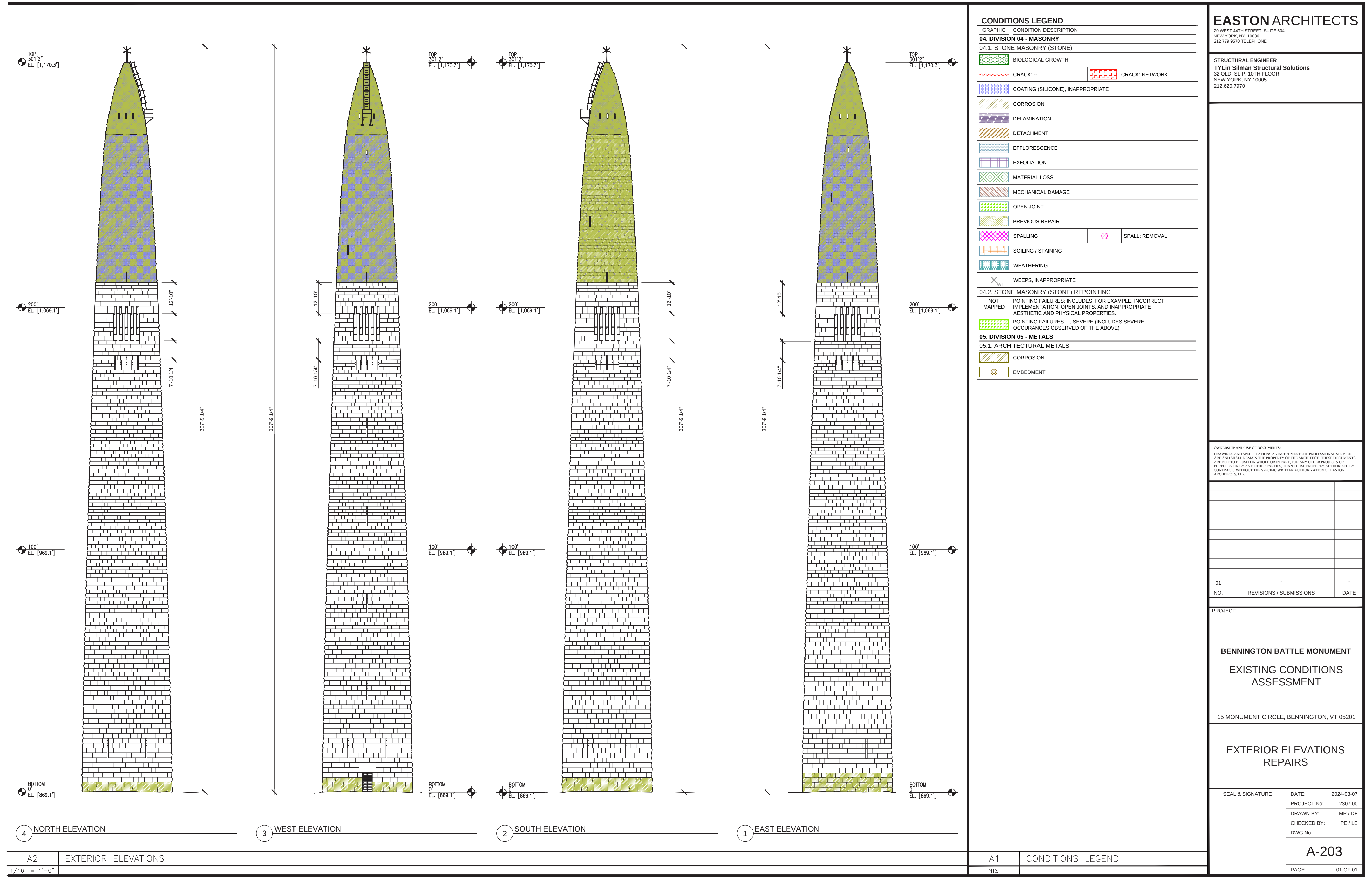


Image 95. Location of Repair Campaigns

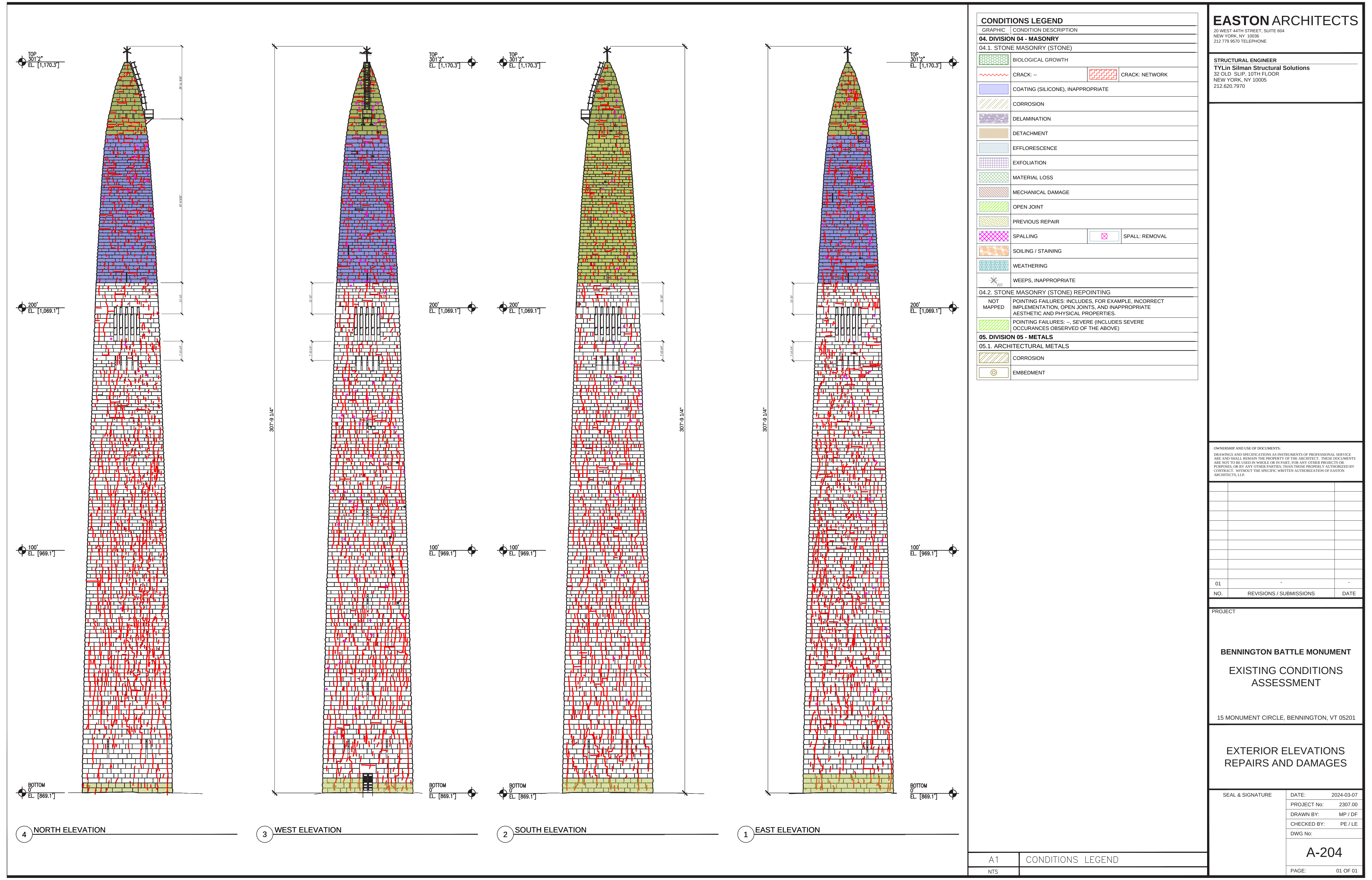


Image 96. Location of Repair Campaigns Overlaid on Conditions

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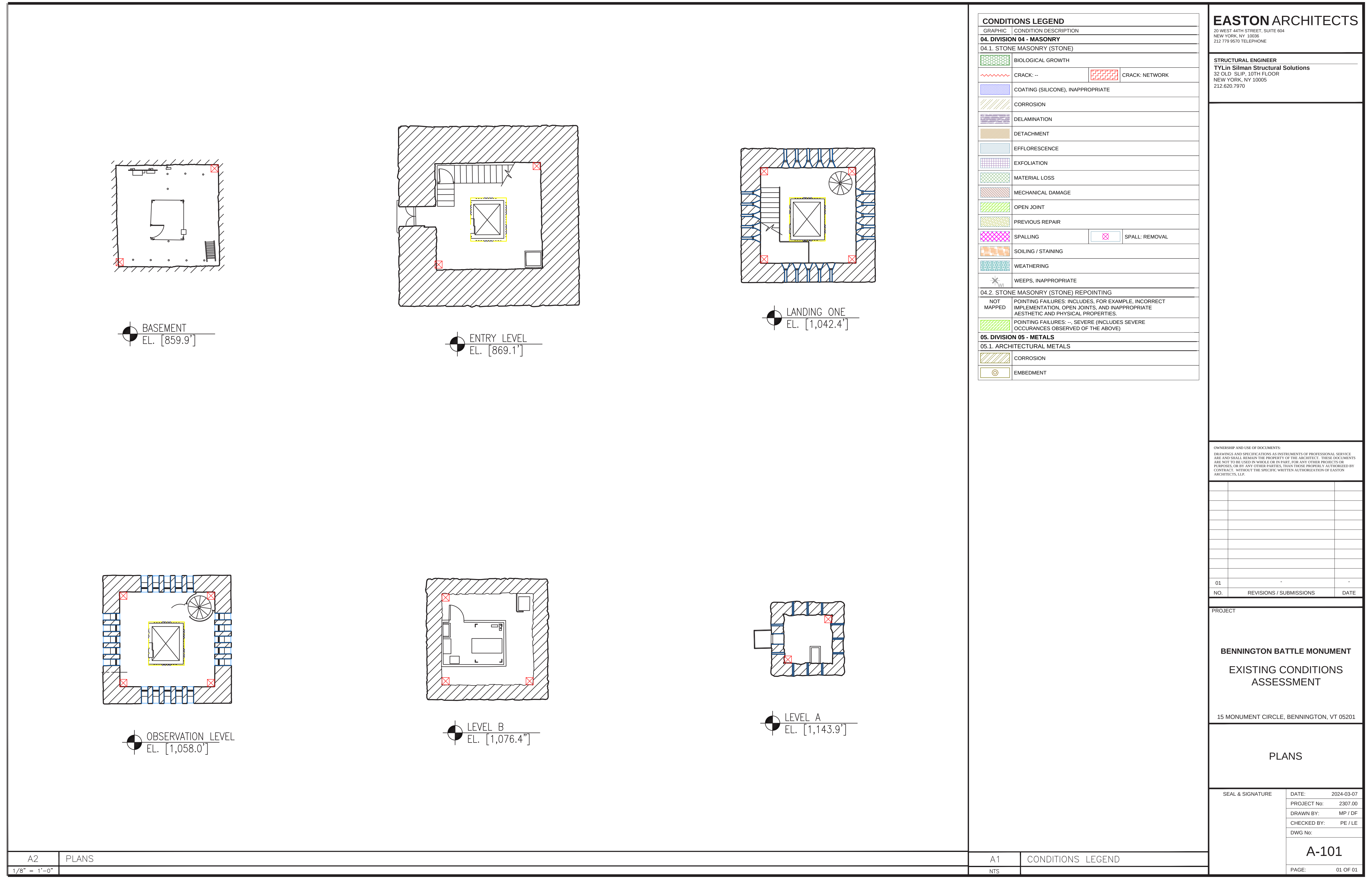


Image 97. Sketch of mechanical intervention location

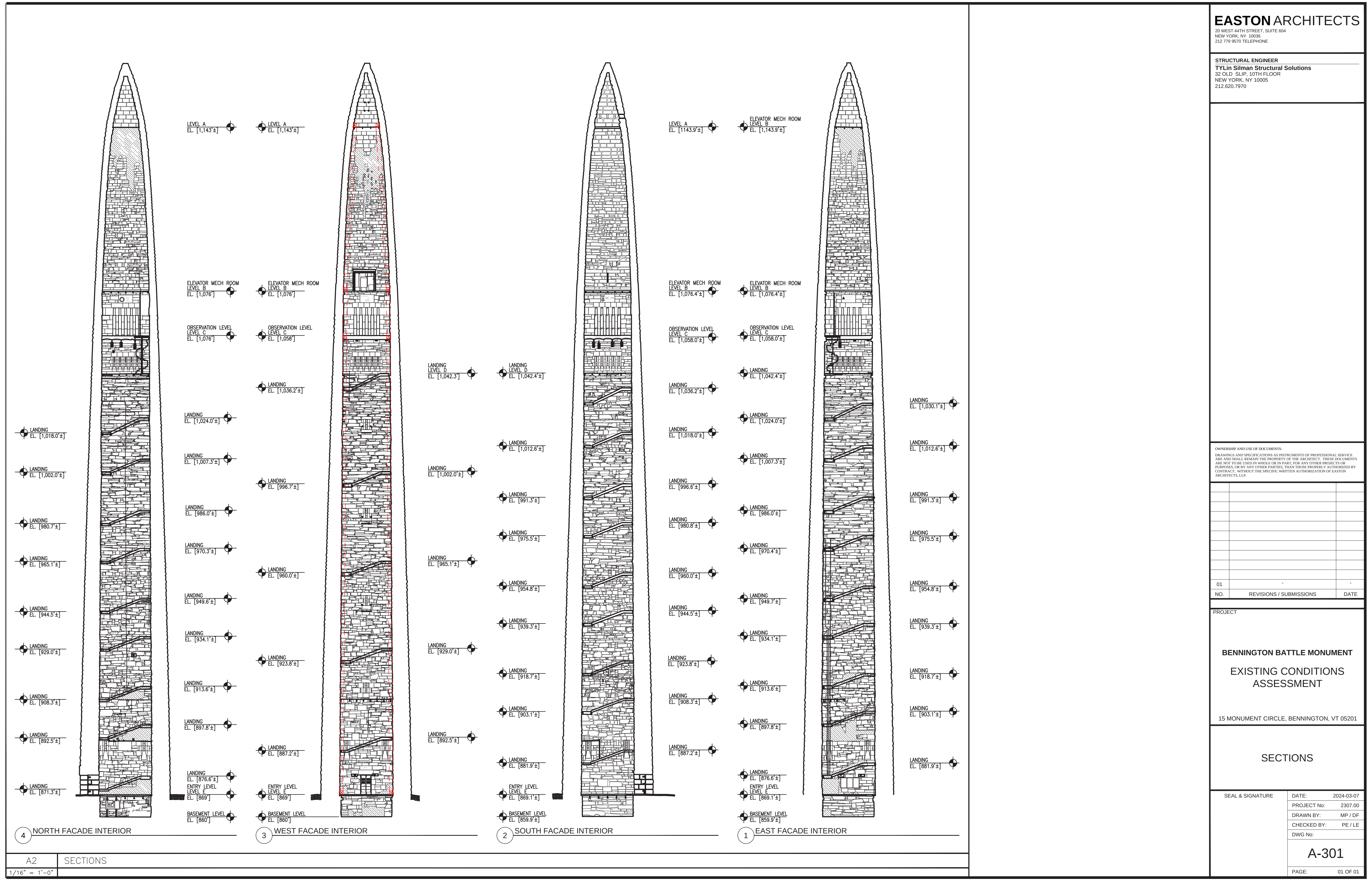


Image 98. Section for ventilation shafts

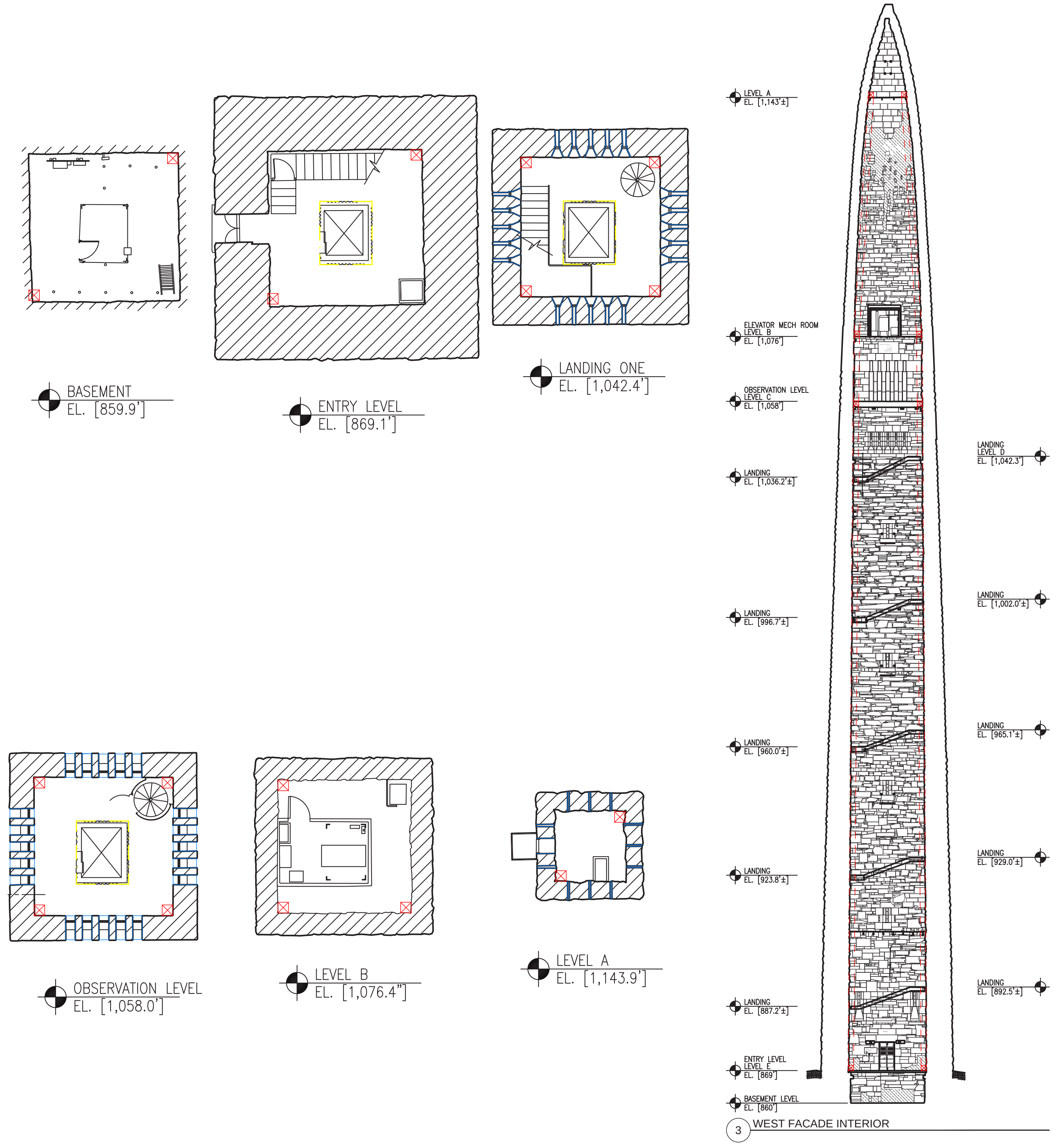
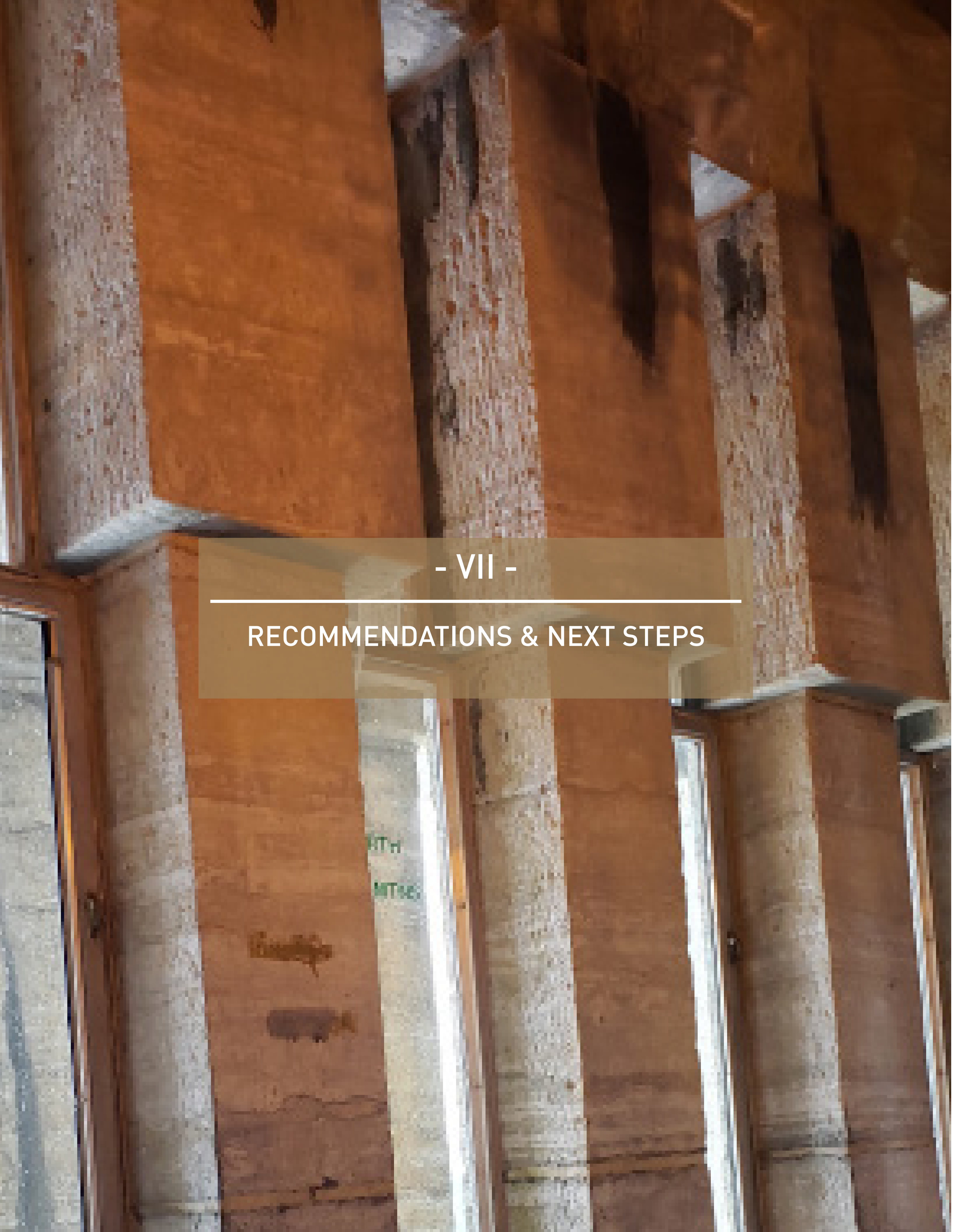


Image 99. Sketch of mechanical intervention location



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RECOMMENDATIONS & NEXT STEPS

RECOMMENDATIONS AND NEXT STEPS

Recommendations

In consideration of the appropriate restoration approach and a development of a Scope of Work for a Schematic Design Phase, the following categories present the key elements to be addressed in a holistic restoration campaign. These factors address the primary issues as they relate to environmental systems, ventilation, water infiltration, and the restoration, repair and preservation of the stone. In developing these recommendations, we have attempted to categorize and prioritize based on sequencing importance and prioritization. There are some elements that logically must be addressed first, and we've looked at varying factors that can have an impact, and where variables may still exist.

Scope of Work Items for Schematic Design Phase

Environmental Controls & Ventilation

The majority of test results, and perhaps the biggest adversary to the health of the Monument is water, in liquid and vapor form, and the continuous level of saturation in the stone and the relative humidity levels on the interior. Ideally, a sequence will occur where the interior relative humidity is lowered, the dryer air begins to draw moisture and water vapor from the stones to the interior, and as the temperature on the interior is regulated, a natural stack effect is in place, the water and water vapor will migrate to the interior of the monument, further increasing the drying rate of the stone. Making the exterior of the monument watertight, repointing with the appropriate mortar, tooling open joints, spalls, and cracks, and monitoring the monument's movement, will allow the structure to exist more passively, and experience significantly less damage. Addressing these issues is a key component to the success of all other work on the Monument. And while there is the potential to debate the chicken and egg theory, it is clear mitigation is a priority. The following interventions are recommended:

- Install dehumidifiers on multiple stair landings at designed intervals throughout the monument to begin drying the stone walls, and to install additional Temperature & Relative Humidity monitoring for the monument at key levels to gauge rate of drying and reduction of RH. This can be done as a "test chamber" to validate calculations and establish a baseline for energy output required and rate of drying, with an added variable of continued saturation and water infiltration.

- Consider designing an actively monitored mechanical system for installation to operate a ventilation system and active heating system based on temperature conditions throughout the year. Mechanically operate louvers can be utilized as dampers and controls when temperatures and humidity levels are less than ideal, and a passive system can be relied on during ideal temperatures and following the drying/dehumidification period.

- To reduce water infiltration through the masonry walls, design repairs are required to minimize liquid water and water vapor infiltration and transmission while maximizing water vapor transmission to the interior to enhance outward drying of the masonry walls. This will be impacted by the reduction of the RH on the interior which will in turn reverse the transmission of water and moisture vapor to move through to the interior of the monument instead of trying to exit at the exterior (and effectively becoming trapped)

- Design and implementation of natural and mechanical ventilation systems. This will include design intervention to penetrate the observation deck floor in order to induce the proper vertical air flow (positive stack effect)

Stone Masonry

The deterioration of the stone masonry is an ongoing and continuous process. The related analyses of the masonry enables us to understand the characteristics of the differing whythes of stones, so we can further comprehend the behavior of the stone, in its natural stone, and the stone(s) as a component of the overall structure. The Schematic Design Phase would incorporate the technical data provided in the reports to develop the appropriate restoration, repair and preservation details. And while there are still variables to consider regarding the structural behavior of the monument as it relates to cracking, including the direction of the stone bedding- it is also proven that there is at a minimum necessary work to the exterior that will help mitigate the deterioration. These are primarily the following:

- Address watertight integrity of masonry walls by performing the following work:

    a. Reverse inappropriate repair campaigns including removal of existing mortar, epoxies, sealants, and caulk.
    b. 100% repointing of interior and exterior masonry with appropriate mortar.
    c. Perform select area masonry repairs including tooling, patching, pinning, Dutchman repairs and full stone unit replacement when repairs are not possible.
    d. Perform masonry crack repairs in coordination with structural engineering recommendations.

- Clean masonry surfaces to remove biological growth, atmospheric staining, and corrosion. This will remove ecosystems that feed on the stone.

- Perform select area repairs in areas of embedded steel for the stair and elevator support systems. This can happen in conjunction with stair repair, with appropriate anchoring details into stone, including flashing and weep details that allow for continuous transmission of water and moisture vapor.

- In theory, the bedding orientation should be as it was formed in the earth, so as to keep the stone in its natural state of compression. Vertical oriented bedding planes can force the stones to perform in tension (as strain is put onto the top of the stone, the bedding planes are stressed to the left and right “stretching” their natural position, thus creating a tensile effect.) Differential bedding could explain vertical cracks in discrete locations but, it is difficult to see how this could explain the global problem. There are just too many cracks for this explanation. However, once the cracks open, it creates space for water to wash out mortar as well as

freeze, exacerbating cracks that originated from something else.

- Local stresses are a contributing cause to the cracking and any repair we undertake cannot cause additional stress concentrations. The future repairs should not be implemented in low for the development of significant new stress concentrations.

- Any mechanical repairs, such as pinning, must consider the location of cracks with respect to header stones and the connectivity between wythes in the masonry. Any reinforcements to lintels, such as at windows or doorways, should be carefully detailed to address concerns about potential new stress concentrations. Continuing cyclical maintenance and repair of the Monument is required. This is discussed in detail in the Phase 1 Report. We cannot reverse the cracking that has occurred or any initial cracking that has been exacerbated by freeze-thaw and moisture ingress. The State of Vermont will need to plan for regular repair campaigns to prevent moisture ingress.

- Areas of future study should include an analysis of thermal stresses within the stone masonry at a molecular scale using techniques such as a Monte Carlo simulation, WUFI Thermal Analysis, and detailed Finite Element Analysis with THERM Software.

- Continued electronic thermal and movement monitoring of the Monument should be performed until repairs are made to ensure that any significant change to the state of the masonry is detected in a timely manner.

Vertical Circulation Systems (Elevator & Stair)

As part of the Phase 1 assessment work, Lerch Bates first audited the elevator at the Bennington Monument on November 12th, 2021 and then again on September 22nd, 2022 due to elevator reliability issues and lack of maintenance. Their recommendation would be to retain the current controller, fixtures, and entrance assemblies since they are all still maintainable and will be for another 10-13 years. We would then replace the machine assembly, the associated steel ropes, the tape reader, the travelling cable, add microswitches to each of the blind hoistway access doors, install a new NEMA rated door operator, replace the current door operator with a NEMA rated enclosed operator and replace corroded pit equipment including the governor relating cam.

- Design and implement holistic upgrades to the elevator system and controls based on Lerch Bates report and desired usability preferred by state. This would include, but not be limited to replacing the machine assembly, the associated steel ropes, the tape reader, the travelling cable, add microswitches to each of the blind hoistway access doors, install a new NEMA rated door operator, replace the current door operator with a NEMA rated enclosed operator and replace corroded pit equipment including the governor relating cam.

Also as part of the Phase 1 assessment work, Hodgman Engineering & Permitting Pllc (HEP) observed and assessed the staircase from the ground floor to the floor directly below the observation deck, as well as the spiral stair up to the observation deck On May 11th and 12th, 2022. It was concluded the stair system, including the spiral staircase from sub-observation deck to the observation deck, is best characterized as emergency stairs, or a fire escape. This is due to its inability to meet dimensional requirements for standard egress stairs for public use. The final repairs are recommended:

- Provide additional bearing for all stringer channel supports at landings
- Provide additional bearing for major floor landings support beams
- Replacement of cracked treads and cracked landings.
- Removal and replacement of structural bolts in framing and tread locations that show
- greatest levels of corrosion of bolts and/or surrounding base metal
- New coatings for all handrail assemblies
- Spiral staircase between sub-observation deck and the observation deck is due
- for in-place refurbishment.

Building Systems (Electrical, Lightning Protection)

The existing electrical system was assessed during Phase 1 by DuBois & King, and the existing lightning protection system was assessed by Smokestack Lightning for this phase (report attached). Both are integral elements in an overall Preservation Work Plan, and it is understandable that each can be considered for its own level of priority, based on scope, need and budget. Our recommendation is to design and implement a holistic electrical system upgrades based on demands of the mechanical ventilation system, interior and exterior lighting, emergency lighting, backup power, and elevator. This is an important consideration, and can be developed during the Schematic Design Phase with the State's input. There are multiple factors to consider, including intended future/expanded use (i.e. stairs as circulation, exterior lighting improvements, mechanical ventilation system, code requirements, etc)
The following items are a minimum recommended to be addressed:

- Provide backup electricity system in case of global failure.
- Provide surge protection on the main electrical service panel in the monument.
- Remove abandoned and failed light fixtures
- Upgrade emergency lighting
- Provide adequate lighting for stairwell
- Provide emergency lighting battery unit equipment suitable for cold weather operation.
- Conduct electrical tracing and combine/eliminate wiring and conduit systems.

- Design and install new lightning protection system. As outlined, there are no code requirements for a lightning protection system, only standards to follow that result in an effective system for the relevant structure. Based on Smokestack Lightning's report, the prudent approach is to have a new system installed. The current system can be addressed for upgrades, offering this section of work as a lower priority based on phasing and budget considerations.

Next Steps: Phase 3: Schematic Design Phase and Preservation Work Plan

The next phase of work includes developing the schematic design for the multi-disciplined restoration approach for the monument. The primary goal of the schematic design phase is to develop a Preservation Work Plan that defines the technical approach, develops and implements mock-ups and onsite technical engineering tests of the design that addresses key architectural and engineering concerns arising from the interpretation and synthesis of the data from Phase 2. The design, mock-ups and engineering tests will provide a clear path to addressing the mechanisms of deterioration at work, resolve the deficiencies that exist and can be presented to the State Historic Preservation Office. This phase will also develop a detailed approach for phasing possibilities, project sequencing, accurate cost estimates and timelines, budgeting forecasting for the State, and for construction management scheduling.

The logistics of the proposed project will be a significant component of the overall project cost and schedule. It is recommended to engage a shoring/ bracing/ scaffolding engineer as part of the Schematic Design Phase to address the challenges that will be faced in preparing the Monument for restoration, while protecting the Monument and keeping it open and safe for visitors.

Based on our assessment of conditions and verification of research performed in Phase 1, and the engagement of a full complement of consultants during Phase 2, we propose preparing a Preservation Work Plan that addresses the scope of work items presented here for the holistic preservation, restoration, and rehabilitation of the Monument. Our methodology is based philosophically on accepted and established preservation theory and practice as advocated by The Secretary of the Interior's Standards for the Treatment of Historic Properties, the National Trust for Historic Preservation, and the American Institute of Conservation.

The design of restoration, repair, rehabilitation, and preservation details and specifications will rely heavily on the development of mock ups to test the performance of the design, and develop the implementation process for the restoration techniques, dehumidification tests, and passive ventilation approach. These mock ups and tests will enable us to better understand the major factors involved in arriving at the most appropriate design solution. These mock ups and onsite tests will identify conflicts and challenges with potential treatment interventions that will inform our design solutions earlier in the design process. These options will be developed and coordinated with the State to ensure appropriate standards are followed. The following is a short list of recommended actions and items to be considered during the Schematic Design Phase that will inform the methodology:

- Masonry Cleaning test to remove sealants, epoxies, and biological growth
- Develop appropriate mortar mix and perform onsite testing

- Prepare a pointing mock up on interior and exterior
- Prepare mock up for tooling techniques at area of stone requiring repair
- Prepare mock up for area of patching of stone
- Perform test for mortar extraction- methodology, depth, sequence
- Source samples for stone replacement and perform mock up to match existing
- Mock up for stone pinning
- Mock up/technique for vertical crack repair
- Dehumidification chamber test
- Localized masonry drying test

Following the successful implementation of the mock ups and tests, the next step would be to test the validity of the work, primarily for the prevention of water intervention and for the maintaining of appropriate humidity levels and stone saturation and moisture levels. The tests performed on the repaired areas would include:

- Spray-bar water testing
- RILEM testing of the mockup areas to test for watertight integrity and success of dehumidification and reduction of water and water vapor in the masonry.

Project Sequencing

The final key component to the Schematic Design Phase is the design of an integrated scaffolding system to enclose the monument for drying and performing the conservation and restoration work for the project. This component addresses a number of key issues in the sequencing of the project and is closely related to the geotechnical report submitted by Langan Engineering. This scaffolding has numerous moving parts, timelines, and parameters to consider, but one approach can look as follows:

- Design and construction of walkway bridge over Monument entrance

- Scaffolding design for enclosing the entire Monument, with skrim, but constructed in sections

- Section 1 completed to allow for isolated testing and mock ups, i.e. creating a “work chamber”

- Following the successful implementation of mock ups and tests, scaffolding over entire Monument is constructed to begin the drying out and dehumidification process. Calculations for length of time can be performed based on chamber test.

- During this process, design and implementation of passive and mechanical ventilation system is developed and installation can begin independently of exterior work.

- Design Development and Construction Documents phases developed during the period of masonry drying and Monument dehumidification, along with other monitoring and testing procedures.

Prioritized Action Items: *Immediate Life Safety Hazards, Stabilization, Full Scale Restoration, and Ongoing Maintenance.*

- *Immediate Life Safety Hazards and Stabilization*
  Scaffolding- provide walkway and scaffolding at perimeter base for safety and protection for visitors

- *Full Scale Restoration-Primary*
  Stone masonry restoration design and mock ups
  Passive and mechanical ventilation system design
  Electrical upgrades

- *Full Scale Restoration-Secondary*
  Elevator
  Stair rehabilitation design
  Lightning Protection System

- *Ongoing Maintenance*
  Design of Monitoring systems (cracks, humidity, temperature control)
  Proposed sequence for exterior/interior upkeep based on monitoring data. Design and process/schedule of work will be developed in coordination with a cyclical maintenance plan that is suitable for the state.

Summary:

The analyses provided from the work performed in Phase 2 has provided our team with a tremendous amount of relevant information, and we believe we have succeeded in narrowing our focus to not only what we believe are the mechanisms of deterioration at work, but most importantly, a clear path of how to approach the full restoration and develop a Preservation Work Plan. The major factors that need to be addressed include:

- Saturated stone
- Walter infiltration
- Vertical cracking, spalling and stone damage
- High humidity
- Inverse stack effect for ventilation
- Outdated electrical and lightning protection systems
- General deterioration due to moisture and moisture vapor on stairs and elevator mechanisms
- Exacerbated deterioration due to ineffective and inappropriate repair campaigns
- Generalized material deterioration due to petrographic make up of stone

RECOMMENDATIONS AND NEXT STEPS

Our team believes, and we have stated in our documents, that as an objective, preservation enables us to gain a sense of ourselves, and the historic places we cherish tell us who we are, where we have come from and help direct us into a more consistent and meaningful path into the future. While the preservation of historic places is related to the significance of a physical landmark and its importance, there is more to it than the tangible , and/or practical side of a physical building, or in our case, an extraordinary monument. Preservation provides us with tangible objects that provide identity, memory and continuity to our communities and our own personal history. It helps root us in our heritage, it develops unity and provides a spirit that defines a neighborhood, a community, a city, and a nation. There is an emotional connection with these important places that provides a connection to the past that helps link the present.

There are the names and places associated with this emotional connection, from highways and roadways to state parks, hotels and motels, restaurants and bars. It is all based on memorializing and preserving the richness of our past so we can understand the reasons behind where we are today. In this particular case, we embrace the legacy of John Stark, Seth Warner, Ethan Allen, the Green Mountain Boys, the Republic of Vermont, the negotiations with Quebec before British surrender, then the negotiations with the U.S. to enter the Union, and all of this is representative of the Battle of Bennington as a key victory in our Revolutionary War, as much as it is of Vermont's battle for its own statehood, and the efforts of ultimately becoming the 14th state of the Union.

As the Vermont Historical Society professes "Every person and every moment create the story of Vermont. Through sharing these collective stories, Vermonters will increase their knowledge of our state's complex past, inform our present, and understand how our unique experiences impact and shape this ongoing narrative." The Bennington Battle Monument is part of this story, is a valuable link in Vermont's history, and a source of pride that can be continuously celebrated.

From a preservationist's perspective, it is important to understand a site's historic context, and this in return helps one understand a site's significance alongside the physical representation of this context. Historic context provides the political, social, cultural, and economic background for a particular idea, event, movement, or individual. Historians place historic events within a "historic context" to understand the meaning of an event or a property within a specific culture and/or period. Placing an event in its context enables historians to better understand if an event was unique or typical of the period, and/or how it may have impacted a culture or period. With a National Historic Landmark, the historic context enables us to understand the role the property played in American history overall.

From the practical perspective, Preservation is defined 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 on the ongoing maintenance and repair of historic materials and features rather than extensive replacement. 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. The Standards for Preservation require retention of the greatest amount of historic fabric along with the building's historic form. This is an important distinction when it comes to the development of the project scope of work and timeline.

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