20-065

Structural, Electrical, and Elevator Assessment of the Bennington Battle Monument

Old Bennington, Vermont

December 22, 2023

PREPARED FOR:

Agency of Administration
Department of Buildings and General Services
133 STATE STREET
MONTPELIER, VERMONT

AND THE

Agency of Commerce and Community Development
Division for Historic Preservation
ONE NATIONAL LIFE DRIVE
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1.0 EXECUTIVE SUMMARY

Stevens & Associates (S&A) in partnership with Silman have been retained by the State of Vermont to conduct a multi-faceted year-long study of the Bennington Battle Monument, located in Bennington, Vermont. The study began in November of 2021 and a preliminary partial draft of this report was provided in December of 2022 prior to the completion of the twelve-month monitoring portion of the study and prior to having completed an opinion of probable cost for a repair scope. The twelve-month monitoring program was completed by April 2023, and an opinion of probable cost was developed over the spring and summer of 2023. At the time of writing this report, a second phase of investigation is underway and the findings of which will be included in an amended report.

The observations and concerns expressed by the State that ultimately led to this study can be summarized as follows:

- **Stone Masonry** – A large-scale masonry repair campaign in the early 1990's documented repairs to approximately 2,000 to 5,000 cracks in the exterior stones of the Monument. The cause of these cracks is unknown. At present, bulk moisture migrates through the walls to the point of flowing down the face of the interior walls and forms large sheets of ice in the winter. Observations of efflorescence, failing mortar joints, buildups of leachate deposits, and exfoliation of the exterior stones indicate that the stone masonry is deteriorating, and moisture related processes are contributing significantly. There are also high levels of humidity and large temperature variations within the monument that create challenging conditions for the interior framing and electrical equipment, including the elevator.
- **Stairs & Steel Framing** – The existing stairs and landings are believed to be original to the Monument. They are currently off limits to the public and only used as emergency egress when the elevator malfunctions. The floors and stairs have been repaired on an emergency basis in the late 1980's and again after being cited by the Department of Labor and Industry in the early 2000's. During both projects the scope of work for the stairs was reduced. As the stairs and landings have continued to deteriorate there are concerns there may be unsafe conditions.
- **Elevator** – A modernization project was completed on the elevator in 2016. However, the reliability of the elevator is still questionable, the elevator breaks down or is shut down for emergency repairs for extended periods multiple times a year and visitors are turned away. Maintenance costs continue to be exceptionally high and there have been several entrapment incidents with the elevator where visitors or staff have needed to be rescued by the fire department.
- **Electrical** – The Monument does not have a back-up power source. When power goes out, the elevator has a battery back-up to bring the cab to the closest landing and open the doors but is not able to complete multiple trips. Any remaining observation deck visitors must then navigate down the stairs if they are able to. There are several generations of failed and abandoned light fixtures throughout the Monument and many of the emergency light fixtures do not work. These issues create unsafe conditions during an emergency.

A multi-disciplinary team was assembled to investigate these issues. The team includes Atkinson Noland & Associates (ANA), Hodgman Engineering and Permitting (HEP), DuBois & King (DK), Vertical Access (VA), Lerch Bates (LB), Langan Engineering, and Allegrone Companies.

The State has never possessed a complete set of drawings of the structure, so the first major milestone involved creating an accurate, to scale, as-existing full set of interior and exterior drawings (plans, elevations, and sections) of the Monument for use by the project team. This was achieved by Langan with three-dimensional laser scanning of the entire structure. The drawings accurately depict almost every exposed individual stone of the structure. These drawings were utilized by all members of the design team and will continue to be invaluable to the State for future projects at the Monument.

STONE MASONRY

The goal of the stone masonry investigation is to understand the root causes of the observed distress (widespread cracking, efflorescence, excessive moisture, etc.) and to provide recommendations that will lead to an effective and maintainable solution that considers lessons learned from past restoration campaigns.

The nature of the problem is that excessive moisture is currently accelerating the deterioration of the masonry. Past repairs have had limited success solving this problem with fairly standard repair practices, and in some cases the prior repairs may have caused, or are now causing, negative impacts.

The challenge is to reduce the amount of moisture that is migrating into the walls in the first place, and to repair or improve the damage that has already been done. This means understanding the causes of the cracking in order to limit future cracking, finding a workable solution for the existing cracks, and restoring damage in a way that will not perpetuate past issues.

The investigation of the stone masonry was led by Silman, and their comprehensive structural report is attached as an appendix. The effort included utilizing industrial roped access by Vertical Access's (VA) team to perform hands-on, close-up examination of the exterior of the monument. Additionally, non-destructive evaluation tools such as Surface Penetrating Radar (SPR) coupled with preliminary material testing were employed by Atkinson-Noland Associates (ANA) to inform the team's understanding of the interior composition of the walls. Moisture levels within the walls of the monument and crack movements are also in the process of being monitored remotely. Preliminary structural analysis based on building code loads has been completed by Silman and a preliminary finite element model was created based on the laser scan data. Finite Element Analysis (FEA) is beyond the current scope of this investigation but will likely be necessary at later design phases to inform and evaluate proposed repairs. FEA utilizes software to create a 3D structural model of complicated geometries. The software breaks the model into a "mesh" of much smaller, discrete "elements" that are assigned certain physical properties. The program can be used to apply loads, or other factors such as thermal changes or ground movements, to the structure and then analyzing the resulting effects element-by-element and iterating these calculations thousands of times until the model converges on a final solution. FEA provides insights that are not humanly achievable with simple equations. With FEA solutions localized stresses are able to be visualized and quantified at a much more granular level than other forms of analysis.

<u>The Priority 1 conditions noted in VA's report should be repaired as soon as possible</u>, and we recommend that the State establishes temporary protective measures. It should be considered to have VA remove all of the potentially loose materials. We anticipate additional masonry materials may continue to fall off the monument as additional weathering occurs, and this should be monitored.

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.
2. **Mortar:** Original construction documents specified both Rosendale and Portland cement-based mortars, each for unique applications. 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 caused by moisture expansion, thermal cycles caused by shifting of the stones, and freeze-thaw cycles. When the mortar is too hard, the stones then become the softer, sacrificial component of the wall system.
3. **Freeze-Thaw cycles:** Freeze-thaw cycles are currently accelerating the deterioration of the stone masonry. Water expands roughly 10% when it freezes. This creates stresses when the water is initially confined in pores or small cracks. Large enough stresses will widen existing voids and allow more water entry, and the cycle perpetuates. This will weaken the stone over time which will cause stresses to redistribute and compound on the next strongest point.
4. **Moisture and Humidity:** Limiting the moisture in the walls is a high priority as this will limit the amount of freeze-thaw action that can occur as well as prolong the service life of the existing mortars. The data collected at the time of writing this report suggests that the wall is continuously damp inside and does not dry out naturally even during “Moderate Drought” conditions. At present there are no active ventilation or condition controls within the Monument, and the interior conditions provide no opportunity for the wall to dry towards the interior of the building.
5. **Local Stresses:** A very high percentage of the observed cracks are vertical through the stones and perpendicular to the natural bedding layers of the stone, rather than cracking along (parallel to) the more vulnerable bedding planes. This suggests that the forces that are cracking the stones are tensile forces. The exact failure mechanism is not immediately evident, but it is likely caused by localized stresses developing from concentrated forces, or built-up internal forces possibly due to thermal expansion or freeze-thaw cycles.

Additionally, many of the initially suspected contributing factors have been ruled out as likely causes of the cracking:

- From the laser scan, the Monument was found to be plumb within construction tolerances and is not exhibiting any lean or excessive displacement or bulging.
- It is impossible to perfectly predict, model, or measure the interaction of the building movement with the observed cracking. However, it must be noted that the types of cracks observed that are caused by building settlement do not match what was seen at the Monument.

- The initial analysis using the assumption of a uniform cross section load distribution indicates that the stresses in the wall under gravity and wind loads, which are considerably more common than seismic events, are within allowable limits. Global loading, such as overturning and sliding, are within appropriate limits.
- The wall is not rubble filled at the interior. Often in multi-wythe stone masonry wall construction the middle third of the wall is filled with rubble and voids, allowing moisture to travel freely. That does not appear to be the case at the Monument; internal construction appears to be of solid masonry.

As outlined in the Recommendations section of the report, we have identified further recommended testing and monitoring in order to best understand the root causes of structural deterioration and to specify appropriate repairs. This includes bringing on board a masonry conservator, a mechanical engineer, and a building envelope specialist. Additional testing includes water infiltration and infrared (IR) testing, masonry strength testing, and a geotechnical survey. Lastly, we recommend performing a structural finite element analysis of the existing masonry structure as a whole.

INTERIOR FRAMING AND STAIRS

There are seven metal framed floor levels, thirty-three staircases and landings, as well as a steel framed elevator shaft within the Monument. The stairs and floors are original to the 1891 construction. The lobby and observation deck are the only levels served by the elevator and are the only floors accessible to the public. The stairs essentially function as a large escape when the elevator is not working.

The condition of the interior framing was visually observed by Hodgman Engineering and Permitting (HEP) and S&A, and limited Ultrasonic thickness (UT) testing was performed by ANA. A large percentage of interior framing currently requires significant maintenance and limited repairs in order to be suitable for continued use and to extend the useful service life. The primary failure mechanisms we have identified are as follows:

1. **Coating Failures:** The existing coatings have failed to varying degrees on all of the steel framing within the Monument. There are little to no traces of existing coatings left on the original stair assemblies and handrails. Cleaning and painting the stairs has been recommended in all assessments since the 1950s but has not been initiated. The coatings that were applied to most of the floor beams and plates in the late 80's and even in 2005 have recently failed. Coatings on the elevator framing, lobby framing, and Level E framing coatings are at more advanced stages of failure and corrosion is advancing.
2. **Corrosion:** Corrosion is related to coating failures. When the bare metal is no longer protected by a coating and is exposed to moisture and oxygen it will oxidize, or rust, leading to base metal loss. Corrosion is an exponential process, meaning the rate of corrosion accelerates as the metal deteriorates. The results of the two UT tests indicate that the steel framing in the staircase appears to still have adequate web thickness next to the beam pockets in the wall, though the condition of the steel within the wall is not confirmed due to being concealed by masonry. Visually, framing section loss due to corrosion does not appear to a widespread issue yet. The exceptions being at some of the post bases in the basement, at some railing attachment locations along the staircase, and a selection of beams where water can pool on the top flanges.

Corrosion is contributing to the fracturing of steel plates at some of the floor and landing levels. The cast steel floor plates and stair treads corrode by becoming more susceptible to brittle fracture (cracking) as iron is leached out of the base metal. Rolled steel, such as the supporting beams, is more prone to lamellar corrosion that causes expanding and flaking. This can lead to a process called rust jacking when the expanding corroded steel lifts or dislodges other components. This process is occurring between the rolled steel beams and the cast steel plates. The corroding beams are inducing stresses on the cast steel plates and this is occasionally leading to the fracture of the plates. This process is also causing damage within the grout filled beam pockets within the stone masonry, in some cases the grout has become dislodged and at a few locations, broken stones were observed. The original steel framing that is concealed within the brick arches of the Observation Deck are also susceptible to creating rust jacking issues and there is evidence that this is occurring; the cracking of the Observation Deck topping slab is likely a result of this action.

3. **Loss of Bearing Support:** Several observed bearing conditions are sub-optimal and should be repaired or bolstered. Additionally, it was a common observation that the beam ends nearest the stone supports, or embedded in the stone walls, were also the locations of the most observed corrosion. In general, the steel directly next to the exterior walls still had sufficient thickness and could serve as a second, redundant, bearing location.

As outlined in the Recommendations section of the report, we have recommended a comprehensive cleaning and coating scope of work for the interior framing, repairs to fractured floor plates and stair treads, as well as reinforcement of the steel framing at bearing locations. These recommendations should proceed into design phases.

ELEVATOR

The elevator was installed in the late 1950s. A modernization in 2016 included replacing the elevator motor, governor, controller, fixtures, doors, and in-kind replacement of some of the safety mechanisms and sensors within the hoist way. The original Otis machine (hoist) was retained.

Lerch Bates visually reviewed the condition of elevator and associated equipment with assistance from the Otis technician (formerly Bay State). Additionally, the elevator broke down multiple times during the first several months of the investigation (primarily during the off-season), thus providing the Lerch Bates consultant with direct experience with the more immediate issues that are facing the existing equipment and opportunity to provide useful maintenance guidance. In response to the consultant's recommendations, work was carried out that lead to an overall successful 2022 season with no entrapments.

Based on this investigation and the expertise provided by Lerch Bates, we have arrived at the following conclusions:

1. Currently, the primary sources of shutdowns and malfunctions in the elevator are the equipment within the hoist way, including the various sensors and contacts, the dated governor tail sheave, as well as the new door operator unit. The equipment from the 2016 modernization is generally functioning properly, other than the new door operator.

2. The existing sensors and contacts and sheave are dated technology and not well suited for the moist environment observed within the shaft. Some of this equipment was installed near the time when the Monument was enclosed, and a heating system was installed. The thinking may have been that the interior conditions were not going to be as severe as they are presently.
3. Additional targeted maintenance, beyond the standard state contract agreement, proved to effective for limiting shutdowns in the 2022 season.
4. The original Otis Elevator machine is leaking oil and showing signs of impending bearing seizure and needing a larger more in-depth rebuild, or replacement with a current piece of equipment. Servicing the nearly 70-year old machine may become harder as parts become sparse.
5. The 2016 modernization focused on the controls, motor, and cab and door improvements. The equipment installed is third party and can be serviced by any provider. The newer equipment is functioning well overall, but the new door operator unit may not have been the most ideal choice of unit due to very tight clearances in the existing shaft as well as high levels of moisture.

The repair scope outlined in the Recommendations section of this report includes completing the modernization of the remainder of the elevator equipment. This would involve replacing the original 1950s era Otis machine, as well as modernizing the hoist way equipment with better suited NEMA rated sensors and micro-switches. This work is ready to proceed into design phases. For the near-term, we recommend continuing the additional maintenance tasks outlined in the Lerch Bates (LB) memos and performing this comprehensive maintenance prior to opening for the season, during the season, and prior to the foliage busy season.

ELECTRICAL

The electrical systems within the Monument were visually reviewed by DuBois & King (DK). Two feasibility studies for emergency backup power for the Monument have also been completed by DK in 2015/16 and 2019. These studies explored options including conventional standby generators (diesel, LPG, Natural gas) as well as a later study into a Tesla-style battery bank. This effort was not duplicated in this current investigation.

The results of the electrical system investigation include the following:

1. The main panel, cabinet, and feed from the GMP transformer are adequate for continued use.
2. Overall, the electrical systems related to the elevator are in good, serviceable condition. There are some cable supports that violate the electrical code, and there are improvements regarding labeling in the machine room that could be completed. The existing Square D Type QO load center in the elevator machine room is currently in working and serviceable condition but is not the recommended equipment for this application.
3. The generations of wiring systems for the lights and outlets throughout the rest of the Monument are somewhat haphazard at this point, the conditions of the fixtures vary from good and serviceable to failed and corroded. Being an unheated structure with wide humidity swings, including water and ice formations on the walls and floors, all of the wiring methods must be suitable for damp conditions and large fluctuations in temperatures. Some of the existing wiring systems and many of the fixtures are not suitable for these conditions and will require repairs more often than would otherwise be required by the correct equipment.

4. There are a variety of wiring runs that were determined to be abandoned and no longer serving anything.
5. The existing lighting fixtures (non-emergency fixtures) will require more frequent repair and replacement since many do not appear to be rated for moist exterior-like conditions and temperature ranges.
6. Overall, the stairwell is not adequately illuminated. NFPA 101 provides the performance requirements such as the required level of illumination of 10 fc (foot-candles) (or 108 lux) in stairways, measured at the walking surface. This minimum is not satisfied at many locations.
7. The existing emergency lighting of the stairs does not satisfy the Life Safety Code. Section 5-8.1.3 states that "The floors of means of egress shall be illuminated at all points including angles and intersections of corridors and passageways, stairways, landings of stairs, and exit doors to values of not less than 1 foot-candle (10 lx) measured at the floor." It also states that "Any required illumination shall be so arranged that the failure of any single lighting unit, such as the burning out of an electric bulb, will not leave any area in darkness".
8. The number of convenience receptacles (outlets) is inadequate. This is based on feedback from staff. The condition of some receptacles is good, and they appear to be newer, but others are older with corroded fittings. All receptacles should be GFCI and suitable for exterior conditions.

As outlined in the Recommendations section of the report, we have identified a recommended scope of work that includes retaining the existing wiring systems for the elevator equipment, with minimal improvements, and replacing and upgrading all of the other wiring and lighting systems within the Monument. The lighting and wiring systems are relatively simple and are only complicated by the long vertical runs and exterior-like conditions within this unique structure. We recommend proceeding with design services for the electrical system upgrade.

CONSTRUCTABILITY AND OPINION OF PROBABLE COSTS

The design team has prepared an opinion of probable costs for the design and rehabilitation of the Monument for the purpose of raising sources of funds for the work. This opinion is based upon our understanding of the scope of work at this point in the investigation. The Design Team is in the initial stage of this project, working on the Investigation & Base Data Phase. No design phase work has been completed at this time. Typically, a cost estimate would be prepared as part of the Schematic Design Phase; however, the size and scope of the project required preliminary cost data to inform an order of magnitude budget.

Components such as scaffolding and metal work are reasonably well understood while others including the extent of masonry repairs & replacement are still being analyzed (and will be further analyzed during the CD phase). Allegrone Companies, a construction management company that specializes in this type of work, provided cost estimates for the masonry, steel, and scaffolding, see Appendix G for further detail. Allowances for other divisions of work were informed by the work to date and were included to provide a comprehensive opinion of cost. Industry standard allowances were used for design and other soft costs. A 15% estimate contingency, plus inflation escalation factors were used to reach an opinion for budgeting.

Our opinion of probable cost has incorporated some additional knowledge/insights gained during the on-going Phase 2 of investigation, however, that work is incomplete. The following are potential risks and uncertainties in the cost opinion:

1. No design or mock-ups have been completed; the cost estimate should be updated upon completion of each Phase of Design moving forward.
2. The condition and material analysis of the stones has not been completed. Although we have attempted to be conservative, additional study, mockups, and design will change the quantities of the various repairs and replacements.
3. The structural finite element analysis of the monument is currently incomplete and together with the material strength determination may inform the scope of work. Additional design, material testing, and installation of mockups during subsequent phases of work will inform, advance, and alter the scope of masonry structural interventions—thus changing the final schedule and costs.
4. There are many hidden conditions in a structure that is 8 feet thick at the base and 306 feet tall. Subsequent phases of investigation, design, and mockups will continue to inform the Design Team's recommendations regarding contingency for uncertainties during construction.
5. The nature, scope and scale of this work is such that there are a limited number of qualified contractors in the United States. A highly specialized project with a limited number of contractors could affect the costs when the final project is put out to bid. There may be unaccounted for costs associated with the need to sustain a qualified labor force that is remote from the original headquarters of the potential restoration contractors.
6. The cost of capital and construction inflation has been unprecedented in the last two years.
7. Phasing the project should be expected to increase the total project costs due to the sequencing inefficiencies, higher overhead, and multiple mobilizations.

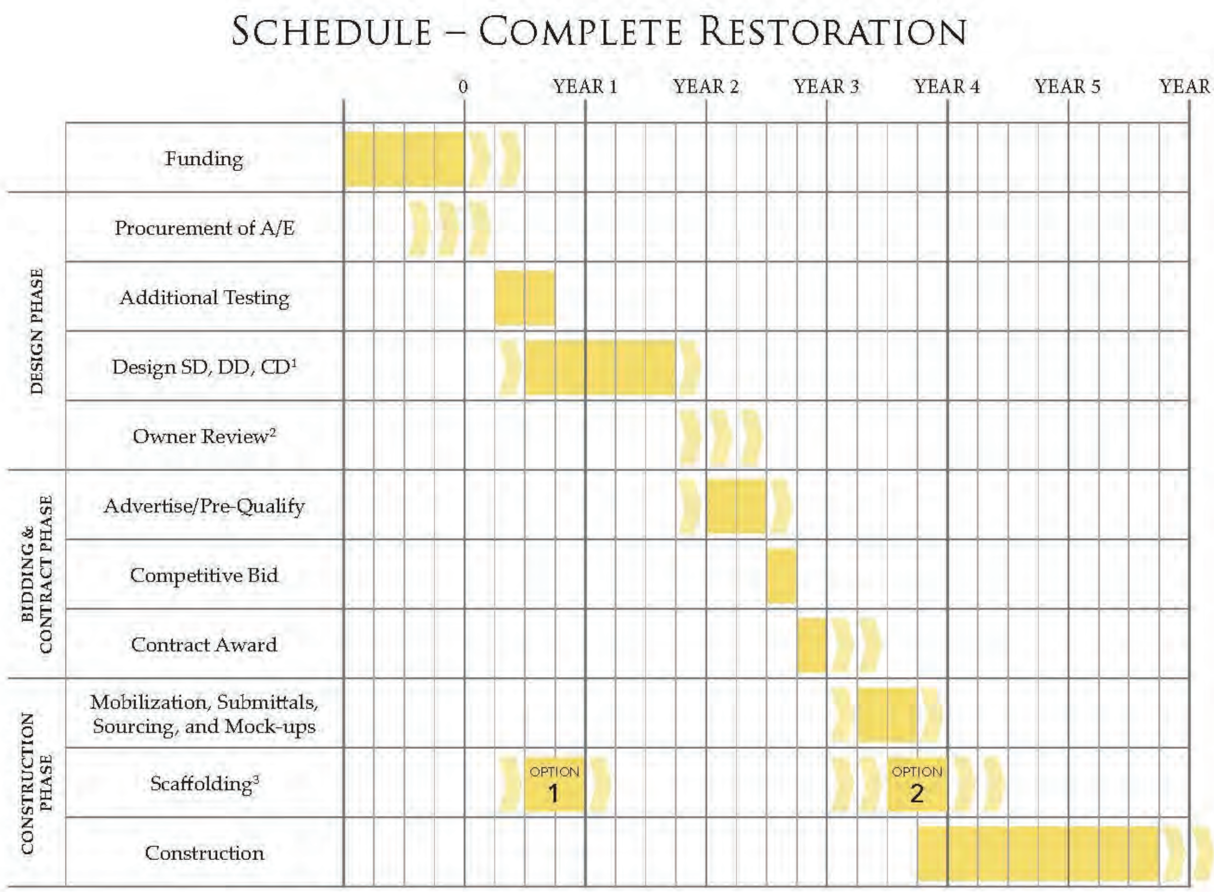
A contingency of 15% and escalation of 5% are a reasonable assumption but should be considered a minimum given the special nature of this project and the risks. As design progresses and contractor estimates are prepared confidence will increase. Once concept sequencing plans are prepared for a phased project, opinions of cost for a phased approach can be prepared.

A summary table of the project costs follows below, see Appendix F for further breakdown:

Soft Costs			
	A&E Design & Permitting (@ 10% Const Cost)		2,900,000
	Other Soft Costs (Testing, Inspection, Clerk, etc)		950,000
Hard Costs			
	Contractor General Conditions		1,655,000
	Scaffolding		5,500,000
	Masonry – Clean, Repair, Repoint		11,850,000
	Metals - Repairs, Refinish, Repair		3,025,000
	Additional Improvements		1,635,000
	Construction Cost Sub-Total		23,665,000
	Estimate Contingency @ 15%		3,550,000
	Contractor Overhead, Profit, Bonds & Insurance		$1,785,000
Sub-Total Opinion of Hard Construction Costs			**$29,000,000**
	Hard & Soft Cost Subtotal:		**32,850,000**
	Owner's Contingency (10%)		3,285,000
	Estimated Project Cost		**36,135,000**
	Escalation (1 YR @ 5% annum)	$	**37,942,000**
	Escalation (3 YR @ 5% annum)	$	**41,831,000**

SCHEDULE

The design team, in collaboration with Allegrone Companies, prepared a preliminary schedule for the comprehensive restoration of the Monument. This project is expected to take approximately six (6) consecutive years, including the completion of Final Design & Bidding. In general, further investigation & final design is expected to take between two (2) and three (3) years. The construction phase is also expected to take between two (2) and three (3) years. This schedule assumes there are no inefficiencies due to phasing. See further discussion about sequencing and phasing below.



[1] Includes sourcing stone and mock-ups at site.
[2] Owner review at completion of each design phase would likely extend schedule.
[3] Scaffolding: Option 1 if purchased by State of Vermont. Option 2 if included in bidding of construction project.

SEQUENCING & PHASING

The complexity and cost of the comprehensive restoration project is expected to result in phasing the project. Sequencing plans need to be developed during schematic design to inform appropriate and feasible levels of phasing. Certain elements regarding the construction sequencing are known at this time and will impact the phasing and construction costs for the project:

- **Lightning Protection:** As part of the Phase 2 investigative work, it has been identified there are improvements needed to bring the Monument's lightning protection system into compliance with current Codes. Given the unpredictable nature of lightning strikes, and the relatively low cost of these improvements compared to the overall project, it is recommended that this work be completed as soon as possible. A copy of the Lightning inspection completed by Smokestack Lightning company was provided separately to the State of Vermont in advance of the completion of other Phase 2 work.

- **Scaffolding**: Sequencing of the scaffolding will affect both the interior and exterior work for the monument. The entire exterior of the monument will require scaffolding to complete the project and this is a significant cost item. Therefore, sequencing all the exterior work to occur concurrently would maximize the use of the scaffolding and be more cost effective. If work on the exterior of the monument is to be phased, the scaffolding costs will increase due to an extended timeframe on-site, or from dismantling and re-erecting additional times.

  The State could consider purchasing the scaffolding to control costs. As represented on the schedule graphic above, purchase and installation of the scaffolding during Final Design would reduce risks and uncertainties regarding the scope of construction work to be bid, by allowing the Design Team and perspective bidders to observe the Monument prior to bidding. At this time it appears the payback on purchasing the scaffolding is between two (2) and three (3) years, compared to the rental costs through a general contractor.

  Interior scaffolding will be needed for elements of the work inside the structure, but consideration for the metal work and elevator improvements will be needed. If the interior work is to be phased, sequencing plans and a timeline for the interior work will be needed to confirm the appropriate scopes of work in each phase. There is not a need to consider purchasing the interior scaffolding by the State of Vermont due to the stairs providing reasonable access for observation.

  We recommend that the State consider a pre-bid effort to more thoroughly analyze the potential interior and exterior scaffolding options/ technical engineering issues, to advance the design of these scaffolds (perhaps to a 50% or a 100% DD level), and to then provide a more comprehensive cost of the design, fabrication, and installation of the scaffolds.

- **Elevator:** The sequencing of work related to the elevator improvements will be critical to maintaining potential access to the public during phases of construction. Therefore, the State will need to identify requirements and timelines for any on-going elevator use by the public. Complete rehabilitation of the elevator should be considered as part of a comprehensive restoration project, which could also impact sequencing. Additionally, removal of the elevator shaft and components would facilitate easier installation of interior scaffolding, however, removal may impact access during construction for workers and moving materials.

- **Mechanically Conditioned Space**: Ventilating and/or heating the monument may be recommendations resulting from the on-going Phase 2 investigation and are likely to require electrical upgrades to accommodate their installation. If these improvements are considered for an early phase of the restoration, sequencing plans developed during schematic design will inform the feasibility and potential pros and cons associated with completing these improvements prior to future interior work (including metal and/or masonry) that could impact the mechanical systems.

2.0 INTRODUCTION

The Bennington Battle Monument is a stone obelisk located at the top of Monument Avenue in Bennington, Vermont. The 301-foot-tall structure was completed in 1891 to commemorate the 1777 Battle of Bennington in nearby Walloomsac, New York, and is the tallest manmade structure in the State to this day. The Vermont Division for Historic Preservation's State-Owned Historic Sites Program has operated and maintained the Monument and the associated gift shop since 1953. Tens of thousands of tourists visit the structure during the May to October season, paying $5 per adult to ride the elevator up 189-feet to the observation deck.

PURPOSE:

The purpose of this report is 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.

Our approach to this investigation included engaging several specialized subconsultant firms including DuBois & King as electrical engineers, Lerch Bates as elevator consultants, Atkinson Noland & Associates for non-destructive evaluation, structural monitoring, and material testing, Vertical Access for industrial rope access, Allegrone Companies for project cost estimating and miscellaneous contractor support, and Langan Engineering & Environmental Services for 3D scanning the interior and exterior of the Monument to create accurate base drawings and 3D models.

Observations began in November of 2021 and are presently on-going at the time of writing this draft report in December of 2022. Readers are encouraged to review the full detailed reports from each specialty firm attached as appendices.

STATEMENT OF THE PROBLEMS:

The following list outlines the concerns expressed by the Department of Building and General Services as well as the State-Owned Historic Sites program leading up to this investigation:

- **Stone Masonry** – A large-scale masonry repair campaign in the early 1990's documented repairs to approximately 2,000 to 5,000 cracks in the exterior stones of the Monument. The cause of these cracks is unknown. At present, bulk moisture migrates through the walls to the point of flowing down the face of the interior walls and forms large sheets of ice in the winter. There are high levels of humidity and large temperature variations within the monument that create challenging conditions for the interior framing and equipment. The moisture also leaves the walls vulnerable to freeze thaw damage in the winter months and contributes to the advancing mortar and stone weathering evidenced by efflorescence, buildup of leachate deposits, and exfoliation of the exterior stones.
- **Stairs & Steel Framing** – The existing stairs and landings are believed to be original to the Monument. They are currently off limits to the public and only used as emergency egress when the elevator malfunctions. The floors and stairs have been repaired on an emergency basis in the

late 1980's and again after being cited by the Department of Labor and Industry in the early 2000's. During both projects the scope of work for the stairs was reduced. As the stairs and landings have continued to deteriorate there are concerns there may be unsafe conditions.

- **Elevator** – A modernization project was completed on the elevator in 2016. However, the reliability of the elevator is still questionable, the elevator breaks down or is shut down for emergency repairs for extended periods multiple times a year and visitors are turned away. There have been several entrapment incidents with the elevator that have required guests and/or State employees to be rescued by the fire department.
- **Electrical** – The Monument does not have a back-up power source. When power goes out, the elevator has a battery back-up to bring the cab to the closest landing and open the doors but will not be able to complete multiple trips. Any remaining observation deck visitors must then navigate down the stairs if they are able to. There are several generations of failed and abandoned light fixtures throughout the Monument and many of the emergency light fixtures do not work. These issues create unsafe conditions during an emergency.

BACKGROUND

Designed by Boston architect John Phillip Rinn and built by contractor William Ward of Lowell, MA. The cornerstone of the Monument was placed in June of 1887 and the capstone was set in November of 1889 at a total cost of approximately $112,000 including purchasing the site. The Monument was officially dedicated in 1891, the centennial of the State of Vermont.

The overall form of the structure is a 301-foot tall, four-sided, hollow stone obelisk. The base of the structure is roughly 37-feet by 37-feet at the ground level, and the stone walls are initially roughly seven-and-a-half feet thick. The four sides slowly taper inwards vertically as the walls become thinner, and finally the four walls curve gently together and form a peak at 301-feet above grade. At approximately 189-feet above the ground floor is the main Observation level with five tall viewing windows in each exterior wall. The Observation level is served by a centrally located elevator as well as a much older metal stair system that traces along the four walls all the way down to the lobby. A few intermediate floor levels and large landings are also part of the metal stair circulation.

The distinct rough faced exterior stone blocks of the Monument are a blue-grey magnesian limestone called Sandy Hill dolomite from present day Hudson Falls, NY. The interior stones are irregularly shaped and were sourced more locally from both the now shuttered Lyman and Fillmore quarries. The original "Contract and Specification for the Bennington Battle Monument" dated March of 1887 called for a natural Rosendale cement bedding mortar as well as a Portland cement-based mortar for pointing the exterior joints and filling larger cavities within the wall.

When completed, and for the first sixty to seventy years after construction, the Monument did not have an elevator, nor any glass windows in the stone openings, even at the observation deck, and the only access was to climb the 419 steps up to the observation level.

HISTORY

The history of the Monument is not well documented prior to the state taking over operations in 1952. A 1988 report prepared by Ryan Biggs Associates (RBA) outlines the known history at that time between 1952 and 1988. Some of the primary source documents referenced in the RBA report were able to be located and reviewed during the course of the current assessment work. Digital and paper files were also provided by the State that primarily outline the restoration efforts between 1987 and 2005. An abbreviated history is as follows:

<u>1891 to 1952 —</u> The Bennington Monument Association operates and maintains the Monument.

<u>1891 —</u> The Monument dedication ceremony is attended by United States President Benjamin Harrison, the Governors of Vermont, New Hampshire, New York, and Massachusetts. Vermont Governor Carroll Page accepts the dedication of the monument and pledges "*Vermont's interest in this monument shall ever be something more than a mere property interest so long as the sons and daughters of Vermont shall honor bravery and patriotism and revere the memory of a loyal, self-sacrificing ancestry; so long, I am sure, with this memorial of a patriotism as pure and holy as ever made its home in the breast of man, be guarded and cared for as a sacred trust. It shall stand here untouched, save by the finger of time, to tell to our children and our children's children the story of the struggle for liberty, and to inspire all who may come beneath its shadow with a deeper love of country, and a higher appreciation of those men whose sacrifices made possible the priceless blessings we are today privileged to enjoy.*"

<u>1909 —</u> A newspaper article describes the first visit of the season to the Monument and notes "the interior of the Monument is now very damp… This condition usually continues until the middle of May".

<u>1920's —</u> Cracks in the exterior stones are first reported. (This was the timeframe reported in a 1953 assessment of the structure).

<u>1931, Sept. 16 —</u> Newspaper article "Argue Over Life of Shaft" is published. Sculpture of Stone Mountain confederate memorial August Lukeman inspects the Bennington Monument and claims, "*that it would crumble of its own weight within 50 years*" and cites the already evident cracks. Engineer and architect Henry Parsons Jones takes vigorous exception, determining a limestone shaft would have to be 5,950 feet high to crumble under its own weight.

<u>1952 to 1988 —</u> In 1952 the Monument is in poor condition and the Bennington Monument Association is no longer able to function or care for the structure. The association disbanded and transferred care of the Monument to the State Board of Historic Sites in October of 1953.

Much of the history below is paraphrased from the 1988 report history prepared by Ryan Biggs Associates:

1953 — A 1953 assessment reported that cracks first started forming in the Monument in the 1920's. The 1953 report indicated the Monument was in poor condition and only minor repairs had been performed prior to then.

1954 — Bids for repairing the Monument ran as high as $200,000. $25,000 was appropriated to pay for emergency repairs to the top 100 feet of the Monument.

1955 — The legislature appropriated $103,000 to the Vermont Building Council to continue the masonry repairs, install an elevator, install a heating system, and add a new ticket office. Funds for interior masonry repairs were requested but not approved. Hayes and Coffey was contracted to complete the repairs. The operation of the heating system is not documented, and it was anecdotally reported that the system was out of service at some point in the 1970's.

1959 — Architectural firm of Perry, Sha, Hepburn & Dean from Boston, MA, and consultant John Nicholson of Nicholson and Galloway of New York, as well as two architects from the National Park Service Eastern office, reviewed the condition of the Monument and determined the previous repair work completed by Hayes and Coffey was substandard.

Estimates for the repair work ran as high as $165,000. $12,000 was authorized for emergency repairs.

1964 — Windows installed at the Observation level.

1967 — Consulting engineer Thomas Oakes prepared a report titled "A Restoration Program for the Bennington Battle Monument". He estimated $175,000 to $200,000 for the restoration work. There are no records indicating that his recommendations were carried out.

1980 — Raymond E. Kelley, Inc. was hired to repair the exterior south wall from the Observation level to the top. The cost of the work was $6,130.

1981 — Raymond E. Kelley, Inc. was the successful bidder for repairing the north, east, and west exterior walls from the Observation level to the top of the Monument. The contract amount was not to exceed $22,000.

1987 — Ryan-Biggs Associates (RBA) was hired to assess the metal framing and stairs in the Monument. An estimated $90,000 worth of necessary repairs to the stairs, landings, and various floor levels were identified and the Monument was temporarily closed. $30,000 of emergency funds were authorized for the most urgent emergency repairs. Good Erectors was hired for the steel repair work.

<u>1988 —</u> A reduced scope of emergency repairs to the steel decks continued. In the summer, RBA was retained by the State to further study the Monument and make recommendations for masonry repairs. RBA published Monument Restoration Report.

<u>1990 to 1991 —</u> Joseph Gnazzo Company (JGC) was the successful bidder for the masonry restoration work. Hanging scaffolding was used to repair and repoint all four exterior sides of the Monument. The work was completed in time for the centennial celebration of the Monument and the State's bicentennial.

<u>1990 to 1991 —</u> $250,000 of funding for stair restoration was approved over two years (one year allocated to Building and General Services, the next year to Historic Sites). This work was put on hold as the focus shifted to the masonry restoration at this time. Repair work on the stairs and landings was delayed until 2000 when the Department of Labor and Industry cited the State for the stairs' poor condition.

<u>2000 —</u> Two incidents of passengers becoming stuck in the elevator. The Department of Labor and Industry cited the Monument for the poor condition of the stairs and the Monument was temporarily closed. RBA assessed the stairs and noted a number of deficiencies and provided recommendations. RBA confirmed the stairs were safe enough for emergency egress and the Monument was able to re-open.

<u>2001 —</u> RBA provided recommendations for restoring and repainting the stairs as well as finishing repairs to the sub-observation deck and repointing the top 95 feet of the Monument.

<u>2002/2003 —</u> Other projects such as installing emergency lighting along the stairs, removing asbestos insulation, steam pipes and intercom as well as insulating, heating and fire rating the elevator machine room took priority. Funding became available to add exterior up lighting to the Monument.

<u>2004 —</u> October 19th the elevator stopped working at the top of the Monument and a repairman was called. This continued to happen three days in a row.

<u>2005 —</u> Joseph Gnazzo Company (JGC) was the successful bidder for the 2005 restoration work. Bids were over $500,000, and the available funds from 90-91 were only approximately $250,000. As a result, the scope of work was reduced to exclude major repainting of the stairs and repair of the observation deck slab.

<u>2005 —</u> July 4th, passengers were stuck in elevator and Fire department was called to help extract them. Elevator stopped working again on August 2nd. Elevator stopped working again on October 3rd (foliage season) and 148 visitors were turned away.

<u>2006 —</u> June 26, elevator stopped working and staff turned away 225 visitors.

2015-19 * — Dubois & King was retained to complete a feasibility study for providing emergency backup power for the Monument. The initial study looked into utilizing a standby diesel or natural gas generator, and a follow up study examined using a backup battery bank option. Both systems were determined to be feasible, though the battery bank would cost two to three times more than a traditional generator.

2016 — Elevator modernization was completed. Many controls, doors, cab, and hallway equipment were replaced but the original Otis machine from the 1950's was retained. Miscellaneous dated sensors in the shaft way were replaced but not updated.

2019 — Some emergency lighting was replaced along stairway. An emergency battery for the elevator was installed, allowing the elevator to reach a safe level and open the doors in the event of a power outage.

2021 — Labor Day entrapment service call for passengers stuck in Elevator. Elevator was down for at least three days for service and ordering parts. Elevator was down again on December 12th (off season during current investigation).

2022 — May 6th to 9th. As the current project team, including several out of state subconsultants were arriving for a weeklong investigation of the Monument, including roped rappelers, the elevator was not working. A field technician was able to get the elevator operational within a few hours.

3. INVESTIGATION AND FINDINGS

3.1 STRUCTURE

The Monument is a stone masonry structure, consisting of an estimated nineteen-million pounds of stone and mortar. There is no additional reinforcing or concealed structural elements. The walls range from approximately seven-and-a-half feet thick at the base to approximately two-feet-nine inches thick at the top.

The overall structural soundness of the Monument is directly related to the integrity of the stone and mortar from which it is constructed. Stone masonry is a very durable and strong building material, however, frequent exposure to moisture will, over time, deteriorate the stone and mortar. This is because mortars have water soluble compounds that eventually dissolve, and the mortar loses its ability to bind together. In colder climates like the northeast, moisture also damages the stones and mortar through the seasonal action of freezing and thawing. Initially small pores or defects in the stones and mortar are enlarged by the expansive forces of freezing water; creating a larger void that allows more moisture migration and the cycle repeats.

These two moisture related processes are currently causing damage to the Monument. It has not been established, however, whether moisture initially caused the extensive cracking in the stones reported as early as the 1920's when the structure was only thirty years old.

A comprehensive solution to the ongoing moisture issues requires an understanding of why the stones have cracked and finding a solution that addresses the existing cracks and attempts to reduce the formation of new cracks.

Structure Approach

The investigation of the stone masonry, including moisture and cracking concerns, was led primarily by Silman. Their comprehensive structural report is attached in Appendix A1. It is strongly recommended to review the Silman assessment in its entirety. The investigation was conducted as follows:

- **Existing documentation of previous repair efforts were compiled and reviewed**. Available documents include the original project specifications from 1887, an undated field survey (likely late 1950's or early 1960's) by F.E. Hockensmith of Lennox Industries Inc. regarding issues with moisture and recommendations for ventilation, preliminary Otis Elevator shop drawings from 1955, Ryan Biggs Associates (RBA) 1988 assessment and bid drawings for the interior stairs and floors, 1989 RBA assessment of the stone masonry, 1990-91 RBA masonry restoration drawings, specifications, and field reports, 2000 RBA assessment of stairs and floors, 2005 RBA stair and masonry repair drawings and specifications.

- **The exterior and interior of the Monument was three-dimensionally laser scanned by Langan Engineering & Environmental Services** on February 10th through 12th, 2022. The scan yielded accurate stone by stone drawings of each interior and exterior face of the Monument as well as several plan views and building sections with accurate wall thicknesses. These drawings served as the base drawings for all the subconsultants. No accurate existing conditions drawings have existed for the monument prior to this effort. Additionally, an accurate 3D model of the existing conditions suitable for future construction documents and a 3D mesh for future finite element analysis of the Monument were also created.

- **The interior and exterior stones of the Monument were visually observed, and the existing conditions documented.** The interior stone masonry was observed where walk-up access was available and interior elevations were annotated with observations. The exterior was observed and documented via industrial roped access performed by Vertical Access over the week of May 9th, 2022 (figure 1). Vertical Access documented the exterior conditions using their TPAS system that allowed them to accurately key photographs and notes to the CAD elevations created by the laser scan. One of the investigative "drops" on the west side of the south facing wall was live streamed to the project team on the ground and enabled the engineers to participate in the up-close examination of the stones and become familiar with the conditions that were being observed. The live stream session was recorded and will be provided digitally with the final report.

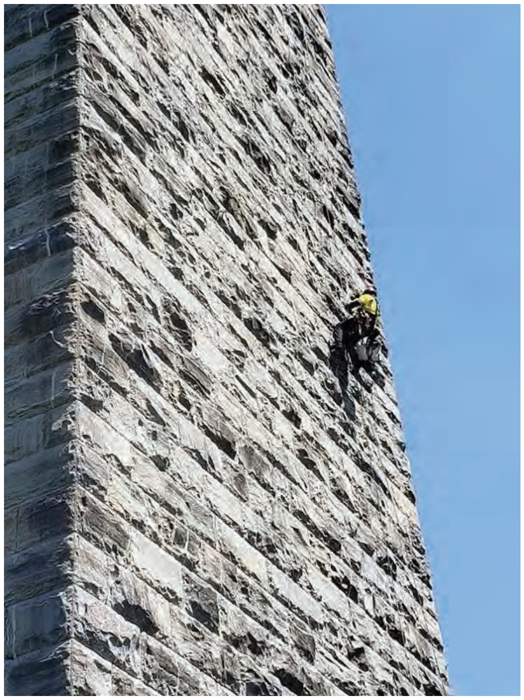


FIGURE 1

- **The moisture inside the Monument was monitored over the course of a year.** The monitoring was carried out by Atkinson Noland & Associates (ANA) with instrumentation installed by BDI (Bridge Diagnostics, Inc.) of Boulder, Colorado. The instrumentation included three temperature and relative humidity meters; two of which were embedded approximately 9 inches into the interior face of the stone walls within mortar joints, and one monitor was left exposed alongside the elevator shaft to record ambient temperatures and humidity. The sensors wirelessly upload data every 15 minutes. BDI installed the monitors March 2nd and 3rd, 2022. Sensor locations are noted on the interior elevations in Appendix D2.

- **Three existing cracks on the interior of the Monument were monitored for move-ment.** The monitoring was carried out by ANA with vibrating wire crackmeters installed by BDI on March 2nd and 3rd, 2022. The meters are sensitive enough to record changes in the crack size due to the changes in temperature. The meters record and upload measurements every 15 minutes. Sensor locations are noted on the interior elevations in Appendix D2.

- **Four seasonal site visits were completed** to visually observe the interior conditions of the Monument and document dampness and other moisture related observations**.** Visits occurred on November 1st, 2021, March 1st, 2022, May 9th, 2022, and after a significant rain event on September 7th, 2022.

- **Five stone samples and six mortar samples were collected** by Silman and ANA engineers with assistance from Allegrone and Vertical Access. Petrographic analysis was able to be completed on three of the stone samples (two core samples crumbled upon removal). X-ray diffraction was able to be completed on all the stone samples. Three mortar samples were tested by ANA for their chemical composition. One mortar sample was recovered as a fine brown powder from the ANA drill bit that extended deep into the Monument wall. These samples were collected during the week of May 9th, 2022.

- **Surface penetrating radar (SPR) was used by ANA to determine the composition of the stone walls.** In massive stone masonry structures, it is not uncommon for the interior of thick walls to be filled with rubble. The SPR provided insights into whether the full thickness of the walls were one solid wall laid with coursed stones or as two independent walls with rubble infill. Additionally, the SPR coupled with videoscope observations was used to determine if voids within the wall are developing. The SPR and videoscope observations were completed during the week of May 9th, 2022. Vertical Access assisted with the scanning effort by using the ANA SPR equipment to complete a single full height scan along the south face of the Monument.

- **Preliminary structural analysis was performed** by Silman based on the information gathered in the SPR scans and 3D laser scan. The analysis focused on global stresses and stability using estimated stone weights (based on literature) and current code prescribed gravity and lateral loads. At that time, hand calculations and spreadsheets were developed to calculate the axial and bending stresses along the height of the Monument as well as bearing stresses at the base. Traditional empirical design practices that would have been used for stone obelisks were also researched and compared against the as-built conditions of the Monument.

Structure Findings

The structural findings are discussed at length in the attached Silman report as well as in the subconsultant reports, see Appendix A1. A brief summary of the key findings are as follows:

Existing Document Review:

- The State put a significant amount of effort and resources into the Monument in the 1950's and early 1960's when Historic Sites first took over operation of the landmark. The approved funds typically provided 10%-50% of the bid amounts or estimates, so it is presumed that the various project scopes were significantly reduced from the original recommendations. Nonetheless, the work included exterior masonry repairs to the upper approximately 100 feet of the Monument, the installation of the elevator, closing in the observation deck and other openings with glass windows, and consulting with a HVAC specialist about the interior moisture conditions. This work ultimately led to installing heating and ventilation equipment in the Monument in an effort to dry out the interior and mitigate freeze thaw deterioration.

- Through the 1960's and into the 1980's fewer projects took place until a major masonry campaign in the late 1980's early 1990's. A few assessments were completed, and it seems moisture continued to be a concern. It was reported, but no documents were found, that the heating and ventilation system was essentially abandoned in the 1970's, possibly due to energy costs at that time. The system was not used again.

- All of the assessments completed since the State has overseen the structure have recommended developing a routine maintenance schedule for the exterior stone. A routine maintenance schedule has never been implemented.

Laser Scan & 3D Model

- Beyond accurate existing condition drawings, the 3D scan allowed global measurements and distortions to be assessed. The 3D model was imported into Revit and overall plumbness checked. Additionally, several plan sections were cut and overlayed to check for any bulging or warping in the horizontal cross sections of the Monument. This effort was necessary because such observations would be too subtle to notice visually from afar and too global to notice with close-up observation. (See figure 2 and 3)

- Overall, the Monument was found to be notably plumb and straight, well within expected construction tolerances. No significant leaning or bulging was observed.

FIGURE 2

FIGURE 3

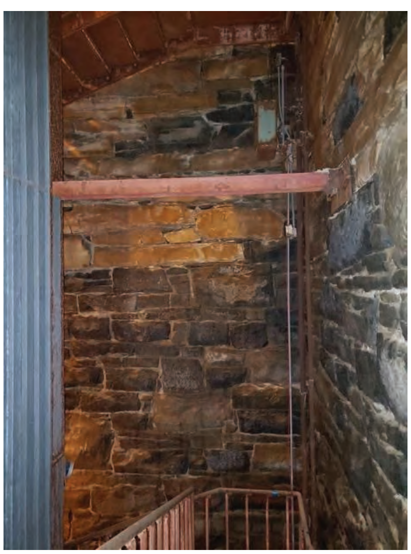


FIGURE 4

FIGURE 5

FIGURE 6

Visual Observations – Interior Stones

- A survey of the interior stone masonry was completed by Stevens & Associates over the course of several seasonal site visits and the final write up is included in the fourth seasonal site visit report in Appendix C5.

- The interior stones are irregular in size and shape and lack regular coursing. The only exceptions are at the observation level where the interior stones are squared blocks similar to the exterior, and at the very top of the Monument where the walls are a single stone thick. The interior stones were sourced from two different local quarries, and there is a distinct transition within the main stair tower space where the stones transition in color from darker grey stones to a predominantly tan color (figure 4). Samples of both types of stone were collected and are discussed in the Material Sampling section below.

- There are fewer cracks visible in the interior stones than on the exterior. Overall, the majority of observed cracks were less than ¼″ wide, and many hairline cracks were noted. No cracks larger than ½″ were noted. Some apparent trends included that more cracks were observed around openings such as windows. This is expected due to the transferring of loads around openings. Additionally, from the observation deck level down, most of the cracks were observed in proximity to the corners of the Monument (figure 5). This is a concern as the corner stones serve an important function of transferring stresses between the walls of the Monument in order for the structure to behave as a monolithic construction.

- There have been very few repairs to the interior masonry. No crack repairs were observed other than at the observation level and a handful of epoxy repairs at the very peak where the walls are one stone thick. The interior stones above the observation level have been heavily repointed with a hard Portland cement-based mortar, it is believed this occurred after 1987. Limited repointing has occurred along the main stair tower, and most of the repointing has been concentrated at the corners of the structure. The south wall appears to have been repointed more than the other interior walls.

- Dust from deteriorating mortar quickly coats surfaces within the Monument (figure 6). Clean marking tape was placed on the handrails during the initial November visit. By early February the tape was coated with a thick film of dust. This was during the off season when the structure is closed, and air flow is minimal.

- There is not an apparent correlation between the interior cracked stones and the exterior cracked stones. The physical nature of how the building was constructed (due to how thick it is) inhibits the ability to find a direct correlation between internal cracks and external cracks. There are too many paths for the crack patterns to follow between the outside and the inside for this exercise to be useful. Even as the structure becomes thin enough to be two stones deep with bonding or header stones between interior and exterior, it is very difficult to correlate an external crack with an internal crack.

- Localized areas of a white horizontal efflorescence or leaching deposits were observed on several interior stones (figure 7). A core sample was attempted at one of these locations and crumbled upon removal from the parent stone.

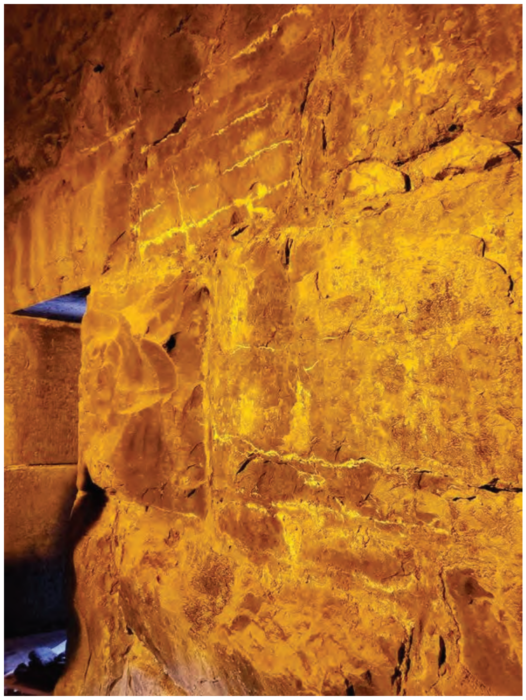


FIGURE 7

Visual Observations – Exterior Stones

- Vertical Access prepared a report dated June 2, 2022 documenting their findings regarding the exterior stones, see Appendix B2. Additionally, digital CAD and PDF files using their proprietary TPAS system, as well as video files from the live feed session on May 11, 2022 have been provided.

- The cracking of the exterior stones and the deterioration of the mortar joints is widespread on all four sides of Monument (figure 8 and 9). The south and west faces of the Monument have the most cracked stones and most prevalent surface loss (exfoliation). This may be due to these elevations being subject to the prevailing winds and harshest weather, as well as longer exposure to solar energy. Many of the cracks have been previously repaired, typically by covering 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 (see figure 8 for examples of different repairs). Many of the unrepaired cracks that were observed were less than 1/16 of an inch wide. It is believed that most of the existing repairs date from the 1990-91 restoration campaign. Many of the observed cracks on the north and east facades have been previously repaired.

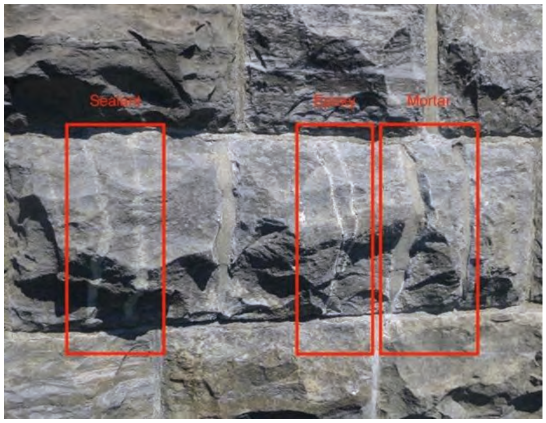


FIGURE 8

FIGURE 9

FIGURE 10

- There are currently hazardous conditions involving sizable pieces of stone and loose material from failed patch repairs that are loose and could fall. Vertical Access noted these conditions as Priority 1 and made an effort to remove loose material, but potentially dangerous pieces remain (figure 10).

- Cracks through single stones are common on all elevations at all heights. Crack systems – that is cracks extending through multiple courses of stones and mortar joints – were more commonly observed below the observation deck level, and typically extend through five to ten horizontal courses.

- The sealant used for repairing a high percentage of the cracks is failing (figure 11). The sealant is over 30 years old and is beyond its useful service life. It is cracking and separating from the stone surfaces. In many cases, the failed sealant now has a deleterious effect of trapping moisture within the wall, or at least slowing down the natural drying process.

- Many of the wider cracks that were repaired with mortar are failing. In a few areas loose mortar was removed, and it was observed that the crack had been routed out, or widened, and the result is a wide wedge-shaped mortar joint that is now failing (figure 12).

- Missing mortar and loose mortar in the joints between the stones were common observations. Loose mortar poses a falling hazard. These repointing mortars are presumed to be from the 1990-91 restoration when all four sides of the Monument were repointed.

- Deposits of leached salts were observed seeping through the mortar joints at most of the exterior masonry. This is a result of bulk moisture movement behind the surface of the mortar joints.

- Biological growth was noted at some mortar joints. This is a sign of persistent moisture.

- Bronze U-shaped straps, or “staples”, are visible on the surface of some cracked stone units. The staples are oriented horizontally across the crack and are generally covered with a urethane sealant, though some are encased in mortar. Most of the staples are found near the base of the monument and are visible at ground level, and only a handful were noted at the upper elevations of the monument.

FIGURE 11

FIGURE 12

Interior Remote Monitoring and Seasonal Observations

- The remote moisture and crack monitoring of the Monument was carried out for twelve months and at the time of writing this report it has been decided and approved to increase and extend the monitoring program until spring of 2024. The monitoring was started in March of 2022 and required a few weeks to acclimate to the interior conditions. The Phase 1 twelve-month monitoring campaign was completed in April 2023.

- Quarterly monitoring reports were prepared by ANA and are attached in Appendices C6-C9.

- Seasonal site visits to visually review the moisture conditions in the Monument were conducted by Silman and Stevens & Associates in November 2021, early March 2022, May 2022, and September 2022. Field reports from the site visits are included in Appendices C1-C5.

- Varying amounts of moisture were observed during all site visits (figure 13, 14, and 15). Areas of the walls varied from dry, to almost dry, to light surface moisture, to a heavy coating of moisture with a visible sheen. In general, Winter of 2021-2022 was a fairly mild winter with few snowstorms. By mid-summer Bennington was considered to be in a moderate drought. Visibly damp stones were observed in all seasons and the embedded moisture meters reported 99-100% moisture (meaning liquid water was present at the meter) for the entire duration of the Phase 1 monitoring program.

- In general, the upper half of the Monument typically had more signs of moisture than the lower elevations. An exception being that the below grade basement walls were observed to be damp in all visits, and especially damp in the fall and spring visits. In the winter, a large area of ice was observed along the middle of the south wall below the sub-observation level and extended multiple landing heights down (figure 15).

- At the time of this report writing, the remote moisture meters that are embedded and sealed within the walls of the Monument have consistently reported higher than expected levels of moisture. Readings have indicated 100% relative humidity (meaning liquid water is present at the meter) for extended periods of time and have rarely decreased by only a few percentage points. This held true over the summer months when Bennington was experiencing moderate drought conditions. The data suggests that the walls do not fully dry out naturally on their own and instead remain very damp inside even during an exceptionally dry summer.


FIGURE 13


FIGURE 14


FIGURE 15

Material Samples and Testing

- A Stone Petrography Test report, submitted by Twining Concrete Insight, is referenced in ANA's report and has been provided in Appendix B3. The report includes the x-ray diffraction results as well as the findings of the petrographic analysis of three of the samples.

- Four of the five interior samples were found through x-ray diffraction to contain high percentages of calcite and dolostone. Two of these samples were also examined petrographically and found to be a Calcitic Dolostone. This is a sedimentary rock similar to limestone but composed mostly of the material dolomite rather than calcite. Dolomitic stone is a harder stone, and stronger in tension and compression than calciferous limestone, but nonetheless is a sedimentary stone that is porous and permeable, and thus susceptible to allowing moisture migration into the stone material.

- One sample from the lighter colored stones found higher in the interior of the Monument was determined to be limestone with fine to medium grained calcites with minor amounts of mica, feldspar, quartz, and clary materials.

- Three mortar samples tested by ANA from the exterior of the Monument were found to most closely match the mortar formulations for Type K mortar. Three additional samples were found to be a Type N mortar. Additional review of the results with ANA and the material testing companies is required and will be discussed in the final report.

- The exterior stones were typically observed to be set with their natural bedding planes oriented horizontally. As an anisotropic sedimentary stone that will easily split along the cleavage planes, it is ideal that the bedding planes are horizontal as this will help protect against spalling and delamination.

- Many of the more locally sourced interior stones were observed to have their bedding planes oriented vertically. This makes them more susceptible to deterioration.

Structural Analysis and Non-Destructive Evaluation

- A comprehensive structural report prepared by Silman is provided in Appendix A1. The report discusses the multiple ways that the stone structure was evaluated, including early empirical methods (traditional methods based on ratios and proportions), hand calculations using spreadsheets and fundamental principles, as well as the development of a preliminary finite element analysis model.

- ANA determined with surface penetrating radar (SPR) that the walls of the Monument are most likely constructed as mortared stone walls that coursed through their full thickness, rather than two separate walls with rubble fill between faces (figure 16, 17, and 18). The head and bed joints between exterior stones were found to be solid and sound. Some small voids were found in collar joints, but videoscoping confirmed these were small, isolated voids that did not appear to be interconnected. SPR also confirmed that based on a broad statistical analysis of the 100 or so scans, roughly 17% of the scanned stones appear to be header stones. These are stones that extend lengthwise into the wall, tying the blocky exterior stones and irregular interior stones together.

This finding approximately aligns with the original specifications that call for one-fifth (20%) of the stones to be header stones.

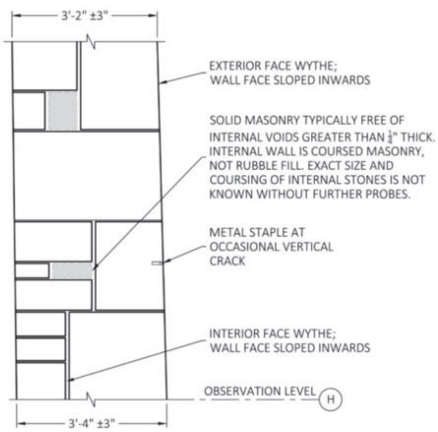


FIGURE 16

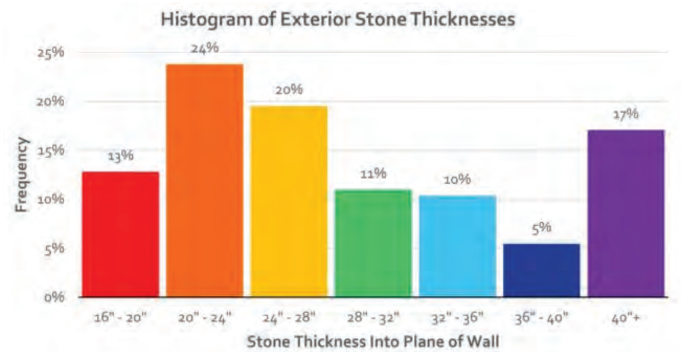


FIGURE 17

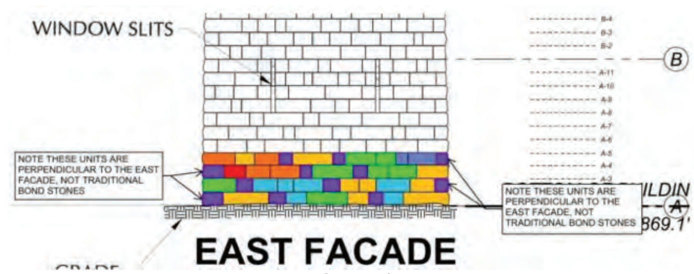


FIGURE 18

- Soil-Structure interaction was not examined as geotechnical information for the site is not available. It is reasonably well documented that the Monument was constructed on bedrock material, though the properties of the bedrock are not confirmed. Preliminary analysis suggests a bearing pressure on the order of 20,000 pounds-per-square-foot (PSF) at the base of the Monument. While this is a high bearing pressure, it is within the range that could be supported by reasonably sound bedrock. The overall plumbness of the Monument also suggests that the subsurface conditions below the foundation are adequate.

- The initial analysis indicates that the overall proportions of the obelisk are reasonably in line with older empirical design rules.

- A more detailed "hand calculation" level of analysis using spreadsheets and assuming uniform cross sections of the building at varying elevations also found that, in general, the stresses within the stones should be within an acceptable range for the code prescribed gravity and wind loads. The assumption of a uniform cross section load distribution means we have assumed that the entire cross section is solid and has uniform material properties. This is a simplifying assumption that does not take into account the likely irregularities such as discontinuities caused by cracked stones or localized "hard" or "soft" areas caused by point-to-point stone contact or weakened mortar joints.

- The structure was determined to be stable against overturning and sliding forces resulting from current code level wind and seismic loads. This stability is largely due to the massive weight of the Monument.

- An initial simplified lateral analysis indicated that if a seismic event were to occur in accordance with modern code loads, this would likely put the wall assembly into tension, and both the tension and compressive stresses would be above allowable limits. Conservative assumptions were made about the subsurface conditions in determining the code level seismic event due to the absence of site-specific geotechnical data, and a more accurate dynamic analysis was beyond this initial phase of analysis.

- Some seismic events local to Bennington and nearby Vermont and New York towns have occurred in 1953 and 1962. These events were on the order of magnitude of 4.0. At this time, cracks had already been reported in the Monument, but these events could have contributed to additional cracking.

3.2 INTERIOR STEEL FRAMING

Much of the metal floor framing and stairs within the Monument are believed to be original to the 1891 construction. The stairs have held up reasonably well given their age and the amount of moisture in the Monument. In the late 1980s, a substantial overhaul including cleaning, coating, replacing damaged cast steel plates, and bolstering of existing observation level steel beams was initiated, then put on hold. A reduced scope was completed in 2005/2006. To our knowledge, based on available records, the historic metal stairs have only received minimal emergency repairs, and the 1950's era steel framed elevator shaft has not been assessed nor received any structural maintenance or repairs.

There are a total of six floors framed within the Monument referred to as Levels A through E as well as the lobby at ground level. See Appendix D2 for interior elevations. Prior to the installation of the elevator in the mid 1950s, the vertical circulation within the Monument for a visitor would have been to enter at the lobby level (elevation 0.0') and ascend the 33 metal staircases and landings that wrap along all four walls of the Monument, passing level E at approximately elevation 39.3', and eventually reaching the sub-observation deck (Level D) at elevation 173.3'. Ascending a metal spiral staircase, the guest would then reach the Observation Level (Level C) at an elevation of 189.0'. A fixed metal ladder extends above the ceiling of the observation deck up to level B at elevation 207.0'. This level is an open, dimly lit 70+-ft tall space. Level B supports the now the fully enclosed elevator machine room. A second fixed steel ladder extends from the top of the machine room upwards roughly 60-ft to Level A at an elevation of approximately 274.0'. Reaching Level A provides access to a hatch which leads to an exterior platform just below the peak of the Monument on the west elevation. This platform and an exterior fixed ladder are used to access the airport light at the very top of the Monument.

Since the 1950's guests have enjoyed riding an elevator directly from the lobby level up to the observation deck. The elevator shaft is constructed of braced steel framing and enclosed in corrugated metal sheets. The shaft extends from the basement below the lobby, up to Level B directly above the observation deck. There are only two elevator stops, however there are four additional emergency exit doors that can be used to rescue entrapped patrons from the elevator shaft between the lobby and observation level. Since the installation of the elevator, the long circuitous series of metal stairs have functionally served as a large emergency fire escape.

Approach

The assessment of the metal stairs and elevator shaft was led primarily by Hodgman Engineering & Permitting (HEP). Their two comprehensive condition reports are attached in Appendices B6-B7. The assessment of the floor framing was carried out as a joint effort between Stevens & Associates and Hodgman Engineering and the conditions are discussed in this report. The investigation was conducted as follows:

- **Existing documentation of previous assessments and repair efforts were compiled and reviewed.** Available documents include the 1987 Ryan Biggs Associates assessment, a series of sketches prepared by RBA that comprised the emergency repairs of the late 1980s, a follow-up re-assessment of the stairs completed by RBA in 2000, and subsequent construction drawings detailing various framing repairs in 2005. The original elevator shop drawings were also available for review, though they did not depict the entirety of the shaft framing. Creating existing framing plans for the floors and shaft was beyond the scope of this assessment.

- **The existing conditions were visually observed.** Visual observation was the primary means of assessing the condition of the metal framing for the stairs, floors, and elevator shaft.

- **Ultrasonic thickness testing was performed at two locations.** During the week of May 9th to 12th, ANA assisted with the inspection of the stairs by using their UT equipment to test the web thickness of two typical steel members that frame the stair landings. The members were mechanically cleaned of loose flaking rust and dirt prior to testing, Allegrone assisted with the preparation. The test locations were typically adjacent to the end bearing of the channels. The very ends of the channels could not be tested because they are encased with grout within the stone walls.

Findings

The findings regarding the conditions of the stair framing and elevator shaft framing are discussed at length in the attached Hodgman Engineering reports titled "Bennington Battle Monument Stair Condition Assessment" and "Bennington Battle Monument Elevator Shaft Structural Framing Condition Assessment", see Appendices B6-B7. A brief summary of the key findings are as follows:

Historic Document Review

- Cleaning and painting the stairs has been recommended in all the reviewed assessments since at least 1959 as a very practical and proactive way to significantly extend the service life of the stairs. Based on our review, this proactive maintenance has not happened during the time that the State has operated the Monument. Cleaning and painting were put out to bid in 2005 along with additional repairs
but was listed as an alternate. Bids for the painting came in at around $110,000 and the effort was value engineered out of the project.

- Emergency repairs to the floors and stairs were completed in the late 1980s and in 2005. The 1987 RBA assessment of the stairs and floors found them to be in poor condition; many of the cast floor plates had cracked presumably due to the excessive rust building up on the metal support beams. Many bolts had broken, and the beams were heavily rusted. The spiral staircase between Levels C & D also required significant repairs.

- Testing of the steel plates was performed in 1987 and the analysis at that time suggested that they were a type of cast steel rather than cast iron, which was the initial assumption. Welders at the time confirmed that the electrodes they planned to use for cast iron did not seem to be compatible with the plates, and electrodes used for steel were more effective. The steel beams do not appear to have been tested and may be wrought iron or an early rolled steel.

- Levels A and B were restored in 1988-89. Level D was restored in 2005. The 2005 campaign also included adding new beams to bolster the observation deck as well as new steel columns in the basement space to strengthen areas of the lobby floor.

Visual Observations – Floor Levels

- Levels A, B, D, and E are similar in construction, and are typically only accessible to staff and maintenance personnel. The floor construction consists of many individual cast metal plates typically about 20” wide and 36” long, and approximately 3/8” thick. The plates bridge across metal I-beams that are typically 8” tall and spaced at approximately 3-ft on-center. Level A is supported by plates of steel oriented vertically rather than I-shaped beams.

- The framing at Level A appears to be in fair to good condition. However, the existing coatings are beginning to fail and bare steel is exposed along the floor plates and steel hangers supporting the platform. The supporting beams (vertical plates) and all the bolted connections are only observable from the underside of the level. Close observation of the bolted connections was very limited due to the 74-ft height of the space below the platform. The connections that were observed from the top of the ladder appeared to be acceptable.

- The framing at Level B also appears to be in fair to good condition. The existing coatings on the beams and plates are beginning to fail. The rust and rust staining is very visible from the observation deck since Level B serves as the ceiling of the observation level (figure 19). The framing consists of 8” tall I-shaped beams spaced at approximately 3-ft on-center that span north-south across the Monument and are supported at either end on a stone ledger that protrudes from the Monument walls. Some of the heaviest rust was observed at the beam ends. However, a tall ladder is required for closer observation, which should be completed in early design phases.

- The Observation deck, Level C, is comprised of framing from two eras (figure 20). The original construction still exists and is comprised of metal I-shaped beams with brick arches spanning between the bottom flanges of the beams. The arches support an original stone slab floor that has since had a poured concrete topping slab added. Only the very bottom flanges of the original steel beams are visible, and the remainder of the beams are concealed within in the brick and mortar. In the late 1980s the slab was cored in two locations exposing the top surface of the original beams, which were observed to be rusted. In 2005, new steel beams were added directly below the original steel beams and secured to the stone walls. The newer framing is still in fair to good condition, though the coatings are beginning to fail. The heaviest rust was observed at the support locations of the newer beams along the stone walls. The original steel framing is still rusting but has functionally been abandoned other than for supporting the brick arches. The brick arches are chipping and spalling, likely due to moisture related processes.

FIGURE 19

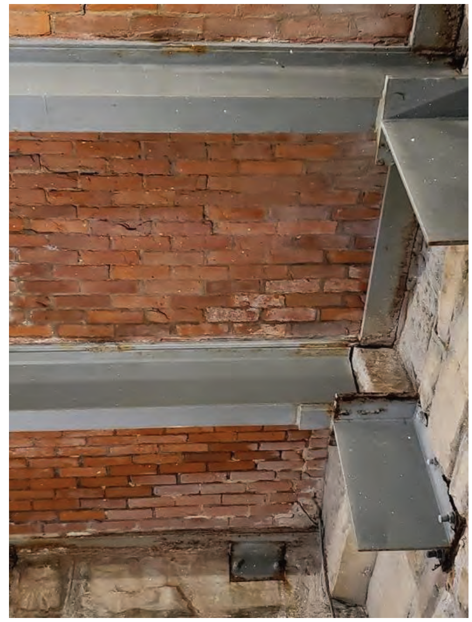


FIGURE 20

- The Sub-Observation level, Level D, was cleaned and repaired during the 2005 campaign. The repairs included replacing several buckled and broken floor plates and cleaning the existing steel that was to remain. The condition of the steel framing was generally good, though the coatings are beginning to fail, and a handful of cracked floor plates and loose bolts were observed. The floor beam bearing conditions were observable from the stairs below. The beams bear on stone ledgers and appear to be rusting at these locations. In some cases, the beam ends do not appear to be adequately supported. Gaps between the beams and stone ledger are visible, possibly due to a stone shim becoming dislodged as the mortar deteriorated.

- Level E is essentially a floor level that serves as a large stair landing. This would have served as the lobby ceiling before the current ceiling was constructed. No records were found that suggest this floor has ever been included in a repair campaign. The beam supports for this floor are embedded into the stone walls. The red coating on the beams is failing and rust is frequent, the heaviest rust is at the ends of the beams. A few floor plates have cracks and are buckled slightly due to rust jacking on the supporting beams.

- The lobby framing consists of steel beams spanning in the north south direction supporting large stone slabs (figure 21). The coatings on the beams appear to be newer, similar in color to the coatings known to have been applied in the late 1980s and 2005. The coatings have failed on many of the beams. Several newer steel posts have been installed near the ends of the floor beams; this is from the work in 2005. The reason for the posts appears to be to add redundant support at the beam ends that are embedded into the stone walls and were observed to be heavily rusted.

FIGURE 21

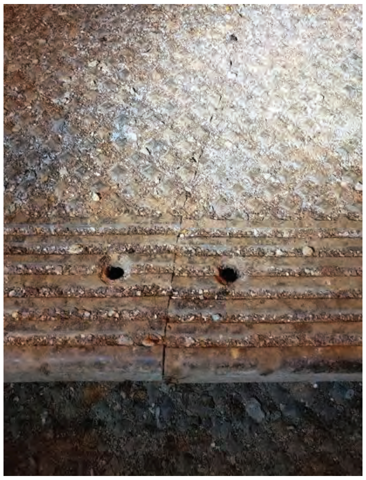


FIGURE 22

FIGURE 23

Visual Observations – Stairs

- There are no coatings left on the stairs, railings, or landings. Minimal amounts of failed coatings remain on some of the stringers and the underside of the stair treads.

- Cracked stair treads and floor plates were noted on several flights and landings of the main interior staircase (figure 22) as well as on the spiral staircase between Levels D and C. The specific locations of cracked treads and plates are noted in the HEP stair condition report. The stair treads are a cast metal, and we did not find records of them being tested for metallurgy. The floor plates were determined to be a cast steel in the 1988 RBA assessment, but this has not been verified with new testing.

- The stair landings are supported by varying bearing conditions. At some landings, the stringers are embedded into grout filled beam pockets in the stone masonry, sometimes the stringers are in a beam pocket that is not grout filled, and other times there are stone ledgers that protrude from the walls and support the stringers. Corrosion was observed on all the types of bearing supports. Loss of support was occasionally noted, primarily at stone ledger supports (figure 23), where the metal framing is no longer in contact with the ledger or is supported only by a small stone shim wedged between the stone and the framing.

- Loose fasteners and crevice corrosion around fasteners were also noted in several locations along the staircase. The stair treads are bolted to angle steel that is then bolted to the channels that serve as stair stringers. The crevices of these connections are prone to corrosion as moisture can collect in the crevices and the coatings may be damaged or not present on the fasteners.

- The attachment point of the handrails to the stone masonry is in poor condition at a number of locations noted in the HEP report. The face mount fitting at the end of the pipe railing is heavily rusted and flaking, and the anchors to the stone are corroded.

Visual Observations – Elevator Shaft

- The condition of the elevator shaft framing was observed from the pit at the base of the Monument, and from the top of the elevator cab for approximately the top half of the shaft. A comprehensive discussion of the observations is provided in the HEP Elevator shaft report in Appendix B6.

- The condition of the steel framing is fair to good for most of the shaft. The coatings are failed on many of the horizontal framing members, specifically along the topsides of members (figure 25), and it appears to be related to moisture and debris collecting on these surfaces (figure 24 and 25).

- A significant amount of dust and debris has collected within the shaft. This poses a maintenance concern for some of the more sensitive elevator equipment within the shaft and could shorten the service life of the wire ropes of the elevator.

- The bases of the four corner columns of the elevator pit are significantly corroded (figure 26). The columns extend to the floor of the basement. At the floor level the base plates and bottoms of the columns are heavily corroded and flaking, likely as a result of frequent exposure to moisture.

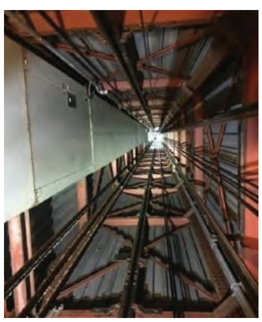


FIGURE 24 (BOTTOM SIDE)

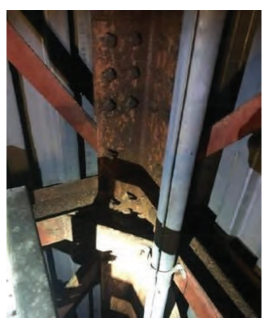


FIGURE 25 (TOPSIDE)

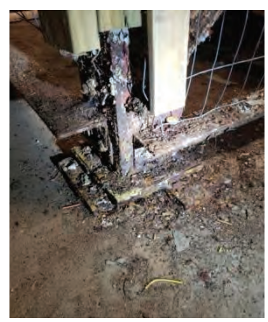


FIGURE 26

Ultrasonic Thickness Testing

- Two locations were UT tested. The first area tested served as the "control" measurement and was a section of the stair stringer beams that visually appeared to be minimally corroded and presumed to represent the original thickness of the stair stringers. The average thickness from this series of measurements was 0.390 inches, slightly more than 3/8". The second location being near the embedment of a corroded end of a stair stringer that had been power tool cleaned of loose rust.

- The UT results indicated that the web thickness near the embedded end of the corroded beam was only 0.046 inches (less than 1/16”) thinner than the thickness of the control measurement. This amounts to a loss of nearly 12% of the original thickness.

3.3 ELEVATOR

The elevator is an Otis Elevator and was installed in the mid to late 1950s. The enclosing of the observation deck with large glass windows and the addition of a heating system was also completed within a few years of the elevator project. The elevator is heavily used between April and October as the only means for guests to access the observation deck. A state employee operates the elevator as it is not self-service. Having only two elevator stops means the machine runs the full height of the shaft every use, dozens of a times a day, seven days a week, for six months of the year. During the winter months, rather than winterizing the machine, the current practice is for the staff to operate the elevator a few times a week.

The elevator has required more maintenance than would be expected and continues to break down, usually a few times a year. Multiple entrapments of visitors have happened and on even more occasions the state’s operator has been stuck in the elevator. Records of these incidents have informally been kept since around 2000. The response to entrapments has varied over the years, prior to the recent modernization of the controls there had been a manual crank that could be operated by a staff member to lower the cab to one of the four emergency doors along the shaft way. Since the modernizing there has not been a way to manually move the cab. The new controls are supposed to return the elevator to the nearest stop in the event of a power outage, however, the more recent stoppages have been caused by sensor and safety switch malfunctions or mechanical issues, and the fire department has had to extract occupants through a small roof hatch in the elevator’s cab and any guests stranded at the top of the Monument have had to descend using the stairs.

Approach

Lerch Bates is an international consulting firm that offers specialized expertise in vertical transportation (elevators and escalators). Lerch Bates was initially contracted to assess the existing equipment for purposes of longer-term capital improvements to update and improve the reliability of the elevator. This report is included in Appendix B8. The elevator broke down multiple times during the larger investigation of the rest of Monument, thus providing the Lerch Bates consultant with direct experience with the more immediate issues that are facing the existing equipment and provide useful maintenance guidance. In response to the consultant’s recommendations, work was carried out that lead to an overall successful 2022 season with no entrapments. The additional memorandums provide by Lerch Bates for these maintenance tasks have been included in Appendices B9-B10.

The assessment of the elevator was carried out as follows:

- **Existing documentation of previous repairs, maintenance, and modernizations was reviewed.** This included reviewing the available maintenance records for the elevator, the existing elevator maintenance contract, and available information about the recent 2016 repairs. Some of this effort was initially completed as part of helping develop a preseason maintenance scope and troubleshooting current issues.

- **Visual observations of the existing equipment were completed.** A consultant from Lerch Bates (Sam Laudati) visited the Monument with the current Bay State service technician (Steve Carrington). The machine room, pit, cab, and shaft way conditions were observed. The shaft was able to be observed from the top of the cab while the technician operated the elevator. This work was initially completed on November 12th, 2021, however the Lerch Bates consultant visited a second time on September 7th, 2022, prior to the fall foliage rush and was able to complete a follow up observation with the Bay State technician, with similar access to the equipment as during the initial assessment. This provided perspective to inform recommendations for certain maintenance intervals.

- **Current emergency procedures were reviewed.** This became an additional item as part of the preparation for the peak foliage season. An agreed upon approach was needed should an entrapment occur. A site meeting was held at the Monument with representatives from Bay State, the Bennington Fire Chief, staff from Buildings and General Services and Historic Sites, Stevens & Associates, and Lerch Bates.

Findings

The findings regarding the conditions of the elevator equipment are discussed at length in the attached Lerch Bates Elevator Survey Report, as well as two maintenance memorandums provided by Lerch Bates, see Appendix B8. A brief summary of the key findings are as follows:

Existing Documents:

- The 2016 modernization included 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 Hollister Whitney governor, new ADA compliant car station, hall fixtures, position indicators, direction lanterns, and braille labels. A new GAL MOVFR door operator and new car and hall doors were installed, as well as new infrared door protection systems. The original Otis elevator drive that actually moves the cab was refurbished and retained (figure 27). The bearings and gears within the drive were retained but new seals and fresh oil were installed.

- A technician report from September and October of 2021, right before the larger study commenced, was prepared by the Bay State technician, and detailed an extensive maintenance and troubleshooting of the elevator that had taken place as a result of a breakdown and entrapment on Labor Day of 2021. The elevator was not operational for a substantial part of the foliage season.

- Prior maintenance records proved to have little technical information about the maintenance tasks that were performed.

- The maintenance of the elevator is currently included in the State's overall maintenance contract with Bay State, and no special or additional requirements are outlined for the Monument elevator.

FIGURE 27

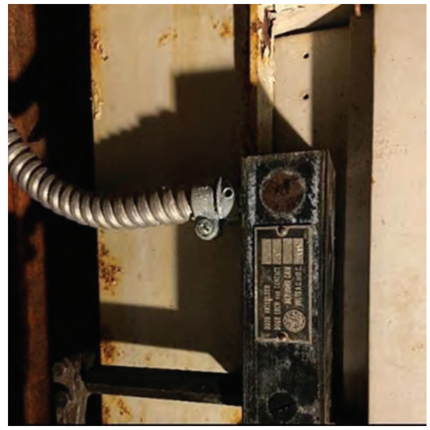


FIGURE 28

Visual Observations

- The existing elevator equipment was generally found to be very standard equipment. The conditions within the Monument are not typical for most elevator shafts, being that there is higher moisture within the Monument than in regular buildings, nor is there temperature control in the Monument.

- The original Otis machine from 1956 is leaking oil and makes a noticeable ticking noise that is believed to be bearing chatter. These observations may forecast a seized bearing, which could be a major and costly service event and would shut the elevator down for multiple days or weeks depending on the availability of parts.

- The various sensors within the shaft consist of magnetic tape and copper contacts (figure 28). These are wear items that usually need to be serviced or replaced every few years. These sensors are malfunctioning multiple times a year at the Monument, despite being replaced and/or cleaned annually. When these malfunction, the elevator will not run. This has caused multiple shutdowns.

- The governor sheave was not replaced when the new governor was installed. This caused unsettling noises to the occupants and operator and eventually lead to at least one shutdown.

- The newer door operator unit has caused at least two shutdowns, these happened in the off season during the investigation. The technician explained the existing shaft has very tight clearances for this type of system and they have had to make several fine adjustments and re-adjustments to keep the opener working properly. When not functioning correctly, the doors are not opening and closing properly, and the elevator will not run.

- The existing steel ropes will need to be replaced in the near future. These ropes are typically expected last three to five years. The moisture and excess debris within the shaft are causing the service life of the ropes to be on the shorter end of this interval.

- The components installed in the previous modernization are in good condition and can be retained (though replacing the newer door opener with one better suited for the environment is recommended). The components are third party products that can be maintained by any service provider as they do not require proprietary tools or software.

Emergency Procedures

- The existing emergency procedures were causing conflicts between Bay State and the local fire department. Bay State has had difficulties getting to the site in a timely manner, the existing contract requires a 90-minute response time. The fire department did not have familiarity with the newer controls and systems. The technician and Lerch Bates consultant walked the fire chief through the newer controls and switches and explained various built-in safety features. This meeting is discussed further in the Seasonal Site Visit report for September of 2022, which is included in Appendix C5. All parties agreed upon appropriate procedures, and it was decided to post the procedures in the cab and the gift shop.
- The emergency phone line was tested and though functional, the dispatcher noted a lot of interference and had trouble hearing the occupant. This is most likely a phone line issue and the state contacted to phone provider shortly after this test.

3.4 ELECTRICAL

The Monument's existing electrical system essentially consists of power for the elevator machine room and equipment, the airport light at the top of the structure, lights and outlets at the observation level, lights and outlets at the lobby, some makeshift light fixtures and very few outlets along the stairway, and a newer emergency lighting system along the stairs. Additionally, there is a lightning protection system and exterior lighting that are beyond the scope of this investigation, though some general observations were made.

In recent history the main electrical concerns have been in regard to lacking a back-up power supply. The primary expressed concerns with the existing electrical system prior to this assessment has been the excessive need to replace light fixtures within the Monument, and generally poor lighting and lack of convenience outlets throughout the building.

The elevator has a battery backup supply that was installed in 2019 for minimal back up power to bring the cab to the nearest stop in the event of a power outage. Two comprehensive feasibility studies for Monument wide back-up power options, including a diesel generator, or a Tesla-style battery bank, were completed by DuBois & King in 2015-2016 and that effort was not duplicated in this assessment.

Approach

DuBois & King (DK) was subcontracted to provide electrical engineering investigations for the Monument. They visually reviewed the electrical systems throughout the Monument, including power to the elevator, lights, outlets, and emergency systems.

Findings

A comprehensive electrical assessment report prepared by DuBois & King can be found in Appendix B11. A summary of key findings is as follows:

Visual Observations of Electrical System

- Power is supplied to the Monument underground from a Green Mountain Power pad mounted transformer near the giftshop. The main panel is in the basement of the Monument enclosed in a NEMA rated cabinet. The panel is dated 2006. The transformer, main feed, panel, and cabinet are in good, serviceable condition and are adequate for continued use.

- Power is fed to the elevator machine room with a jacketed metal clad (MC) cable – Type XHHW copper, MC#3/c-6 AWG with a #8 AWG ground wire, which is an IEEE 1202 (UL) listed assembly. There are some improper support methods (zip-ties, nylon rope to other conduits) that are in violation of the electric code, but the cable is otherwise in good condition and suitable for continued use.

- The wiring systems and devices observed in the elevator machine room are in serviceable condition. Some minor corrections to cable supports, conduits, and improved labeling should be considered.

- There is a Square D Type QO load center within the elevator machine room that appears to be in serviceable condition but is not what would be recommended for this application. A bolt-on panelboard would be more appropriate.

FIGURE 29A

FIGURE 29B

- There are several different wiring and conduit systems throughout the remainder of the Monument. The observed systems include electrical metallic tubing (EMT), rigid galvanized steel (RGS), polyvinyl chloride conduit (PVC), SO cord, liquid-tight flexible conduit, and both jacketed and un-jacketed metal clad (MC) wiring. In general, a number of the wiring installation methods lack good workmanship. The conditions of the existing systems vary from serviceable and good, to rusted, deteriorating, and abandoned. Many of the electrical wiring junction and device boxes - and associated conduits and wiring fittings - are corroded and rusted (figure 29A and 29B).

- Along the stairs and landings there are several varieties of lighting fixtures with varying types of lamps. Several were functioning, while several were not. Some fixtures were quite old and corroded, and some of the newest fixtures had already stopped working. Many of the fixtures do not initially appear to be specifically rated for exterior use or a temperature range that would align with the conditions within the Monument. Overall, the stairwell is not adequately illuminated to NFPA 101 performance requirements.

- There are multiple types of emergency lighting battery unit equipment ("unit equipment") along the stairs and landings. The units are typically mounted to the elevator shaft enclosure. The majority of the units appear to be newer and may have been installed over the past several years, presumably updated after a power outage in the fall of 2019. It is unclear whether these fixtures are suitable for cold-weather operation, which would be necessary within the Monument, and also affects the batteries that are in each unit. Efforts were made to manually test the units. Some of the units worked properly, while others did not. It is unclear if the issues exist within the unit or in how they are wired into the Monument's electrical system, as a variety of wiring methods have been deployed.

- The existing lightning protection system is quite dated and could even be original to the Monument based on the 1887 specifications. It is apparent that some maintenance has been performed based on the types of connectors and terminations observed. The system consists of a single cable extending from the basement to the very peak. The cable is bonded to the stair tower steel structure at several locations, which seems like a questionable practice. However, lightning protection is a specialized disciplined within the electrical industry, and the current project team does not include an expert in that field.

- The exterior lighting is beyond the scope of this assessment; however, it was informally discussed as related to a concurrent project involving lighting the monument blue and yellow for Ukraine. It was noted that the existing system is very dated, and requires very expensive and inefficient bulbs, and there are many current systems that would be more efficient and less costly.

4.0 CONCLUSIONS & RECOMMENDATIONS

4.1 STRUCTURE

Conclusions

This investigation has provided a lot of 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 cement bedding mortar and Portland cement-based pointing mortars and concrete type mix for larger voids. 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 from 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.

3. **Freeze-Thaw cycles:** Freeze-thaw cycles are currently accelerating the deterioration of the stone masonry. Water expands roughly 10% when it freezes. This creates stresses when the water is initially confined in pores or small cracks. Large enough stresses will widen existing voids and allow more water entry, and the cycle perpetuates. This will weaken the stone over time which will cause stresses to redistribute and compound on the next strongest point.

   The 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. A number of the wider crack repairs completed with cementitious mortar are also not effective anymore due to missing mortar that is presumed to have dislodged by freeze-thaw action as a result of how the crack was prepared before the repair. The moisture movement is advanced to the point where we now see ice deposits developing on the interior surface of the masonry – especially towards the top of the structure.

   The challenge moving forward is to develop a repair strategy for the thousands of cracks that can be effectively and efficiently maintained. A lesson learned from the existing sealant detail is that after the sealant has failed it worsened the moisture issues.

4. **Moisture and Humidity:** Limiting the moisture in the walls is a high priority as this will limit the amount of freeze-thaw action that can occur as well as prolong the service life of the existing mortars. The data collected at the time of writing this report is suggesting that the wall is continuously damp inside and does not dry out naturally. At present there are no active ventilation or condition controls within the Monument. We have collected environmental data from within the Monument that should be studied further to understand if the interior conditions also limit the ability of the wall to dry out, or possibly contribute to the moisture in the walls. This additional study would inform a strategy for facilitating the drying out of the walls with active or passive ventilation systems.

5. **Local Stresses:** A very high percentage of the observed cracks are vertical through the stones and not along the natural bedding layers that are more vulnerable to cracking. This suggests that the forces that are cracking the stones are tensile forces. The exact failure mechanism is not immediately evident, but it is likely caused by localized stresses developing from concentrated forces, or built-up internal forces possibly due to thermal expansion or freeze-thaw cycles. A differential moisture profile within the wall may also be contributing the cracks due to the consistently wet interior stones being slightly larger than the exterior stones that have the opportunity to dry out. Flexural tension stresses may also be occurring locally where the stones experience bending such as near openings, or where the stones are bridging areas of missing or weakened mortar or point-to-point stone loads. Previous repairs, if completed with incompatible mortars or improper epoxies, can also induce local stresses, and perpetuate cracking. These conditions should be further investigated using finite element analysis to confirm that the magnitude of these stresses could be sufficient to explain the root cause and widespread distribution of the observed cracks.

6. **Headers & Wall Construction:** The ANA scans confirmed the inclusion of header stones that extend back into the wall and confirmed the wall is coursed throughout its thickness and does not appear to be a rubble filled wall. Stones that extended 40″ or more into the wall were considered header stones since that is approximately twice the thickness of the exterior stone blocks. Based on the scan data, the typical header stone was between 40″ to 60″ thick. This means at the lower levels of the Monument (from approximately the observation level down) the header

stones do not extend all the way through the wall, since the wall is wider than these stones.

The general stiffness of the wall is different where there are full through-wall header stones as opposed to "cross-headers" that extend part way through the wall. More crack systems were observed in the lower portion of the Monument which has these cross-header stones. This is an observation that should be further studied to understand how it may affect our analysis and if our recommended repair strategy needs to improve the effectiveness of the cross-header stones.

7. **Loading:** The Silman analysis indicates that a current code level extreme seismic event, which could occur in the future, would cause tension and compression stresses beyond the assumed allowable stresses of the masonry. Seismic events are not suspected to be the primary cause of the observed cracks, but previous and future seismic events may contribute to the cracking of the stone. By code, it would not be required to seismically upgrade the structure, but any repair options should consider performance-based design for future earthquake loads and improving the performance of the Monument. The subgrade soil conditions should be confirmed before the final design of any repairs.

Additionally, many initially suspected contributing factors have been ruled out as the likely causes of the cracking:

- From the laser scan, the Monument was found to be plumb within construction tolerances and is not exhibiting any lean or excessive displacement or bulging.

- It is impossible to perfectly predict, model, or measure the interaction of the building movement with the observed cracking. However, it must be noted that the types of cracks observed that are caused by building settlement do not match what was seen at the Monument.

- The initial analysis using the assumption of a uniform cross section load distribution indicates that the stresses in the wall under gravity and wind loads, which are considerably more common than seismic events, are within allowable limits. Global loading, such as overturning and sliding, are within appropriate limits.

- The wall is not rubble filled at the interior. Often in multi-wythe stone masonry wall construction the middle third of the wall is filled with rubble and voids, allowing moisture to travel freely. That does not appear to be the case at the Monument; internal construction appears to be of solid masonry.

Recommendations

Priority Repairs

The Priority 1 conditions noted in VA's report should be repaired as soon as possible, and we recommend that the State establishes temporary protective measures. It should be considered to have VA remove all of the potentially loose materials. We anticipate additional masonry materials may continue to fall off the monument as additional weathering occurs, and this should be monitored by subsequent inspections by roped access. Initially, inspections should occur on an annual basis at first to help establish the expected rate of deterioration, and then the frequency of the inspections could be revisited to determine an appropriate interval.

Additional Testing and Investigation

Based on the information gathered in this phase of the investigation, we have identified and recommend the following additional investigation, testing, and design scopes of work:

a. *Masonry Conservator:* A masonry conservator should be brought on board to review the stone and mortar compatibility (See items "1" and "2" above), as well as to opine on the architectural conservation aspects of the existing masonry so that future repairs are compatible with the existing construction. They will also be critical (along with the petrographer and the masonry grout consultant) to the specification, testing, and final selection of the recommended mortars and grouts (for bed, head, and collar joints within the walls). The masonry conservator should assist the geotechnical engineer and the masonry grout consultant in the evaluation of the existing mortar as well.

b. *Building Envelope and Hygrothermal Review:* As noted above, a primary driver of continued deterioration of the Monument is the presence of moisture in the wall, indoor environmental conditions, and thermal changes within the Monument. This could help to identify the thermal extremes (inside/ outside and east/ west/ north/ south, and moisture freeze/ thaw points of concern. This should also include further monitoring of moisture condensation/ infiltration/ movement, in particular on the upper third of the monument.

c. *Mechanical Engineering:* A mechanical consultant should be brought on board to review passive ventilation, modifications to control relative humidity at interior and exterior of building, including HVAC improvements and consideration of active ventilation to aid the removal of moisture from within the structure.

d. *Water Infiltration (Spray) & IR testing:* Conduct on-site spray testing with water on all sides of the Monument to examine water infiltration in conjunction with Infra-red (IR) testing to investigate movement of water in and through masonry wall. This testing would help to identify the rate of such water infiltration and the paths of such movement through the wall (e.g., vertically and/ or horizontally).

e. *Masonry Testing:* Additional field testing of the existing structure should be performed to determine the in-situ stresses and calibrate against the structural analysis model. This may include masonry prism testing or in-situ flat-jack testing. We recommend that additional stone samples be extracted (perhaps with supplemental extraction techniques) to endeavor to obtain a set of complete samples of this type of unit. Some alternative laboratory testing of these stones in such a matrix may also be appropriate. Assessment of the masonry may also include some accelerated freeze/ thaw durability testing in accordance with ASTM standards.

   Absorption rates of the stone was tested by RBA in the late 1980's and found to be low compared to the absorption rate of the mortar. Modern testing should be done to validate these findings. It is also possible that the natural defects in the dolomitic limestone are an issue that could be contributing to the deterioration.

f. *Structural Engineering - Finite Element Analysis:* Detailed structural modeling of the Monument for global and local performance of the structure is recommended to investigate potential modes of failure. This would include three-dimensional finite element model using manipulation of mesh to explore two options (macro-modeling and discrete localized element modeling), two-dimensional push-over and limit state analysis, as well as additional hand calculations, and review and research capabilities of FEM to look at thermal stresses in structures. Note that there is not significant research or data available on this for unreinforced masonry structures, but we will determine if there are viable modeling methods to incorporate. Consideration should be given to the localized modeling of cracking (a second order analysis). Modeling of all of the cracks within the monument may be beyond the capabilities of modern computer analysis of unreinforced masonry. This should be confirmed during a subsequent phase of additional assessment work or very early on in the design phases.

g. *Mock-ups:* Producing Mock-ups is an important step to inform effective and cost-effective solutions for repairs prior to finalizing construction drawings. Such mockups may include grouting, deep repointing, stone crack injection, and localized pinning. Mock ups would be useful and informative during assessment phases, but could be pushed back to early design phases.

h. *Geotechnical Investigation:* Further evaluation of foundation stability- perform geotechnical tests – borings –to identify bedrock capacity that the Monument is built on. The geotechnical report should include site specific seismic information. The geotechnical investigation should also include the completion of at least two test pits (one on the interior and one on the exterior) to evaluate the depth, cross-section, construction detailing, condition, and bearing strata at the bottom of the foundations.

i. *Ongoing electronic monitoring:* Continue to gather environmental and crack monitoring data. A full analysis of the electronic monitoring will be performed after one year of data has been gathered (April 2023). Consider additional monitoring points. Given the extent of water infiltration and the suspicious nature (i.e., unidentified cause) of some of the observed cracks we recommend additional electronic monitoring points. Consideration should be given to measuring several additional points for movement

j. *Historic Structures Report*: Consideration should be given to performing a comprehensive historic structures report (HSR) on the monument. This would compile the full history of the structure and allow for effective long-term preservation goals and planning.

Repair Scope

As noted above, there is additional investigation and research recommended in order to establish a full repair scope of the Monument. The priority should be to make the outer walls more weather resistant, then implement an effective ventilation system to move the air internally to assist in drying out the structure.

Minimizing the internal relative humidity will go a long way towards providing long-term stabilization of the structure's stone and mortar. It is also important to accept the natural limitations of the inherent behavior of the structure. There are limits to what can be expected of long-term projection and restoration of an unreinforced masonry structure with this geometry in a northern climate that is subject to seasonal freeze-thaw cycling.

At a bare minimum, it will be necessary to dry out the Monument to the best level possible. This could include installing an effective passive ventilation system or an active ventilation system, introduction of weep holes, grouting and pinning the walls, and raking and repointing the joints with a compatible mortar.

A full-scale renovation scope to the stone masonry could include the following scope of work:

- Devise a ventilation system that will drive down the relative humidity inside the Monument to control inner moisture that is a destructive force during winter months.

- Grout injection with compatible injection fill to fill inner voids and ensure support of stones within the walls. This grout injection would be complimented by the mortar work listed below. Achieving uniform bearing between the stones appears to be desirable at this point. The next design phase will need to evaluate the extent and methods of such mortar removal and replacement (with grout and/ or mortar).

- Deep rake and repoint with a compatible mortar, to seal the interior mortar in and minimize water intrusion. As noted above, mockups (during the Design phase) will be important to advance and then finalize the detailing of the mortar work, grouting, pinning, and stone repairs.

- In select locations (e.g., at the exterior of the SW corner of the monument, but also at other locations) consideration must be given to the removal and replacement of stone units with new stone Dutchmen. The size and procedures of such work will require close collaboration between the design team and the masonry restoration contractor. We recommend consideration of such a mockup during the design phase (prior to the issuing of 100% CDs). This work will require the design, fabrication, installation, and use of specialized temporary shoring and bracing schemes. We recommend that this CD phase effort include the collaboration with at least one contractor’s professional engineer. This will help identify the scope of such work and to help constrain the variability of potential bids. The State may even wish to pre-engineer this temporary shoring and bracing (as part of the Contractor’s Means and Methods of Construction) prior to/ separate from the base scope of the remainder of the masonry restoration work. Such pre-CA phase Means and Methods of engineering efforts have become more common in the industry for such specialized projects. Again, while they represent an earlier, initial outlay of funds, they may help save the Owner money, time, and other concerns during the project.

- Pin corners of the masonry walls together with stainless steel grout anchors.

- Consider installing stainless steel header grout anchors to span the width of the walls where the wall is very thick, and where the cross-headers do not extend the full width of the wall. These would be designed to help better tie together the widest portions of the masonry walls.

- Implement a repair campaign that includes inner stair/ floor/ elevator restoration that would include abatement of corrosion and masonry deterioration. Refer to Hodgman Engineering report for additional scope on steel and elevator repair elements.

Long-Term Maintenance Planning

In collaboration with any repair scope that is established, a long-term cyclical maintenance plan should be established by the owner given the age, historic nature, and inherent construction qualities which contribute to the ongoing deterioration of the Monument. This would include regular monitoring and examination of the Monument at least every 2-5 years, and repair campaigns of varying scale, potentially every 20-50 years, depending on the urgency of observed conditions. In each such case, we think it is worth reminding the owners of such buildings that they are responsible for the evaluation, repair, and/or renovation of what is essentially a 306-foot-tall stone wall.

As noted in our proposal and within this report, the completed work does not take the place of a comprehensive (meaning 100% of the exterior and interior surface) examination of the masonry. We recommend that such an examination be completed at the very start of the CA phase. This will require installation of a complete system of scaffolding to allow the State, the design team, and the contractors to fully examine and assess the monument. This close-up examination will permit the Team to verify the scopes of work at the very start of construction and to advise ownership of any potential changes to the scope of work that are identified from such close-up access. Knowing this at the start of the CA phase will be critical to the success of the project. The main alternative to this would be installation of the scaffolding during the CD phase. This is possible and has been performed on some comparable projects (e.g., work at the Washington Monument in Washington, DC).

Such structures as the Bennington Battle Monument require regular close-up examination and evaluation by an experienced design team of architects, engineers, and materials experts

4.2 INTERIOR STEEL FRAMING

Conclusions

A large percentage of interior framing can be restored and repaired for continued use but needs to be maintained in order to extend the useful service life. A comprehensive discussion of the conditions can be found in the Hodgman reports in Appendixes B6 and B7. The primary failure mechanisms we have identified are as follows:

1. **Coating Failures:** The existing coatings have failed to varying degrees on all of the steel framing within the Monument. There are little to no traces of existing coatings left on the original stair assemblies and handrails. The coatings that were applied to most of the floor beams and plates in the late 80’s and even in 2005 have recently failed. Coatings on the elevator framing, lobby framing, and Level E framing coatings are at more advanced stages of failure and corrosion is advancing.

   In instances such as the stairs, rails, ladders, and floor plates some of the coating failure is caused mechanically by wear over the years. We believe the coating failures on the other framing are caused by environmental factors within the Monument, including large temperature changes, moisture, humidity, and in some instances exposure to bulk moisture.

2. **Corrosion:** Corrosion is related to coating failures. When the bare metal is no longer protected by a coating and is exposed to moisture and oxygen it will oxidize, or rust, leading to base metal

loss. Rusting is an exponential process, meaning the rate of corrosion accelerates as the metal deteriorates. The results of the two UT tests indicate that the steel framing in the staircase appears to still have adequate web thickness next to the beam pockets in the wall, though the condition of the steel within the wall is not confirmed. Visually, framing section loss due to corrosion does not appear to a widespread issue yet. The exceptions being at some of the post bases in the basement, at some railing attachment locations along the staircase, and a selection of beams where water can pool on the top flanges.

Rolled steel and cast steel elements corrode differently and this is contributing to the fracturing of steel plates at some of the floor and landing levels. Cast steel corrodes by becoming more susceptible to brittle fracture (cracking) as iron is leached out of the base metal. Rolled steel is more prone to lamellar corrosion that causes expanding and flaking. This can lead to a process called rust jacking when the expanding corroded steel lifts or dislodges other components. This process is occurring between the rolled steel beams and the cast steel plates. The corroding beams are inducing stresses on the cast steel plates and this is occasionally leading to the fracture of the plates. This process is also causing damage within the grout filled beam pockets within the stone masonry, in some cases the grout has become dislodged and at a few locations, broken stones were observed. The original steel framing that is concealed within the brick arches of the observation deck are also susceptible to creating rust jacking issues and there is evidence that this is occurring; the cracking of the topping slab is likely a result of this action.

3. **Loss of Bearing Support:** Several observed bearing conditions are sub-optimal and should be repaired or bolstered. Additionally, it was a common observation that the beam ends nearest the stone supports, or embedded in the stone walls, were also the locations of the most observed corrosion. Where the beam ends are exposed, the steel can be cleaned and coated and adequately shimmed or otherwise supported. Where the beams are encased, the conditions will be concealed and unknown unless selective demolition to expose the beam ends is completed at all of these locations. In general, the steel members directly next to the exterior walls still had sufficient thickness and could serve as a second, redundant, bearing location.

Recommendations

Overall, maintaining the existing framing as much as possible is recommended. Logistically, adding any new framing or waiting to replace failed framing within the Monument would be very challenging and costly. This is due to the uniqueness of the structure and restrictive access as far as bringing equipment and materials to the various levels of the structure.

At this time, we believe the scopes of work pertaining to the interior framing should proceed to design phases. Bidding strategy, available budget, and desired performance goals (comprehensive / selective) will greatly shape the effort required in the design phase. For example, a comprehensive, or widespread, repair approach will require less time and effort in the design phases, be simpler to bid, and yield a more uniform final product in the repairs. A tradeoff, however, is that this approach may be more costly due to more material and labor costs in construction. In comparison, a more selective repair scope will require additional work in the design phases to identify and prioritize specific areas of repair, and additional selective repairs may be required more frequently in the future.

Repair Scope

A comprehensive renovation scope could include the following scope of work:

1. Comprehensive cleaning and coating of all steel framing, floor plates, and connections. All of the steel framing should be properly prepped (most likely power tool cleaned or blasted) to the specifications for the selected coating. A coating suitable for exterior conditions should be specified. During the cleaning process, the framing, plates, connections, and fasteners should be re-inspected for deficiencies, and items such as additional cracked plates or loose fasteners should be corrected prior to applying coatings.
2. Bearing locations at all the landings should be supplemented with galvanized gusset clips that are drilled and epoxied into the stone masonry. These gusset clips would provide redundant bearing for the stair stringers and would be serviceable in the future.
3. At stone ledger supports, the beams that are no longer shimmed should be properly shimmed with steel plates or grout. Additionally, we recommend adding the galvanized gusset clips described in item 2 at these locations as well.
4. Broken stair treads and floor plates should be repaired or replaced. Repairing the existing plates and treads is recommended as the preferred preservation approach. Testing should be carried to determine the weldability of the existing materials and inform the design teams recommendations for repair versus re-casting new steel treads and plates.
5. All fasteners that are removed in the course of repairing the existing framing should be replaced with new, similar, fasteners. Additionally, any loose fasteners observed during the cleaning and prepping of the framing should also be replaced with new fasteners rather than attempting to re-tighten the existing bolts.
6. At this time, the elevator shaft framing should be thoroughly cleaned of dust and loose debris. In coordination with the next major elevator replacement project that is anticipated in the next 10 – 15 years - the elevator shaft steel siding should be removed, and the framing should be cleaned, prepped, and coated.
7. The elevator shaft column bases require repair on a more immediate basis. These repairs cannot be postponed until the next elevator replacement. The repair should include a thorough cleaning and surface preparation of the bottom 2-ft of the columns. The remaining member thickness should be measured. Additional strengthening such as welding on new plate material may be necessary and should be anticipated.

Long Term-Maintenance Planning

Based on the condition of the coatings that are known to be from 2005, it is recommended that the state carry out a visual assessment of the coatings on an 1-3 year basis and plan for recurring cleaning and touchup of the coatings on a regular 5-10 year maintenance interval.

4.3 ELEVATOR

Conclusions

Based on this investigation and the expertise provided by Lerch Bates, we have arrived at the following conclusions:

1. Currently, the primary sources of shutdowns and malfunctions in the elevator are the equipment within the shaft way, including the various sensors and contacts, the dated governor tail sheave, as well as the new door operator unit. The equipment from the 2016 modernization is generally functioning properly, other than the new door operator.
2. Additional targeted maintenance, beyond the standard state contract agreement, proved to effective for limiting shutdowns in the 2022 season.
3. The existing sensors and contacts and sheave are dated technology and not well suited for the moist environment observed within the shaft. Some of this equipment was installed near the time when the Monument was enclosed, and a heating system was installed. The thinking may have been that the interior conditions were not going to be as severe as they are presently.
4. The original Otis Elevator machine is leaking oil and showing signs of impending bearing seizure and needing a larger more in-depth rebuild, or replacement with a current piece of equipment. Servicing the nearly 70-year old machine may become harder as parts become sparse.
5. The 2016 modernization appears to have focused on the controls, motor, and cab and door improvements. The equipment installed is third party and can be serviced by any provider. The newer equipment is functioning well overall, but the new door operator unit may not have been the most ideal choice of unit due to very tight clearances in the existing shaft as well as high levels of moisture.
6. The dust, debris, and moisture in the shaft are shortening the service life of the elevator ropes, magnetic positioning tape, and copper contacts. These items should last for years but are requiring maintenance or replacement semi-annually.

Recommendations

A comprehensive and detailed list of specific recommendations is provided in the Lerch Bates Elevator Survey Report in Appendix B8. At this time, the project team has found successful short-term maintenance tasks that have nursed along the existing equipment, as well as identified longer-term strategies and goals to achieve a more reliable and sustainable elevator.

Repair Recommendations:

1. In the near term, continue to perform the targeted maintenance tasks identified in the Lerch Bates memorandums from April 2022 and September 2022. This maintenance should occur prior to opening the Monument in the spring, semi-monthly throughout the summer, and before peak-foliage in mid-September. This is a costly approach meant to be short-term to keep the existing equipment operating safely with minimal shutdowns. Meanwhile, longer term fixes should be developed. This amount of maintenance likely would not be sustainable on a long-term basis.

2. Proceed into design phases for the recommended modernization scope outlined in the Lerch Bates report. The recommended modernization addresses items not covered in the 2016 effort. The next modernization should include:
    a. Replace the original 1950s Otis Machine, the associated steel ropes, the tape reader, and the traveling cable. New traveling cables should be provided with a minimum of 10% spare conductors and should include a minimum of four sets of twisted shielded pairs of communication wires to provide sufficient spares to accommodate future devices if desired.
    b. Install NEMA rated equipment throughout the shaft way. This equipment is rated for moist environments such as public transit elevators near the ocean and would be better suited for the Monument's unconditioned and damp environment.
    c. Install a heavy-duty stainless-steel tape reader system.
    d. Install NEMA rated enclosed door operator.
    e. Install NEMA rated microswitches at each of the blind hoist way access doors. These are more current and will be more reliable than the existing copper contacts.
    f. Clean and coat the shaft way steel.
    g. Clean and repaint corroded pit equipment. The existing governor sheave should be updated to current standard equipment. New pit lighting, GFCI outlets, and a pit stop switch should be installed.

Long-term Maintenance Planning:

The maintenance contract for the Monument elevator should be separated from the State's general elevator maintenance contract. At the time of writing this draft report, the State had engaged Lerch Bates as an additional service to assist in writing a stand-alone contract for the Monument. This contract will include specific maintenance tasks unique to this elevator and provide appropriately strong contractual language regarding the maintenance providers response times as elevator down time costs the State financially due to turning visitors away and prolonged entrapments of visitors are unacceptable to the State. We recommend continuing this work.

4.4 ELECTRICAL

Conclusions

Based on this investigation and the expertise provided by DuBois & King, we offer the following summary of the conclusions provided in DuBois & King's assessment report: (See Appendix B11 for electrical report with comprehensive discussion of conclusions)

1. The main panel and cabinet and feed from the GMP transformer are adequate for continued use.
2. Overall, the electrical systems related to the elevator are in good, serviceable condition. There are some cable supports that violate the electrical code, and there are improvements regarding labeling in the machine room that could be completed. The existing Square D Type QO load center in the elevator machine room is currently in working and serviceable condition but is not the recommended equipment for this application.

3. The generations of wiring systems for the lights and outlets throughout the rest of the Monument are somewhat haphazard at this point, the conditions of the fixtures vary from good and serviceable to failed and corroded. Being an unheated structure with wide humidity swings, including water and ice formations on the walls and floors, all of the wiring methods must be suitable for damp conditions and large fluctuations in temperatures. Some of the existing wiring systems and many of the fixtures are not suitable for these conditions and will require repairs more often than would otherwise be required by the correct equipment.
4. There are a variety of wiring runs that were determined to be abandoned and no longer serving anything.
5. The existing lighting fixtures (non-emergency fixtures) will require more frequent repair and replacement since many do not appear to be rated for moist exterior-like conditions and temperature ranges.
6. Overall, the stairwell is not adequately illuminated. NFPA 101 provides the performance requirements such as the required level of illumination of 10 fc (foot-candles) (or 108 lux) in stairways, measured at the walking surface. This minimum is not satisfied at many locations.
7. The existing emergency lighting of the stairs does not satisfy the Life Safety Code. Section 5-8.1.3 states that "The floors of means of egress shall be illuminated at all points including angles and intersections of corridors and passageways, stairways, landings of stairs, and exit doors to values of not less than 1 foot-candle (10 lx) measured at the floor." It also states that "Any required illumination shall be so arranged that the failure of any single lighting unit, such as the burning out of an electric bulb, will not leave any area in darkness".
8. The number of convenience receptacles (outlets) is inadequate. This is based on feedback from staff. The condition of some receptacles is good, and they appear to be newer, but others are older with corroded fittings. All receptacles should be GFCI and suitable for exterior conditions.

Recommendations

A comprehensive and detailed list of specific recommendations is provided in the DK Electrical Assessment Report in Appendix B11. A summary of the key recommendations is as follows:

1. The existing wiring infrastructure within the Monument – except for the main electrical panel and portion of the wiring system and equipment utilized for the elevator equipment – should be completely removed and upgraded. The non-elevator related wiring system is fairly basic and straightforward and is really only complicated by the long vertical runs and logistics of working in the Monument. The abandoned wiring systems should be removed. This work can proceed into design phases at this time.
2. In the elevator equipment room, the main disconnect should have its source identified and nameplate updated. New LED lighting and wiring corrections including GFCI receptacles should be included in the renovation. The existing load center should be replaced with a bolt-on circuit breaker panel board. This work can proceed into design phases at this time.
3. The normal lighting fixtures located on the landings, observation deck, and elevator service deck, should be replaced with exterior grade, UL listed watertight, LED type lighting fixtures with a minimum operating temperature of -40 °C to 40 °C and tested in accordance with IESNA LM-79 and LM-80 standards, as well as meet the requirements of the Vermont Energy Code and Efficiency Vermont, and be DLC listed. This work can also proceed to design phases.

4. The following emergency lighting solutions should be considered, and a cost comparison should be made to determine which system will best serve the Monument and State:
    a. Replace and upgrade all of the emergency lighting battery fixtures with heavy duty units that are listed and suitable for outdoor weatherproof service with a minimum operating temperature of -30°C. The units should be supplied with self-diagnostics features as well as the capability for remote heads. Each landing and stair riser requires emergency lighting.
    b. The consideration for an emergency power system: either the use of a generator or central battery system. This would utilize the normal lighting fixtures and would eliminate the need for individual battery unit equipment. A separate wiring system would be needed from an emergency panel power source through transfer switches. One transfer switch would be needed for the elevator and one for the required life safety lighting system fixtures.
5. The lightning protection system should be independently evaluated and tested by a lightning protection specialist with a certification in good standing from the Lightning Protection Institute and the State. The existing lightning protection system should be certified and carry a UL listing and upgraded to meet the latest requirements of NFPA 824.
6. An emergency power system to supply power for the elevator and lighting should again be considered. D&K conducted feasibility studies into multiple options for this in 2015/16 and 2019 and determined that multiple options are viable. Their findings are again summarized in their Electrical Assessment Report in Appendix B11.

5. CONSTRUCTABILITY AND OPINION OF PROBABLE COSTS

5.1 CONSTRUCTION COST

The design team has prepared an opinion of probable costs for the design and rehabilitation of the Monument for the purpose of raising sources of funds for the work. This opinion is based upon our understanding of the scope of work at this point in the investigation. The Design Team is in the initial stage of this project, working on the Investigation & Base Data Phase. No design phase work has been completed at this time. Typically, a cost estimate would be prepared as part of the Schematic Design Phase; however, the size and scope of the project required preliminary cost data to inform an order of magnitude budget.

Components such as scaffolding and metal work are reasonably well understood while others including the extent of masonry repairs & replacement are still being analyzed (and will be further analyzed during the CD phase). Allegrone Companies, a construction management company that specializes in this type of work, provided cost estimates for the masonry, steel, and scaffolding, see Appendix G for further detail. Allowances for other divisions of work were informed by the work to date and were included to provide a comprehensive opinion of cost. Industry standard allowances were used for design and other soft costs. A 15% estimate contingency, plus inflation escalation factors were used to reach an opinion for budgeting.

Our opinion of probable cost has incorporated some additional knowledge/insights gained during the on-going Phase 2 of investigation, however, that work is incomplete. The following are potential risks and uncertainties in the cost opinion:

1. No design or mock-ups have been completed; the cost estimate should be updated upon completion of each Phase of Design moving forward.
2. The condition and material analysis of the stones has not been completed. Although we have attempted to be conservative, additional study, mockups, and design will change the quantities of the various repairs and replacements.
3. The structural finite element analysis of the monument is currently incomplete and together with the material strength determination may inform the scope of work. Additional design, material testing, and installation of mockups during subsequent phases of work will inform, advance, and alter the scope of masonry structural interventions—thus changing the final schedule and costs.
4. There are many hidden conditions in a structure that is 8 feet thick at the base and 306 feet tall. Subsequent phases of investigation, design, and mockups will continue to inform the Design Team’s recommendations regarding contingency for uncertainties during construction.
5. The nature, scope and scale of this work is such that there are a limited number of qualified contractors in the United States. A highly specialized project with a limited number of contractors could affect the costs when the final project is put out to bid. There may be unaccounted for costs associated with the need to sustain a qualified labor force that is remote from the original headquarters of the potential restoration contractors.
6. The cost of capital and construction inflation has been unprecedented in the last two years.
7. Phasing the project should be expected to increase the total project costs due to the sequencing inefficiencies, higher overhead, and multiple mobilizations.

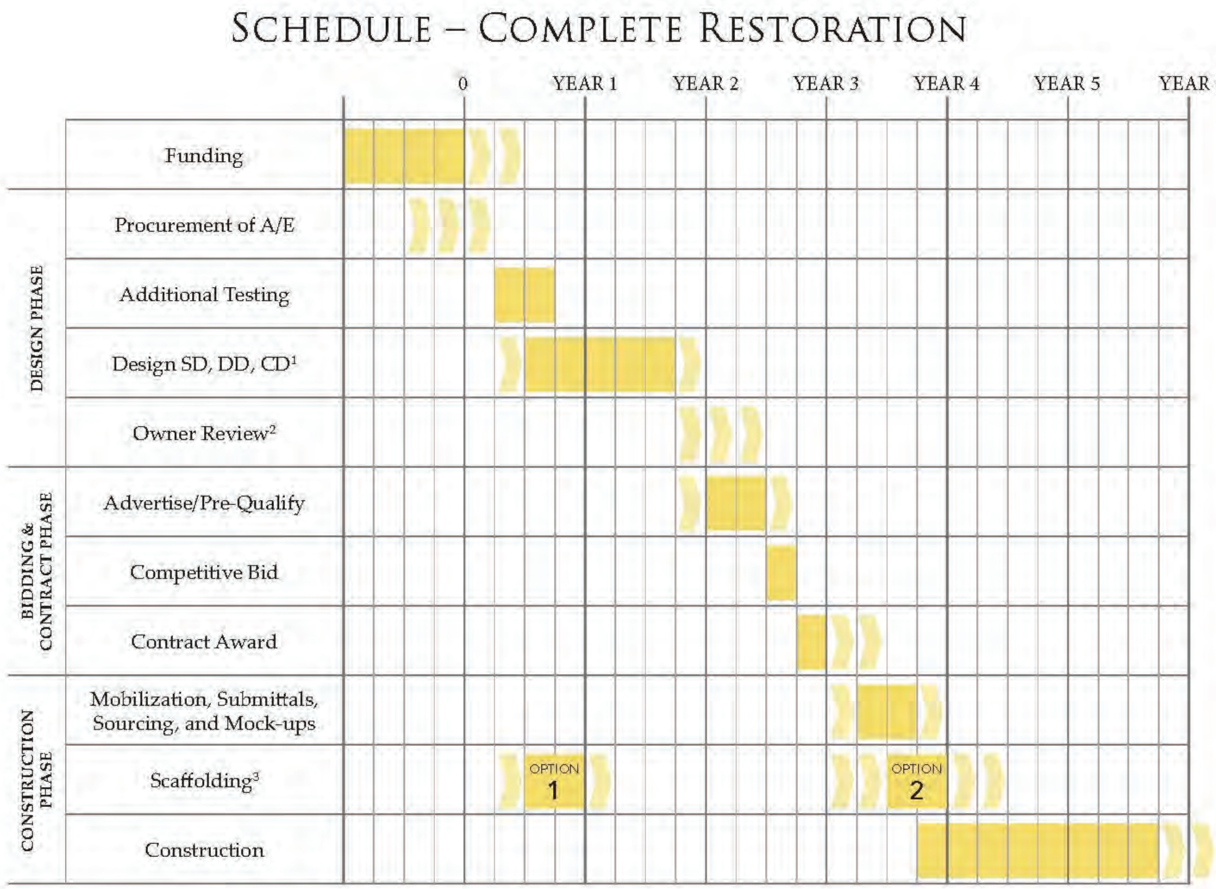
A contingency of 15% and escalation of 5% are a reasonable assumption but should be considered a minimum given the special nature of this project and the risks. As design progresses and contractor estimates are prepared confidence will increase. Once concept sequencing plans are prepared for a phased project, opinions of cost for a phased approach can be prepared.

A summary table of the project costs follows below, see Appendix F for further breakdown:

Soft Costs			
	A&E Design & Permitting (@ 10% Const Cost)		2,900,000
	Other Soft Costs (Testing, Inspection, Clerk, etc)		950,000
Hard Costs			
	Contractor General Conditions		1,655,000
	Scaffolding		5,500,000
	Masonry – Clean, Repair, Repoint		11,850,000
	Metals - Repairs, Refinish, Repair		3,025,000
	Additional Improvements		1,635,000
	Construction Cost Sub-Total		23,665,000
	Estimate Contingency @ 15%		3,550,000
	Contractor Overhead, Profit, Bonds & Insurance		$1,785,000
Sub-Total Opinion of Hard Construction Costs			**$29,000,000**
	Hard & Soft Cost Subtotal:		**32,850,000**
	Owner's Contingency (10%)		3,285,000
	Estimated Project Cost		**36,135,000**
	Escalation (1 YR @ 5% annum)	$	**37,942,000**
	Escalation (3 YR @ 5% annum)	$	**41,831,000**

5.2 SCHEDULE

The design team, in collaboration with Allegrone Companies, prepared a preliminary schedule for the comprehensive restoration of the Monument. This project is expected to take approximately six (6) consecutive years, including the completion of Final Design & Bidding. In general, further investigation & final design is expected to take between two (2) and three (3) years. The construction phase is also expected to take between two (2) and three (3) years. This schedule assumes there are no inefficiencies due to phasing. See further discussion about sequencing and phasing below.



[1] Includes sourcing stone and mock-ups at site.
[2] Owner review at completion of each design phase would likely extend schedule.
[3] Scaffolding: Option 1 if purchased by State of Vermont. Option 2 if included in bidding of construction project.

5.3 SEQUENCING & PHASING

The complexity and cost of the comprehensive restoration project is expected to result in phasing the project. Sequencing plans need to be developed during schematic design to inform appropriate and feasible levels of phasing. Certain elements regarding the construction sequencing are known at this time and will impact the phasing and construction costs for the project:

- **Lightning Protection:** As part of the Phase 2 investigative work, it has been identified there are improvements needed to bring the Monument's lightning protection system into compliance with current Codes. Given the unpredictable nature of lightning strikes, and the relatively low cost of these improvements compared to the overall project, it is recommended that this work be completed as soon as possible. A copy of the Lightning inspection completed by Smokestack Lightning company was provided separately to the State of Vermont in advance of the completion of other Phase 2 work.

- **Scaffolding**: Sequencing of the scaffolding will affect both the interior and exterior work for the monument. The entire exterior of the monument will require scaffolding to complete the project and this is a significant cost item. Therefore, sequencing all the exterior work to occur concurrently would maximize the use of the scaffolding and be more cost effective. If work on the exterior of the monument is to be phased, the scaffolding costs will increase due to an extended timeframe on-site, or from dismantling and re-erecting additional times.

  The State could consider purchasing the scaffolding to control costs. As represented on the schedule graphic above, purchase and installation of the scaffolding during Final Design would reduce risks and uncertainties regarding the scope of construction work to be bid, by allowing the Design Team and perspective bidders to observe the Monument prior to bidding. At this time it appears the payback on purchasing the scaffolding is between two (2) and three (3) years, compared to the rental costs through a general contractor.

  Interior scaffolding will be needed for elements of the work inside the structure, but consideration for the metal work and elevator improvements will be needed. If the interior work is to be phased, sequencing plans and a timeline for the interior work will be needed to confirm the appropriate scopes of work in each phase. There is not a need to consider purchasing the interior scaffolding by the State of Vermont due to the stairs providing reasonable access for observation.

  We recommend that the State consider a pre-bid effort to more thoroughly analyze the potential interior and exterior scaffolding options/ technical engineering issues, to advance the design of these scaffolds (perhaps to a 50% or a 100% DD level), and to then provide a more comprehensive cost of the design, fabrication, and installation of the scaffolds.

- **Elevator:** The sequencing of work related to the elevator improvements will be critical to maintaining potential access to the public during phases of construction. Therefore, the State will need to identify requirements and timelines for any on-going elevator use by the public. Complete rehabilitation of the elevator should be considered as part of a comprehensive restoration project, which could also impact sequencing. Additionally, removal of the elevator shaft and components would facilitate easier installation of interior scaffolding, however, removal may impact access during construction for workers and moving materials.
- **Mechanically Conditioned Space**: Ventilating and/or heating the monument may be recommendations resulting from the on-going Phase 2 investigation and are likely to require electrical upgrades to accommodate their installation. If these improvements are considered for an early phase of the restoration, sequencing plans developed during schematic design will inform the feasibility and potential pros and cons associated with completing these improvements prior to future interior work (including metal and/or masonry) that could impact the mechanical systems.