CONDITION SURVEY OF AQUIA CREEK SANDSTONE COLUMNS FROM THE U.S. CAPITOL RE-ERECTED AT THE U.S. NATIONAL ARBORETUM

Emily Aloiz,*[1] Carol Grissom,[2] Richard Livingston,[3] and A. Elena Charola[4]

Abstract

Aquia Creek sandstone was the preeminent stone used in the architecture of early federal buildings in Washington, D.C., including the U.S. Capitol and White House. In 1826, a portico with 10-meter-high monolithic columns made of the sandstone was completed on the east front of the Capitol. In 1958, columns from the portico were put into outdoor storage and replaced with marble replicas. Thirty years later, 22 of the 24 original columns were re-erected free-standing as a “ruined classical temple” at the U.S. National Arboretum. Since then this site has become the Arboretum’s most prominent visitor attraction. Visible evidence of stone deterioration by delamination and concern about falling pieces from the columns’ Corinthian capitals led to a systematic survey of damage. Each of the columns was documented visually by a series of photographs that were stitched together. Different types of damage and past repairs were defined and mapped digitally. Nondestructive methods included sounding with a handheld tool to detect delaminations or voids. Limited areas were also scanned for delamination using passive thermal IR imaging. A major type of distress is the loss of the original smooth surface layer on the column shafts. This layer is indurated, apparently by evaporation of quarry sap, and it tends to spall, mostly from the bottom of column shafts upwards. Another type of damage is associated with the corrosion of wrought-iron rings, which were embedded into the tops of column shafts. Corrosion of the rings has led to cracking and loss of stone from astragals at the top of the column shafts. Evidence of human intervention is also apparent, including original patches, paint traces, dutchmen, and eight broken shafts that were reconstructed. Treatments to retard deterioration were tested, and consolidation was undertaken on one astragal. Recommendations were made for future stabilization.

Keywords: Sandstone, Delamination

1 Introduction

Many of the earliest buildings in Washington, D.C., made use of Aquia Creek sandstone, including the Bullfinch Gateposts and Gatehouses, U.S. Patent Office (now the Smithsonian

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[1] Emily Aloiz, John Milner Associates Preservation, emilya@jmapreservation.com.

[2] Carol Grissom, Senior Objects Conservator, Museum Conservation Institute (MCI), Smithsonian Institution, USA, grissomc@si.edu.

[3] Richard Livingston, Adjunct Professor, University of Maryland, USA, and Research Associate, MCI, rliving1@umd.edu.

[4] A. Elena Charola, Research Scientist, MCI, charolae@si.edu.

*Corresponding author

Museum of American Art/National Portrait Gallery), White House and the U.S. Capitol. Twenty-two of the 24 Aquia Creek sandstone columns from the east central portico of the U.S. Capitol currently stand in the Ellipse Meadow of the U.S. National Arboretum in Washington, D.C. (Figure 1), where the ensemble is known as the Capitol Columns. Each column is 10 meters high and composed of five blocks. A Corinthian capital was modeled after a design in Sir William Chambers' *Treatise* (1791), carved in two parts, and placed above an un-fluted, monolithic shaft finished with an astragal at top and fillet at bottom. Below the shaft is a single block composed of a circular base and rectangular plinth. A square pedestal supports each column.

Since the Capitol Columns are the Arboretum's most prominent visitor attraction, concern about falling pieces and other deterioration prompted this study of the columns, carried out on site and at the Smithsonian Museum Conservation Institute from March through September 2013. For a systematic survey of damage, each column was inspected and photographed; using AutoCAD software, conditions were mapped on photographs, which had been stitched together. To assess surface detachments and voids behind them, a combination of sounding and thermal imaging was used. Sounding was conducted on all of the lowest portions of column shafts, as well as many upper portions reachable from a lift. A large flat-head screw driver was gently glided over the surface of the stone; a tone change identified the presence of voids. Thermal imaging, conducted by Gary Johanssen of the Smithsonian's National Museum of Natural History, confirmed the location of voids using a FLIR T640 Thermal Imaging Camera. Air heats at a different rate than stone, and distinct infrared radiation of voids was revealed as columns began to heat in the morning.

2 The journey of the columns

The columns are in remarkably good condition considering their nearly 200-year exposure since quarrying on an island in Virginia and placement on the east portico of the U.S. Capitol (1826 to 1958), storage at two locations for 27 years and re-erection at the Arboretum in 1988. Evidence of repairs from their initial carving and their time on the Capitol Building can still be found on the columns. Examples include patching material found to contain white lead and paint remnants in the decorative crevices of the capitals. The columns were regularly painted white, and in 2001 a study by Blythe McCarthy and William Ginell identified 16 layers of paint on them. Gouges also remain where a railing was attached between pedestals on the Capitol building.

In 1958, the columns were removed in separate pieces from the Capitol along with the rest of the portico for replacement there with marble replicas. The shafts were lifted using two bands around their girth, revealing circular lead sheets that were installed beneath them while they were on the Capitol. Once removed, each shaft was covered with slats and stored horizontally, as documented by photographs in the archives of the Architect of the Capitol. The capitals were crated, but the pedestals and base/plinths were left exposed. Without a home or purpose, column pieces were moved multiple times. Eight shafts were broken during that time, and much of the paint was lost.

Figure 1: Twenty-two Aquia Creek Sandstone columns from the U.S. Capitol are seen here at their present location in the National Arboretum in Washington D.C.

After many false starts, the columns were physically transferred to the Arboretum in 1984 to be erected in a classical temple plan with central fountain as envisioned by the noted English landscape architect, Russell Page (1906–1985). The installation process at the Arboretum, which required moving the columns a seventh time, involved considerable planning and diverse voices, including landscape architects, the Friends of the Arboretum non-profit organization, structural engineers, mechanical and electrical engineers, architects and multiple contractors (EDAWinc. *et al*. 1987). A concrete foundation and footer were created for each column, and all column parts were connected with stainless steel dowels epoxied into newly drilled holes. The capital tops, which had never been directly exposed to rain before, were covered with flashing, and a damp-proof metal course was installed beneath the pedestals. In addition, the columns were stripped of remaining paint, and a consolidant with a water repellent, Conservare H (comparable to Wacker H), was applied to two columns.

3 Ongoing deterioration

Aquia Creek sandstone itself has inherent vice: it is not optimal as a building stone in terms of durability, as was already recognized at the time of its selection; rather, it was chosen because it was locally available and easily worked. Aquia Creek is an arkosic sandstone formed by deposition of sediments during the Lower Cretaceous period over 100 million years ago, part of the Potomac Group (Nelson 1992, McGee and Woodruff 1992). The sediments were compacted along the Potomac River near Aquia, Virginia (Figure 2). Major components of the sandstone include quartz, which gives the stone strength and acid resistance, and smaller amount of feldspars, which give the stone warm coloration. Small amounts of iron averaging about 1% according to XRF and ICP analyses (McCarthy and Ginell 2001, p 27) provide red coloration to the stone, appearing in the form of uniform “stains,” lines or dots. Grains are bound with secondary amorphous silica (Hockman and Kessler 1957), but the stone is considered weakly cemented.

Pervasive surface delamination was identified during the condition survey. Contour loss, where the delaminated surface has completely detached, was found on 18 of the 22 shafts during this study, mostly around the bases of the shafts, but also around shaft repairs and isolated areas higher up on the shafts. Figure 3 shows an area of detachment, and Figure 4

Figure 2: Quarry face on Government Island, a state park where Aquia Creek sandstone was once quarried, with horizontal voids indicating stone unsuitable for buildings (2013).

shows an example of contour loss at the base of a shaft. The detached crusts range up to 13 mm in thickness. The same type of deterioration was found on many of the pedestals, although the thickness of the crusts (1-2 mm) was much less than the surface crusts on the shafts. The crusts are well cemented on their surfaces, where McCarthy and Ginell (2001) found a higher quartz to feldspar ratio based on X-ray diffraction intensities and lower porosity by both image analysis and mercury porosimetry.

Hardening of column surfaces apparently first occurred from quarry sap as the columns dried out. Calculations made by Livingston indicate that induration of Arboretum shaft surfaces can be accounted for mainly by deposition of dissolved silica from feldspars attacked by carbonic acid in groundwater at the quarry. The carbon dioxide (CO_2) level in groundwater can be significantly elevated above atmospheric concentrations because of biological activity in the soil. Pore water contains dissolved silica along with other ions produced by the breakdown of feldspars according to the following reaction given by Stumm and Morgan (1981):

$$\underset{\text{Orthoclase}}{KAlSi_3O_8} + CO_2 + 5.5H_2O = K^+ + HCO_3^- + \underset{\text{Silicic Acid}}{2H_4SiO_4^o} + \underset{\text{Kaolinite}}{0.5Al_2Si_2O_5(OH)_4}$$

When the quarry sap evaporates, its dissolved silica content is left behind in pore spaces at or just below the surface of stone, where it acts as a cement, thus producing the case hardening effect observed by McCarthy and Ginell (2001). Once the case-hardened surface layer (or, when they were on the Capitol, the many layers of paint on the surface) is breached, moisture has likely continued to attack the bulk stone by the feldspar dissolution process described above, eventually causing voids to form behind the surface. This creates a zone of weakness at the transition between the case hardened surface layer and the underlying stone.

Figure 3. A detachment on the shaft of column L20, which is has not progressed to contour loss.

Figure 4. The lower shaft of column L20 has the highest contour loss, extending more than six feet; a detached area reaches even higher. The area of detachment can be seen on the left.

Washington D.C. has a humid, subtropical climate with multiple wet/dry and freeze/thaw cycles that would continually stress weaker areas, eventually leading to contour loss, although the exact driving mechanism remains a matter of discussion. Detachment was likely occurring early in the columns' existence while still on the U.S. Capitol or in subsequent storage, since significant contour losses were documented by the architectural firm Oehrlein and Associates just before the columns were erected in the Arboretum (EDAWinc. *et al.* 1987, A2-A7). The earliest photographs that could be obtained showing contour losses were taken by the second author in 1988: comparison to current condition suggests about 10-15% additional loss over the 25 years since then (Figures 5 and 6).

Wrought-iron rings set in lead at the top of each shaft present a second instance of inherent vice. Since the rings are covered by the capitals, it is almost certain that they were installed at the time of original construction, although their purpose remains unclear. Corrosion of the iron has resulted in cracking or loss at 13 of the 22 astragals, as seen in Figure 7.

Deterioration at the tops of the shafts is particularly concerning because of their height from the ground, which could harm visitors when pieces fall. Loose pieces of one astragal were

Figure 5. Contour losses on column L5~~3~~ in 1988~~2000 (Grissom)~~.

Figure 6. Same location as the previous in 2013, showing an estimated 10-15% additional contour losses after 25~~14~~ years ~~(Grissom 2013)~~.

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~~Deterioration at the tops of the shafts is particularly concerning because of their height from the ground, which could harm visitors when pieces fall. Loose pieces of one astragal were~~ removed from column L7 during the survey to prevent this from occurring. The area from which they were taken was disaggregating; in order to strengthen the newly exposed surface, Prosoco's Conservare OH 100 was applied according to the manufacturer's specifications. The same treatment was also applied to the pieces removed from the deteriorated astragal. Comparison of thin sections made before and after treatment showed that the consolidant provides reinforcement along the tangential surfaces of the grains without substantially filling the pores.

Multiple repairs to the columns, including various patches, reattachment of broken pieces with adhesives and dutchmen, appear to have occurred through multiple phases of the columns' existence. The majority of old repairs are in stable condition. –Additional deterioration can be linked to joints made during installation of the shafts at the Arboretum; the joins appear stable, but impermeable epoxy adhesive is likely causing stone at exterior edges to deteriorate and shallow mortar applied to the outside of the epoxy joint to detach.

4 Recommended treatments

Not all damage to the columns requires immediate or any treatment. Many alterations are evidence of the long history of the columns. However, maintenance of old patches is required to prevent moisture from pooling in vulnerable areas, such as where mortar repairs are detaching at the bases of the shafts. Use of epoxy adhesive and a polyester adhesive previously employed to reattach broken fragments is not recommended, because their strength and porosity are not compatible with the stone, and durability is limited in UV light. However, where old repairs are stable and not causing damage to the surrounding

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~~*Figure 7: Detail of stone loss from L13's astragal, revealing its iron ring directly below the bottom edge of the capital.*~~

The astragals present the most complex and difficult problems for the columns, since the lead-bedded iron rings set into the top of column shafts are covered by the capitals. The only means of completely halting deterioration would be to remove the rings. This would be nearly impossible to do without harming the stone, since the capitals are fixed to the shafts with epoxied steel dowels and mortar. In lieu of removal, a method to slow water entry is required such as flashing to top surface of the astragals.

The breakdown and redeposition of minerals on the surface of Aquia Creek sandstone is inevitable outdoors, but loss of surface crusts may be hindered. Grouting is recommended in voids behind detached crusts to reestablish adhesion and stop water from pooling. Where the crusts have already been lost, consolidation can strengthen the fragile surface. Voids were filled on two columns behind detached surface layers. Use of a pozzolanic lime-based grout is recommended as it sets with moisture and chemical reactions to form vapor-permeable solids that have properties similar to Aquia Creek sandstone. Voidspan's CG-70 was tested in four areas of detachment; a year and a half later the surfaces are still intact. Monitoring will determine the long-term effectiveness of the treatment. Applying a surface coating such as paint would not stop void formation and might even encourage it by making the surface layer less permeable. Furthermore, the application of Conservare H in 1988 does not appear to have stopped contour loss on the two columns to which it was applied, but left visible glossy streaking that is still visible today.

Conclusions

The case study of the twenty two Aquia Creek sandstone columns at the National Arboretum

~~The case study of the twenty two Aquia Creek sandstone columns at the National Arboretum~~ demonstrates the complexity of stone heritage preservation. To understand the condition of the stone, its geology is an essential factor, and indeed the inherent vice of the Aquia Creek sandstone has led to delamination of indurated surface crusts; however, additional factors, such as storage, transportation and previous repairs play a role in the monument's durability. Conservation treatment is recommended on a limited basis to areas where patches have failed and in areas of water retention such as in voids behind delaminating surfaces or at top of the shafts where water can reach the iron rings. Where surface crusts have already been lost, consolidation may be a viable option to protect weakened areas newly exposed to the weather. As this popular monument adds new layers to its already multifaceted history, the condition documentation completed during this study will be essential in determining the rate and occurrence of change.

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